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Personal Security Accounts and Mandatory Annuitization in a Dynastic Framework

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The aging of the populations in the countries in the Organization for Economic Cooperation and Development (OECD) has prompted renewed academic research and political discussions of existing social insurance programs. Old-age, disability, health, and unemployment insurance programs have become the most expensive items in government budgets, and demographic projections suggest a significant increase in the old-age and health portions of social insurance in the next few decades.

Several European Union (EU) countries are already implementing reforms to minimize the fiscal burden of the demographic shock on individuals. Similar reform proposals are also being discussed for the United States' economy. In February 2005, the George W. Bush administration announced a reform proposal entitled "Strengthening Social Security for the 21st Century." Emphasizing the actuarial imbalance of the current unfunded system and the further stresses due to the projected aging of the U.S. population, this proposal called for a gradual privatization in which workers would deposit 4 percent of their income into private retirement accounts. Participation into this program was to be voluntary, and personal retirement account options and management were to be similar to that of the current federal employee retirement program, known as the Thrift Savings Plan (TSP). In other words, the most recent Bush proposal was intended to complement a down-sized public retirement system with a privatized system similar to that already in place for U.S. federal government employees. The February 2005 reform proposal failed to gain support, in part because of the excessive levels of current explicit debt and implicit social security debt. The September 11, 2001, attacks, the wars that followed the attacks, and the disastrous after math of hurricane Katrina also dominated the public debate and crowded out retirement issues. However, the underlying problems that prompted reform proposals remain unresolved and will eventually have to be faced.

"Strengthening Social Security for the 21st Century" was based on two previous attempts to draft a reform proposal following extensive academic, public, and political discussions. In 2001, a President's Commission to Strengthen Social Security was appointed to formulate proposals that would help maintain the current pay-as-you-go (PAYG) system's benefits for current retirees while improving the future pensions of current workers through personal security accounts. The Commission proposed three plans. The first plan recommended that workers make a voluntary contribution out of their social security payroll taxes into a personal security account (PSA), which would be owned and managed by the worker and invested in a well-diversified portfolio. The second plan extended this idea further and recommended diverting four percentage points of the social security payroll tax to PSAs while reducing the indexation of current pensions by following price increases as opposed to wage increases. The third plan introduced a mix of add-on and carve-out approaches such that a worker who chooses to voluntarily invest an additional 1 percent of earned income may divert 2.5 percent of social security payroll taxes, up to $1,000 annually, to PSAs. Although all three plans are clearly partial privatization plans, plans 2 and 3 also guarantee thirty-year minimum-wage workers a retirement income above the poverty line. All three plans allow for individual ownership of the accounts that can be bequeathed to heirs. In its key features, the 2001 Commission's proposals were similar to those made by the 1997 Advisory Council on Social Security. One of the recommendations for correcting the long-term imbalance of the program was to convert the current system to a basic, flat-benefit program, and redirect five percentage points of the existing payroll tax to private retirement accounts. This chapter examines, in a generic manner, the quantitative impact of proposals of this nature and the role played in this impact by mandatory annuitization of accumulated retirement wealth.

From Yaari (1965), we know that individuals facing mortality risk in a pure life-cycle model find it optimal to annuitize their wealth. More recently, Mitchell, Poterba, Warshawsky, and Brown (1999) estimate that individuals facing mortality risk in an overlapping-generations model without bequests are willing to give up more than 20 to 25 percent of their wealth to purchase actuarially fair annuities rather than follow the optimal consumption plan without annuities, even in the presence of significant preretirement social security wealth.[1] However, private annuity markets are very small. Diamond (1977) suggests that one possible reason may be the presence of asymmetric information and adverse selection and the accompanying failure in the market for annuities. Friedman and Warshawsky (1990) and Mitchell et al. (1999) document how unattractively private annuity contracts are priced in the United States and argue that adverse selection might lead to this outcome. Indeed, Feldstein (2005) emphasizes that the problem of asymmetric information and adverse selection could "weaken the functioning of private insurance markets."[2]

The large literature that attempts to quantify the overall welfare effects of unfunded social security using applied general-equilibrium models can be summarized as follows. The welfare costs of social security arise because the public provision of retirement insurance leads to a reduction in saving, a distortion in labor supply, and a distortion in the retirement decision (early retirement).[3]

Social security potentially raises individual welfare by improving risk sharing in the population.[4] In particular, social security provides partial insurance against mortality risk, individual income risk, and investment income risk.

Using an overlapping-generations setting without bequests, previous research has largely found that social security imposes an overall welfare cost on the society. As Auerbach and Kotlikoff (1987) argue, the main reason for this negative finding is the large decrease in the capital stock, which in turn leads to a significant reduction in lifetime consumption. Hubbard and Judd (1987) allow social security to provide longevity insurance, but its partial insurance aspect is not sufficient to overturn the negative lifetime consumption effect of social security. İmrohoroğlu, İmrohoroğlu, and Joines (1995, 1999) and Storesletten, Telmer, and Yaron (1999) introduce individual income risk as an additional benefit of social security but obtain a similarly negative outcome for social security.

These findings suggest that we might expect to observe widespread privatizations in the United States, EU countries, and elsewhere. There are at least three explanations for the persistence of pay-as-you-go systems, in spite of the steady-state burdens associated with them.

First, the transitional costs from a pay-as-you-go social security system to a fully privatized retirement system may be large. Huang, İmrohoroğlu, and Sargent (1997) and Kotlikoff, Smetters, and Walliser (1999) consider several alternative policy transitions from the current

U.S. system to a privatized one. De Nardi, İmrohoroğlu, and Sargent (1999) examine various alternative transitional policy responses to the aging of the U.S. population.[5] These studies and Conesa and Krueger (1999) find large transitional costs, with a majority of the currently alive population suffering welfare losses and thus blocking any reform proposal. Second, there may be political-equilibrium considerations that allow the introduction and maintenance of an unfunded social security system, as Cooley and Soares (1999) and Boldrin and Rustichini (2000) argue. Finally, it is possible that not all potential benefits of social security have been carefully modeled.[6] The insurance role of social security in shielding the participants from investment income risk is only recently being carefully analyzed. In a recent paper, Krueger and Kubler (2002) use an overlapping-generations model with a stochastic production technology and incomplete markets to evaluate the welfare consequences of introducing a small unfunded social security system. Their main quantitative finding is that the "capital crowding-out" effect mentioned above outweighs the insurance role of social security against realistic investment income risk.

The studies summarized above make the extreme assumption that consumers have little or no altruism. However, there is a substantial literature that suggests that at least a fraction of individuals behave in a way consistent with an operative bequest motive. Laitner and Juster (1996) and Wilhelm (1996) are recent examples of empirical papers that provide some evidence on the strength of altruism. This chapter assumes that individuals have two-sided altruism: they care both about their parents and their children.

Fuster (1999) and Fuster, İmrohoroğlu, and İmrohoroğlu (2003, 2007) explore the role of social security in a dynastic setting with incomplete markets and distorting taxes and show that there are qualitative and quantitative differences between the pure life cycle and the dynastic environments. They find that the "capital crowding-out" effect of unfunded social security is quantitatively much smaller in the dynastic model due to the strong additional motive to save and that "family insurance" largely makes up for the loss of publicly provided insurance in privatization experiments. Furthermore, they highlight the importance of a "flexible" labor market as one of the key conditions for a successful social security reform. When the pay-as-you-go system is eliminated, there is a sizable reduction in the labor-income tax rate, which raises labor supply and generates large welfare gains from privatization. This is especially true in an economy in which the link between contributions and benefits in the pay-as-you-go system is small.

There are three features of an economy that enhance the success of social security reform: operative bequest motives, flexible labor markets, and weak linkage between contributions and benefits.

In this chapter, we quantitatively evaluate the welfare effects of reforming social security by introducing a PSA with and without mandatory annuitization in an economic environment with uninsurable individual income shocks, two-sided bequests, borrowing constraints, and missing annuity markets. Our setup allows us to assess whether mandatory saving or mandatory annuitization of accumulated PSA wealth at retirement is welfare enhancing and, if so, for what type of households.

In our model, family insurance takes the form of intervivos transfers and bequests. There are three general types of households, depending on the number of surviving household members. In type 1 households, the parents have died, and only the children survive. In type 2 households, the children have died, and only the parents survive. Type 3 households constitute the majority and have both the parents and the children in the household. In this type, we have further heterogeneity. Since the parents and the children receive the realization of generationally persistent "ability" shocks, type 3 households are further divided into four ability combinations depending on the high- or low-ability realizations of the parents and the children.[7]

This framework is well suited to consider the annuity role of social security for single individuals versus for households where families also provide annuity insurance to their members. Our goal is to evaluate quantitatively PSA reforms with or without mandatory annuitization of PSA wealth at retirement. We do this in a setup where some households have a higher desire to annuitize wealth than others do.

We calibrate our economy to the U.S. economy, use numerical, discrete state-space methods to solve the households' recursive decision problem, and restrict attention to steady states under various pension systems.

The chapter presents the model in detail, contains calibration, gives numerical results, and presents concluding remarks.

The Model

The economic environment in this chapter follows Fuster, İmrohoroğlu, and İmrohoroğlu (2003). It is an applied general-equilibrium model with overlapping generations facing lifespan and ability uncertainty and borrowing constraints and exhibiting two-sided altruism. The cost of the model's richness in demographic and productivity dynamics is that we simplify the macroeconomic context. There is no uncertainty to the return to capital in this model. For this chapter to be self-contained, we describe the model, although some of the details can be obtained in Fuster, İmrohoroğlu, and İmrohoroğlu (2003).

Demographics and Endowments

Our setup is a stationary overlapping-generations model where in every period t a generation of individuals is born. Individuals face random lives, and some live through the maximum possible age $2T$. If the individual survives, then his lifetime support overlaps during the first T periods with the lifetime support of his father and during the last T periods with the lifetime support of his children. The total population in the economy consists of $2T$ overlapping generations of individuals with total measure one.

At birth, individuals make a draw from a distribution of abilities. An individual's ability can be high or low, and it determines both the individual's lifetime labor productivity and his life expectancy. If the ability is high, $z = H$, the individual enjoys a permanently higher labor productivity throughout his lifespan than an individual with low ability, $z = L$. The labor productivity of an individual of ability z and age j is denoted by $\varepsilon_j(z)$. We assume that from age R to age $2T$ the labor productivity is zero, so R represents the exogenous retirement age. At any other age, the individual supplies inelastically labor to firms.

An individual with high ability also enjoys a permanently higher conditional survival probabilities throughout his lifespan than an individual with low ability. With this assumption, we want to capture the fact that in the U.S. economy survival rates are higher among individuals with relatively high education levels. We will use $\psi_j(z)$ to denote the probability of surviving to age $j+1$ conditional on having survived to age j for an individual with ability z for age $j = 1, 2, \ldots, 2T$, where $\psi_{2T}(z) = 0$ and $z \in \{H, L\}$.

We assume that abilities are correlated across generations of the same family line. In particular, ability z is a two-state, first-order Markov process with the transition probability matrix

$$\Pi(z', z) = [\pi_{ij}], \quad i, j \in \{H, L\},$$

where $\pi_{ij} = \Pr\{z' = j \,|\, z = i\}$, z is the labor ability of the father, and z' is the labor ability of the new born in the dynasty. To develop economic intuition about how the model works, it is important to note that there are no private insurance markets in the economy to diversify the risk of being born as a low-ability-type individual. However, the informal family structure and some partial annuities, public or privately administered if they exist, do provide some partial insurance against this type of shock.

Cohort shares are time invariant due to our assumptions of constant conditional survival probabilities and population growth rate n. Using $\mu_1(z) = \lambda(z)(1+n)^T$ to indicate the size of cohort 1 (newborns) with ability z, relative to that of cohort $(T+1)$ (parents), where $(1+n)^T$ is the number of children per parent and $\lambda(z)$ is the measure of newborn individuals with ability z, we can obtain the relative sizes of the other generations recursively:

$$\mu_{j+1}(z) = \frac{\psi_j(z)\mu_j(z)}{(1+n)}, \quad j = 1, \ldots, 2T-1.$$

Technology

There is a continuum of identical firms that produce a final good using capital and labor. The technology is represented by a constant returns Cobb-Douglas production function $Y_t = K_t^{\alpha}(A_t N_t)^{1-\alpha}$, where $\alpha \in (0,1)$ is the output share of capital, Y_t is output at time t, K_t is aggregate capital input at time t, N_t is aggregate labor input at time t, and A_t is an exogenous labor-augmenting technological progress growing at a constant rate γ. Capital depreciates at a constant rate $\delta \in (0,1)$. Since all markets are competitive, the profit-maximizing conditions imply that factor prices are set equal to marginal products—that is,

$$\tilde{r}_t = \alpha K_t^{\alpha-1}(A_t N_t)^{1-\alpha}, \tag{7.1}$$

$$\omega_t = (1-\alpha)K_t^{\alpha}(A_t N_t)^{-\alpha}, \tag{7.2}$$

where $\tilde{r}_t$ is the rental price of capital, and ω_t is the wage per effective labor.[8]

Social Security and Fiscal Policy

The Benchmark Social Security System: Pay-as-You-Go In the benchmark economy, we assume that the social security system finances current pensions with the contributions of current workers.

That is, the systems transfers income from workers to retirees. In the U.S. economy, retirement benefits depend on individuals' average lifetime earnings via a concave, piecewise linear function. The marginal replacement rate decreases with average lifetime earnings indexed to productivity growth. It is equal to 0.9 for earnings lower than 20 percent of the economy's average earnings. Above this limit and below 125 percent of the economy's average earnings, the marginal replacement rate decreases to 0.33. For income within 125 percent and 246 percent of the economy's average earnings, the marginal replacement rate is 0.15. Additional income above 246 percent of the economy's average earnings does not provide any additional pension payment.

In our benchmark economy, the function that relates the pension $B_j(z)$, with the individual's ability z mimics the progressivity of the U.S. social security benefits.[9] In particular, at retirement the pension payment for each ability group is calculated as follows:

$$B_R(z) = \begin{cases} 0.9 \cdot (0.2\overline{M}) + 0.33 \cdot (M(z) - 0.2\overline{M}), & \text{for } z = L, \\ 0.9 \cdot (0.2\overline{M}) + 0.33 \cdot (1.25\overline{M} - 0.2\overline{M}) \\ \qquad + 0.15 \cdot (M(z) - 1.25\overline{M}), & \text{for } z = H, \end{cases}$$

where $M(z)$ denotes the average lifetime earnings of an individual of ability z and $\overline{M}$ denotes the economy's average earnings.

Note that an individual's pension remains constant during retirement while technology grows at the rate γ. Thus, the pension per effective labor decreases during retirement at rate γ—that is, $B_j(z) = B_R(z)/(1+\gamma)^{j-R}$. Pensions are financed by taxing earnings at a rate τ, and the budget of the social security system is balanced at every period—that is,

$$\sum_z \sum_{j=R}^{2T} \mu_j(z) B_j(z) = \tau \omega N. \tag{7.3}$$

Reform 1: Personal Security Accounts without Annuitization Under a personal security account system, retirement benefits come from two distinct sources. The first tier is a flat pension benefit equal to 18 percent of per capita gross domestic product (a monthly payment of $410 in 1996). This portion of the total benefit is financed in a pay-as-you-go fashion by taxing current labor income. Hence, the social security tax rate that finances the first-tier system is set such that its aggregate revenue equals the aggregate first-tier benefits:

$$\sum_z \sum_{j=R}^{2T} \mu_j(z) b = \tau_s \omega N, \tag{7.4}$$

where b denotes the flat benefit, and τ_s is the social security payroll tax to finance the first-tier benefits. We can obtain the following close-form solution for the equilibrium tax rate by substituting $b = 0.18y$ and $y = \omega N/(1-\alpha)$ in the above equation:

$$\tau_s = \frac{0.18}{1-\alpha} \sum_z \sum_{j=R}^{2T} \mu_j(z).$$

The second tier of retirement benefits is financed by forced saving. Every period, the individual deposits 5 percent of earnings in PSAs. These funds are owned and managed by the individuals and are invested in the capital market, where they earn the rate of return on capital and cannot be withdrawn until the individual retires. The capital income accumulated in the PSA is not taxed during the individual's working life. The amount of second-tier benefits is determined by the wealth accumulated in these tax-favored personal security accounts.[10] These assumptions define the following law of motion of the PSA (for an individual of ability z):

$$(1+\gamma) s_{j+1}(z) = (1+\tilde{r}) s_j(z) + \kappa \omega \varepsilon_j(z), \tag{7.5}$$

where $\kappa = 0.05$ is the social security tax that finances the second-tier benefits, $s_{j+1}(z)$ denotes the PSA funds of an age-$j+1$ individual with ability z, and $s_1(z) = 0$. At retirement, the individual gets a lump-sum transfer of the wealth accumulated in his account, which amounts to $(1+\tilde{r}) s_R(z)$. If the individual does not survive to his retirement, his PSA funds are transferred to his estate. Note that this reform is essentially a partial privatization achieved by a mandatory saving program.

Summarizing, the pension benefits under PSA (reform 1) are described as follows:

$$B_j(z) = \begin{cases} b + (1+\tilde{r}) s_R(z) & \text{for } j = R \\ b/(1+\gamma)^{j-R} & \text{otherwise,} \end{cases}$$

and the tax rate on earnings used to finance pensions τ is the sum of κ and τ_s.

Reform 2: Personal Security Accounts with Mandatory Annuitization In a modified version of the above reform, we consider the case of partial privatization in which the funds accumulated in the personal security account are annuitized by the institution managing the PSAs. At retirement, individuals are entitled to an annuity payment $b(z)$, which we assume to be proportional to the wealth accumulated in the PSA at retirement—that is, $b(z) = p(1+\tilde{r})s_R(z)$, where the proportion p is determined endogenously as we explain below. The annuity payment remains constant during retirement, just like the first-tier flat pay-as-you-go benefit, and thus the annuity payment per effective units of labor decreases at the rate γ.[11]

To compute the annuity payment of each individual, the social security system has to determine the proportion p of accumulated wealth that the individual receives during retirement. This variable p is set such that the expected present value of the aggregate annuity payments of the generation that retires today equals the aggregate wealth held in PSA (the funds of individuals that are alive at retirement plus the funds of individuals that die before reaching retirement).[12] The expected present value of the aggregate annuity payments of the generation that retires today is given by

$$\sum_z p(1+\tilde{r})s_R(z)\lambda(z)\sum_{j=R}^{2T}(1+\tilde{r})^{R-j}\prod_{i=1}^{j-1}\psi_i(z).$$

The aggregate wealth accumulated in PSA by individuals in this cohort who survived to retirement is given by $\sum_z (1+\tilde{r})s_R(z)\lambda(z)\prod_{i=1}^{R-1}\psi_i(z)$, and the aggregate wealth accumulated by individuals in this cohort who died before retirement is

$$\sum_z (1+\tilde{r})\sum_{j=2}^{R}\left(\frac{1+\tilde{r}}{1+\gamma}\right)^{R-j} s_j(z)\lambda(z)(1-\psi_{j-1}(z))\prod_{i=1}^{j-2}\psi_i(z).$$

As a result, the proportion p must satisfy the following condition:

$$p = \frac{\sum_z s_R(z)\lambda(z)\prod_{i=1}^{R-1}\psi_i(z) + \sum_z\sum_{j=2}^{R}\left(\frac{1+\tilde{r}}{1+\gamma}\right)^{R-j} s_j(z)\lambda(z)(1-\psi_{j-1}(z))\prod_{i=1}^{j-2}\psi_i(z)}{\sum_z s_R(z)\lambda(z)\sum_{j=R}^{2T}(1+\tilde{r})^{R-j}\prod_{i=1}^{j-1}\psi_i(z)}.$$

The above condition implies that the return of annuities is linked to the average mortality rate across individuals with differential mortality (high- and low-ability individuals), and as a result, the return of annuities is not fair. This return could not be offered by private annuities since it would not be accepted by individuals with a high mortality rate (low ability). In contrast, the government can provide this return because annuities are mandatory. In other words, the government can overcome an adverse-selection problem (private information on differential mortality) in the annuity market because PSAs are mandatorily annuitized.

The law of motion of the aggregate wealth held in PSAs by the social security system is

$$(1+n)(1+\gamma)W_{t+1} = (1+\tilde{r})W_t + \kappa\omega N - \overline{B},$$

where $\kappa = 0.05$ and $\overline{B} = \sum_z \sum_{j=R}^{2T} b(z)(1+\gamma)^{R-j}\mu_j(z)$ denotes the aggregate annuity payments at period t. At each period t, the aggregate funds in PSA W_t are invested in the capital market.

Summarizing, the pension benefits under reform 2 are described as follows:

$$B_j(z) = \begin{cases} b + b(z) & \text{for } j = R \\ (b + b(z))/(1+\gamma)^{j-R} & \text{for } j > R, \end{cases}$$

and the tax rate on earnings used to finance pensions τ is the sum of κ and τ_s.

Government Budget In addition to the administration of the pension system, the government taxes labor income, capital income, and consumption to finance exogenously given government purchases. We assume that the government's budget is balanced each period. Since tax rates and government expenditures are exogenous, the budget is balanced by an endogenous lump-sum transfer to the individuals. The government also collects the asset holdings and capital income of individuals who die without descendants. These resources are transferred in a lump-sum fashion to all survivors.[13]

Preferences

The preference structure in our setup follows Laitner's (1992) two-sided altruistic specification in which individuals derive utility from their own lifetime consumption and from the felicity of their predecessors and descendants. An important feature of Laitner's (1992) model is that parents and children have the same objective function during the periods when their lifetimes overlap. Due to this commonality of interest, strategic behavior between the father and the children does not arise, and thus father and children constitute a single decision unit by pooling their resources. We call this decision unit a *household*, which is constituted by an adult male, the father, of generation j and age $T+1$, and his $m = (1+n)^T$ adult children of generation $j+T$ and age 1.

We model altruism as in Laitner (1992) but in a model with uncertain lifetimes. This framework allows us to evaluate the annuity role of various social security institutions when families can also provide annuity insurance to their members. Because we assume uncertain lifetimes, the composition of the household evolves stochastically in our framework. At each period, there are three types of households.[14] Type 1 households are those where the father has died. Type 2 households consist only of the father since the m children have died. Households of type 3 are those where both the father and the children are still alive. Moreover, households are heterogeneous with respect to their asset holdings, age, and abilities.[15]

The budget constraint facing an age-j household, where $j = 1, 2, \ldots, T-1$ is the age of the youngest member(s), is given by

$$[\phi_s(h) + \phi_f(h)](1+\tau_c)c_j + (1+\gamma)a_j$$
$$= [1 + r(1-\tau_k)]a_{j-1} + e_j(h, z, z') + [\phi_s(h) + \phi_f(h)](\xi_1 + \xi_2), \qquad (7.6)$$

where ϕ_s is an indicator function that takes the value m if the children are alive and 0 otherwise, ϕ_f is an indicator function that takes the value unity if the father is alive and 0 otherwise, $h \in \{1, 2, 3\}$ is an indicator of household composition, $r = \tilde{r} - \delta$, $e_j(h, z, z')$ are the after-tax earnings, c_j is the consumption of each household member, a_j denotes the asset holdings to be carried over to age $j+1$, ξ_1 is the lump-sum redistribution of unintended bequests left behind by fathers without sons and confiscated by the government, ξ_2 is a lump-sum transfer to balance the government's budget, and τ_c and τ_k denote the consumption and capital income tax rates, respectively. All per capita aggregate quantities reported in the chapter are divided by the level of the technology A_t and therefore represented in efficiency units. As we restrict attention to steady states, consumption, asset holdings, lump-sum transfers, and earnings are in efficiency units and constant over time.

We represent the net of tax earnings of an age-j household with the function $e_j(h, z, z')$:

$$e_j(h,z,z')$$
$$= \begin{cases} \phi_s(h)\omega(1-\tau-\tau_\ell)\varepsilon_j(z') + \phi_f(h)B_{j+T}(z) & \text{if } j \geq R-T, \\ \phi_s(h)\omega(1-\tau-\tau_\ell)\varepsilon_j(z') + \phi_f(h)\omega(1-\tau-\tau_\ell)\varepsilon_{j+T}(z), & \text{if not,} \end{cases} \tag{7.7}$$

where τ is the social security tax, τ_ℓ is the personal tax rate on labor income, and $B_{j+T}(z)$ denotes the pension at age $j+T$.

For $j = T$, the budget constraint of the household is given by

$$[\phi_s(h) + \phi_f(h)](1+\tau_c)c_T + (1+n)^T(1+\gamma)a_T$$
$$= [1 + r(1-\tau_k)]a_{T-1} + e_T(h,z,z') + [\phi_s(h) + \phi_f(h)](\xi_1 + \xi_2). \tag{7.8}$$

If the children survive to age T, $(1+n)^T$ new households are constituted in the dynasty, and each of them will hold a_T assets. If the children do not survive to age T, the family line breaks.

It is assumed that households face borrowing constraints and cannot hold negative assets at any age:

$$a_j \geq 0, \quad \forall j. \tag{7.9}$$

Individuals obtain utility from their consumption and from their predecessors' and descendants' consumption. We restrict the utility function to the constant relative risk aversion (CRRA) class because we assume a balanced growth path for our economy. We will use the language of recursive economic theory to describe the household's decision problem.

Let $V_j(a,h,z,z')$ denote the maximized value of expected, discounted lifetime utility of an age-j household with the state vector (a,h,z,z'). For a household of age $j \leq T$,

$$V_j(a,h,z,z') = \max_{\{c,a'\}} \left\{ [\phi_s(h) + \phi_f(h)] \frac{c^{1-\sigma}}{1-\sigma} + \beta(1+\gamma)^{1-\sigma} \tilde{V}_{j+1}(a',h',z,z') \right\}$$
$$\text{subject to (7.6)–(7.9),} \tag{7.10}$$

where σ is the coefficient of relative risk aversion,

$$\tilde{V}_{j+1}(a',h',z,z')$$
$$= \begin{cases} \sum_{h'=1}^{3} \chi_j(h,h';z,z')V_{j+1}(a',h',z,z') & \text{for } j = 1,2,\ldots,T-1, \\ \psi_T(z')(1+n)^T \sum_{z'' \in \{H,L\}} \pi_{z'z''} V_1(a',3,z',z'') & \text{for } j = T, \end{cases}$$

$\chi_j(h, h'; z, z')$ is the probability that a household of age j, and type h becomes type h' the next period given that the father is of ability z and the children of ability z'.[16]

Steady-State Equilibrium

A fiscal policy is a set $\{G, B, \tau_\ell, \tau_k, \tau_c, \tau_s, \kappa, \tau\}$. Given fiscal policy, a *stationary recursive competitive equilibrium* is a set of value functions $\{V_j(a, h, z, z')\}_{j=1}^T$, households' decision rules $\{c_j(\cdot), a_j(\cdot)\}_{j=1}^T$, time-invariant measures of households $\{X_j(a, h, z, z')\}_{j=1}^T$, relative prices of labor and capital $\{\omega, r\}$, a lump-sum distribution of unintended bequests ξ_1, and a lump-sum government transfer ξ_2 such that the following conditions are satisfied:

1. Given fiscal policy, prices, and lump-sum transfers, households' decision rules solve households' decision problem (7.10).
2. Firms maximize profits—that is, (7.1) and (7.2) hold.
3. Aggregation holds:

$$\tilde{K} = \sum_{j,a,h,z,z'} a_{j-1}(a, h, z, z') X_j(a, h, z, z')(1+n)^{1-j} + W,$$

$$\tilde{N} = \sum_{j=1}^{R-1} \sum_{z \in \{H, L\}} \varepsilon_j(z) \mu_j(z),$$

$$C = \sum_{j,a,h,z,z'} [\phi_s(h) + \phi_f(h)] c_j(a, h, z, z') X_j(a, h, z, z')(1+n)^{1-j},$$

where $W = \sum_z \sum_{j=1}^R s_j(z)\mu_j(z)$ is the aggregate PSA wealth in the economy, adjusted for growth.

4. The set of age-dependent measures of households satisfies

$$X_{j+1}(a', h', z, z') = \sum_{\{a, h: a' = a_j(a, h, z, z')\}} X_j(a, h, z, z') \chi_j(h, h'; z, z'),$$

$$\text{for } j = 1, \ldots, T-1; \tag{7.11}$$

the invariant distribution of age-1 households is given by conditions

$$X_1(a', 3, z', z'')$$

$$= \pi_{z'z''} \sum_{\{a, h, z: a' = a_T(a, h, z, z')\}} X_T(a, h, z, z') \chi_T(h, 3; z, z'); \tag{7.12}$$

and

$$X_1(0,1,z',z'') = \lambda(z')\pi_{z'z''} - \sum_{a'} X_1(a',3,z',z'') \tag{7.13}$$

—that is, new dynasties, holding zero assets, substitute for the family lines broken during any given period.

5. The lump-sum redistribution of unintended bequests satisfies

$$\xi_1 = (1+r)\sum_{j=1}^{T} a_j(a,h,z,z')X_j(a,h,z,z')\left[1 - \sum_{h'=1}^{3}\chi_j(h,h';z,z')\right](1+n)^{1-j}.$$

6. The government's budget is balanced:

$$\xi_2 = \tau_k r\left[\tilde{K} - \frac{\xi_1}{1+r}\right] + \tau_\ell \omega \tilde{N} + \tau_c C - G.$$

7. The budget of the social security system is balanced—that is, (7.3) or (7.4) hold, depending on the social security system in place.

8. The goods market clears

$$C + [(1+n)(1+\gamma)\tilde{K} - (1-\delta)\tilde{K}] + G = \tilde{K}^{\alpha}\tilde{N}^{1-\alpha}.$$

Calibration and Solution

We are going to calibrate our model economy to the long-run quantities in the U.S. economy to conduct our counterfactual experiments for reforming social security. Our main calibration target is the average capital-to-output ratio in the U.S. economy over the last fifty years—2.5. Table 7.1 shows the major modeling and calibration choices made.

A newborn in our setup is a twenty-one-year-old individual; a model period is five years. Retirement is mandatory at age sixty-five, and maximum lifespan is ninety years. The population growth rate is 1.2 percent per year, and the productivity growth rate is 1.65 percent annually. Again, these are the averages from the U.S. economy over the last fifty years. The depreciation rate is taken as 4.4 percent, and capital's share of gross national product is 31 percent.

Fiscal policy is captured by a constant annual government-to-GNP ratio of 18 percent, and taxes on labor income, capital income, and consumption, at 20 percent, 40 percent, and 5 percent, respectively.

Table 7.1
List of parameters

Demographics	
$2T = 14$	Maximum lifetime (70 years)
$R = 10$	Retirement age (45 years)
$n = 0.012$	Population growth rate (annual)
Preferences	
$\sigma = 2$	Coefficient of relative risk aversion
$\beta = 0.988$	Annual discount factor
Technology	
$\gamma = 0.0165$	Annual rate of growth of technology
$\alpha = 0.31$	Capital share of GNP
$\delta = 0.044$	Annual depreciation rate
$\lambda(H) = 0.28$	Measure of individuals with high ability
$\pi_{LL} = 0.83$ $\pi_{HH} = 0.57$	Transition probability matrix of abilities
Fiscal Policy	
$\tau_l = 0.2$	Labor-income tax rate
$\tau_k = 0.4$	Capital-income tax rate
$\tau_c = 0.05$	Consumption tax rate
$G/Y = 18\%$	Government expenditure to GDP ratio

Table 7.2
Aggregate effects of reforms

	τ_s (percent)	κ (percent)	K	Y	$r(1-\tau_k)$ (percent)	C
Benchmark	9.44%	0%	100.0	100.0	4.62%	100.0
PSA+Annuity	4.38	5	109.5	102.8	4.24	101.8
PSA	4.38	5	108.9	102.7	4.26	101.7
Elimination	0	0	106.1	101.8	4.37	101.2

The coefficient of relative risk aversion σ is set equal to 2, and the subjective discount factor β is taken as 0.988 to obtain a capital-to-output ratio of 2.5.[17]

Numerical Findings

Aggregate Long-Run Effects

We summarize the long-run effects of various types of reform in table 7.2. The benchmark steady-state describes the current U.S. economy, where pensions are provided by a pay-as-you-go system with a replacement rate of 44 percent and a payroll tax rate of 9.44 percent. We set the values of aggregate variables in this steady-state equilibrium equal to 100 for easy comparison with other steady-state equilibria under alternative reform proposals.

The steady state labeled *Elimination* is an equilibrium where there is no unfunded system at all and all individuals are left free to save the optimal amounts desired to support old-age consumption. The steady states labeled $PSA + Annuity$ and PSA enforce mandatory saving at the rate of 5 percent of individuals' gross wage income in each of the years during their working life. Not surprisingly, all three alternative steady states exhibit higher capital stock than the benchmark economy since the distortion on saving is reduced with the decline of the payroll tax from 9.44 percent to 4.38 percent.

According to table 7.2, PSA and $PSA + Annuity$ induce a higher capital stock than the elimination of social security. This is because individuals cannot borrow against the mandatory savings induced by personal security accounts. Also, the $PSA + Annuity$ reform generates a (slightly) higher capital stock than the *PSA*-only reform because the funds of the deceased are invested in the capital market in the former reform, while they are transferred to the estates in the latter reform. As a consequences, aggregate mandatory savings are larger in the case of annuitized personal security accounts.

Welfare Effects

We compare the utility of a newborn household across alternative steady states for different composition and ability types using a consumption equivalent variation measure. We compute the change in consumption in each future period and state of nature, $(1 + c(h, z, z'))$, relative to the benchmark consumption level that is necessary to make the household indifferent between being born in the benchmark economy or in the alternative steady state—that is,

$$(1 + c(h, z, z'))^{1-\sigma} U_B(h, z, z') = U_R(h, z, z'),$$

where $U_B(h, z, z')$ is the average utility of a newborn household type (h, z, z') at the benchmark economy, and $U_R(h, z, z')$ is the average utility of such household at the alternative steady state. The average utility of a newborn household type (h, z, z') is computed by aggregating the utility across asset levels using the stationary distribution of assets. For instance,

Table 7.3
Welfare of newborns

	Type 3				Type 1		
	HH	HL	LH	LL	H	L	Mean
Benchmark	1.0	1.0	1.0	1.0	1.0	1.0	1.0
PSA+Annuity	1.008	0.98	1.037	1.022	1.019	0.980	1.013
PSA	0.980	0.97	1.025	1.018	1.020	1.005	1.006
Elimination	0.990	0.98	1.017	1.003	1.056	1.060	1.005
Measure of types	0.147	0.110	0.107	0.530	0.025	0.080	

$$U_B(h,z,z') = \frac{\sum_a X_{1,B}(a,h,z,z')V_{1,B}(a,h,z,z')}{\sum_a X_{1,B}(a,h,z,z')},$$

where $X_{1,B}(a,h,z,z')$ denotes the invariant distribution of states (a,h,z,z') across age-1 households, and $V_{1,B}(a,h,z,z')$ denotes the utility of an age-1 household with state (a,h,z,z') at the benchmark economy.

Table 7.3 shows the consumption equivalent variation measure for newborn households for different composition and ability types. The second and third rows show the welfare measure under the partial privatization proposals, and the last row depicts the welfare measure of households under full privatization. Notice that a welfare measure higher that 1 means that the household would prefer to be born in the alternative steady state relative to the benchmark economy. The last column of the table shows the aggregate welfare measure across all newborn household types.[18]

Type 1 households prefer the elimination of the pay-as-you-go system entirely. They prefer elimination over partial privatization, with or without mandatory annuitization. There are at least two reasons for their preference. First, these households have no fathers who would generate the demand for annuity insurance, and since these households are very young, they would rather not be subject to forced saving. Second, they might be facing binding liquidity constraints, and mandatory saving would then reduce their welfare. Another way to get the same intuition is to compare their lifetime welfare under the two PSA reforms. They prefer the one without annuitization for the same reasons listed above. In addition, type 1 households prefer the personal savings account reform to the pay-as-you-go benchmark.

Table 7.4
Return of social security for type 1 households (percentage)

	H	L
Benchmark	2.70%	2.90%
PSA+Annuity	5.51	5.49
PSA	5.10	5.41

For type 3 households, the proposed PSA reform benefits those with low preference for annuity insurance. In particular, the households with low-life-expectancy fathers (LL and LH households) are better off, whereas households with long-life-expectancy fathers (HH and HL households) are worse off, relative to the benchmark pay-as-you-go social security system.

A great majority of type 3 households finds it best of all to be born into the steady-state labeled *PSA + Annuity*, where there is mandatory saving at the 5 percent rate and wealth generated by this partial privatization program is annuitized at retirement.[19] This finding might seem surprising since our households care about leaving bequests to their relatives. However, since fathers are alive in these households, they like to hold annuities, and therefore mandatory annuitization does not lower their welfare. Moreover, the fathers are very close to retirement age, and the timing of annuitization is also in line with the households' desire to hold annuities to insure the soon-to-be retirees. The HL households prefer the pay-as-you-go system. These households benefit from the progressivity of the pay-as-you-go system because of the low-ability son, and they also receive a generous pension for the high-ability father.

The *PSA*-only reform benefits LH and LL households and hurts HH and HL households, relative to the benchmark equilibrium. This may be due to the fact that PSA does not provide annuity insurance against lifespan uncertainty, while PAYG social security does so in the benchmark equilibrium. In fact, under PSA and mandatory annuitization, all ability types but HL enjoy higher lifetime welfare than in the benchmark economy.

To see how type 1 households fare under the proposed reforms, table 7.4 calculates the expected rate of return to social security for H and L types.[20]

In both steady states with PSAs, the expected return on social security at birth is higher than the after-tax return on capital. In the case of

PSA without annuitization, there is some progressivity in the benefits since there is a first tier that is a flat benefit for every retiree. Indeed, the expected return of social security is higher for individuals with low ability (5.41 percent) than for the H types (5.10 percent). This difference between the returns for low- and high-ability households disappears when part of the retirement wealth is annuitized. In this case, high-ability households enjoy a higher rate of return (5.51 percent) than low-ability households (5.49 percent) because H types have a longer life expectancy than L types. Therefore, when the part of wealth generated by mandatory saving is annuitized at retirement, a rationale for introducing a flat first-tier pension is to compensate low-ability individuals for the fact that their expected life is shorter.

General-Equilibrium Effects The welfare effects of the different reforms of social security are partially due to general-equilibrium effects on factor prices and on the lump-sum transfers used to balance the government's budget and to redistribute accidental bequests. The increase of the capital stock due to the elimination of the pay-as-you-go system induces a decrease in the interest rate and an increase in the wage rate that favor relatively poor households. The two reforms with personal security accounts reduce the government revenue from capital income taxes (reducing the lump-sum transfer ξ_2), which favors relatively rich households. Moreover, the reform with annuitized personal security accounts reduces the redistribution of accidental bequests (ξ_1), which hurts relatively poor (and borrowing constrained) households.

In this subsection, we evaluate the importance of these general-equilibrium effects. To this end, we fix the values of the factor prices and lump-sum transfers to the levels at the benchmark economy and compute the welfare effects of the alternative reforms. We find that, for all households types, the preference ordering for social security arrangements is as follows: (1) *PSA + annuity*, (2) *PSA*, (3) *Elimination*, and (4) *Benchmark*. In this partial-equilibrium experiment, we conclude that the preference ordering of social security systems is consistent with the differential in social security returns across these economies.

Table 7.5 shows that all households would prefer to be born in the economy with personal security accounts and mandatory annuitization at retirement because the return of social security is the highest (about 6 percent) in this economy. Households of type 1 and type 3 of abilities HL, which are relatively poor and likely to be borrowing con-

Table 7.5
Welfare of newborns (fixed prices and transfers).

	Type 3				Type 1		
	HH	HL	LH	LL	H	L	Mean
Benchmark	1.0	1.0	1.0	1.0	1.0	1.0	1.0
PSA+Annuity	1.159	1.163	1.163	1.172	1.103	1.084	1.158
PSA	1.102	1.108	1.111	1.122	1.067	1.060	1.108
Elimination	1.041	1.036	1.042	1.034	1.049	1.043	1.036
Measure of types	0.147	0.110	0.107	0.530	0.025	0.080	

strained, benefit from the reform *PSA + annuity* because lump-sum transfers do not decrease due to this partial-equilibrium reform. Households of types HL and HH, which are relatively rich, prefer the reform with PSA or the elimination of social security to the benchmark system because the interest rate does not decrease with the partial-equilibrium reforms.

Table 7.5 also reveals that the loss in welfare from nonannuitization is about 5 percent; the average welfare gains for *PSA + Annuity* and *PSA only* are 15.8 percent and 10.8 percent, respectively. This value for annuities is much smaller than the Mitchell et al. (1999) estimates of about 20 to 25 percent. Our welfare benefits are not directly comparable with theirs because they compute the welfare effects of having access to an annuity market while we compute the welfare effects of reforming the pay-as-you-go social security system. Still, there are several reasons why their welfare benefits from annuitization are much higher than our estimates. First, Mitchell et al. (1999) consider the value of annuities for individuals at retirement (sixty-five years old). The closer an individual is to retirement, the higher is the benefit of having an annuity. Our welfare calculations reflect the value of annuitization for a twenty-one-year-old individual, taking into account longevity risk and individual income risk. Second, they consider selfish individuals for whom it is optimal to allocate all wealth at retirement in actuarially fair annuities. This is not the case for altruistic individuals who populate our model.

Conclusions

Public pension programs have come under renewed scrutiny with the projected increase in the share of the elderly in the population.

Economists have argued that existing pay-as-you-go social security systems lead to a reduction in national saving and discourage labor supply. The insurance role of social security against longevity risk, individual income risk, and macroeconomic risks have been mentioned as benefits of pay-as-you-go systems. Despite extensive research that evaluates the costs and benefits of unfunded social security systems, a consensus on their overall value has not emerged.

Most of the research has assumed that individuals have no bequest motives. In this chapter, we examine some of the benefits and costs of social security in a model with two-sided altruism, borrowing costs, and longevity and individual income risk. The households in our setup typically have parents and children coexisting, and their lifetime utility functions include both parents' and their children's lifetime utilities, yielding a dynastic structure. Credit markets and private annuity markets are assumed to be closed. We calibrate the model to the U.S. data and numerically solve steady-states. The welfare gains from three social security reforms are calculated, relative to steady-state, which represents the current pay-as-you-go system in the United States. One reform is a complete privatization. A second reform is a partial privatization where 5 percent of the payroll taxes are redirected to personal security accounts that earn the rate of return to economywide capital. The third reform combines this PSA with mandatory annuitization of accumulated PSA wealth at retirement.

Our main findings can be summarized as follows:

- A majority of households prefer a personal savings account reform (with or without mandatory annuitization) over the current pay-as-you-go pension system. Aggregate capital, output, and consumption, as well as individuals' lifetime welfare, are higher in the reformed pension system.
- Mandatory annuitization benefits most households.
- When we abstract from general-equilibrium effects, all household types prefer PSA with mandatory annuitization.

These results suggest the importance of annuities at retirement, especially in small. open economies whose wage rate and interest rate closely follow the world factor prices. Although the welfare benefits of annuitization are smaller in our altruistic framework, the combination of higher returns to personal security accounts and mandatory annuitization raises individuals' welfare.

Appendix 7A

Transition Probability Matrix

This transition probability matrix is a function of the age of the household and of the abilities of the father and the son and is given by

$$[\chi_j(h,h';z,z')]_{h,h'\in\{1,2,3\}}$$

$$= \begin{bmatrix} \psi_j(z') & 0 & 0 \\ 0 & \psi_{j+T}(z) & 0 \\ \psi_j(z')(1-\psi_{j+T}(z)) & (1-\psi_j(z'))\psi_{j+T}(z) & \psi_j(z')\psi_{j+T}(z) \end{bmatrix}.$$

Computation of the Expected Rate of Return of Social Security

In this chapter, we report the expected rate of return of social security for a newborn individual. The expected return of social security is implicitly defined as the rate of return that equates the present value (at age 1) of expected tax payments to the present value (at age 1) of expected pension benefits. For a newborn individual of ability z, the present value of expected tax payments is given by

$$\sum_{j=1}^{R-1} \frac{\tau\omega(1+\gamma)^{j-1}\varepsilon_j(z)}{(1+r_{ss})^{j-1}} \prod_{i=1}^{j-1} \psi_i,$$

where r_{ss} denotes the expected rate of return of social security, and $\prod_{i=1}^{j-1}\psi_i$ indicates the probability that the individual is alive at any age $j > 1$. The present value of expected pension benefits is given by

$$\sum_{j=R}^{2T} \frac{(1+\gamma)^{R-1}B_R(z)}{(1+r_{ss})^{j-1}} \prod_{i=1}^{j-1} \psi_i,$$

where the term $(1+\gamma)^{R-1}$ in the numerator accounts for the growth of pension benefits in the next $R-1$ periods.[21] Thus, the expected rate of return of social security is defined as the value of r_{ss}, for which the following equation holds:

$$\sum_{j=1}^{R-1} \frac{\tau\omega(1+\gamma)^{j-1}\varepsilon_j(z)}{(1+r_{ss})^{j-1}} \prod_{i=1}^{j-1} \psi_i = \sum_{j=R}^{2T} \frac{(1+\gamma)^{R-1}B_R(z)}{(1+r_{ss})^{j-1}} \prod_{i=1}^{j-1} \psi_i.$$

Notes

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1. This estimate is probably an upper bound on the welfare benefit of annuities for several reasons. First, the utility calculations that yield these estimates take into account only consumption and annuities after retirement, taking as given wealth at retirement. If individuals were to make their decisions at the beginning of their working life, which is what is assumed in almost all life-cycle models, then they could plan better for mortality risk, whereas in the above calculations they are surprised with mortality at retirement. Second, these calculations abstract from general-equilibrium effects. Mortality risk tends to raise aggregate saving, which in turn lowers the return to capital. Finally, they assume that individuals have no bequest motives.

2. Starting with Hubbard and Judd (1987), quantitative models have been used to evaluate the role of social security in providing insurance against mortality risk.

3. Social security has become the last stop in the transition from unemployment insurance to disability and finally to social security for many individuals in EU countries. Although at a relatively smaller scale, the United States has also started to experience a similar transition from one public insurance program to another.

4. Following Kehoe and Levine (1993, 2001), Attanasio and Rios-Rull (2000) use a model with limited enforceability of private contracts to study the effectiveness of social insurance programs in distributing risk across individuals. They find that public insurance, designed to yield more risk sharing (such as more redistributive taxes), hinders the ability of individuals for insuring against the idiosyncratic shock so that overall it leads to a decline in risk sharing and ex-ante welfare.

5. For studies on EU countries and the United States that explore the impact of aging on social security, see Pestieau and Stijns (1999) for Belgium, Gruber (1999) for Canada, Blanchet and Pele (1999) for France, Börsch-Supan and Schnabel (1999) for Germany, Brugiavini (1999) for Italy, Yashiro and Oshio (1999) for Japan, Kapteyn and de Vos (1999) for the Netherlands, Boldrin, Jimenez-Martin, and Peracchi (1999) for Italy, Palme and Svensson (1999) for Sweden, Blundell and Johnson (1999) for the United Kingdom, and Diamond and Gruber (1999) for the United States.

6. Another justification for social insurance programs is the possibility that a fraction of the population might lack the foresight to accumulate sufficient assets for their old-age consumption. For example, Diamond (1977) and Feldstein (1985) argue that many individuals will simply not follow an optimal saving program on their own. Following the time-inconsistent preferences approach suggested by Strotz (1956), Akerloff (1998) argues that the quasi-hyperbolic model might justify the existence of social security as it acts as a commitment device in an economy populated with individuals who potentially value such an institution. However, İmrohoroğlu, İmrohoroğlu, and Joines (2003) examine the welfare effects of social security on individuals with time-inconsistent preferences and find that social security is a poor substitute for a perfect commitment technology in maintaining old-age consumption and that unfunded social security generally does not raise welfare for short-term discount rates of up to 15 percent.

7. Type 1 and type 2 households are of two ability and longevity types—high and low.

8. In what follows, we express all variables per effective units of labor.

9. This function captures the differential in pension across the average college and noncollege worker observed in the U.S. economy. Individuals without college education have average lifetime earnings between 20 percent and 125 percent of the economy's average earnings. The average lifetime earnings of individuals with college education is between 125 percent and 246 percent the economy's average earnings.

10. We do not analyze whether these tax-favored accounts produce new saving. See İmrohoroğlu, İmrohoroğlu, and Joines (1998) for the impact of tax-favored individual retirement accounts on saving in the United States.

11. At any age j, the annuity payment per effective units of labor equals $b(z)(1+\gamma)^{R-j}$.

12. Notice that p is computed for the generation that retires in a given period and that we do not index p by time because we are assuming a stationary equilibrium.

13. In previous work, we have experimented with other distribution schemes for unintended bequests. Since the flow of these is only a small fraction of per-person income, our quantitative results are robust to other schemes.

14. We are assuming that in a given household all children are born at the same period and all of them die at the same period. Furthermore, we take all children in a given household to be identical regarding their labor abilities and vector of conditional survival probabilities.

15. A household survives T periods or until the father and the children have died. If the children survive to age $T+1$, each of them becomes a father in the next-generation household of the same dynasty. Otherwise, the family line is broken, and this dynasty is over. Since the population experiences broken dynasties every period, we assume that these dynasties are replaced by new dynasties to maintain our assumption of a stationary demographic structure. Since mortality rates are higher for low-ability individuals, the number of new dynasties of low ability is higher than the number of dynasties of high ability. A new dynasty begins with an individual of age 1 that holds zero assets.

16. We describe the computation of the measures of households in detail in the appendix to this chapter. For a description of the solution method, see Fuster (1999).

17. For details of the calibration choices, see Fuster, İmrohoroğlu, and İmrohoroğlu (2003).

18. Since we are comparing the welfare effects on newborn households, we do not have any type 2 households in this category.

19. Storesletten, Telmer, and Yaron (1999) also find annuitization welfare enhancing in their study of various social security reforms in a pure life-cycle setting.

20. With *social security*, we mean the sum of the pay-as-you-go payroll tax and the mandatory saving rate. See the appendix to this chapter for the computation of the overall rate of return on social security.

21. We define $B_R(z)$ for each of the social security systems in the section on social security and fiscal policy.

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