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Social Security Reform with Heterogeneous Agents*

Juan C. Conesa

Universitat de Barcelona and University of Minnesota

and

Dirk Krueger

University of Minnesota and Federal Reserve Bank of Minneapolis, Minneapolis, Minnesota 55480
E-mail: krueger@atlas.socsci.umn.edu

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This paper analyzes the quantitative role of idiosyncratic uncertainty in an economy in which rational agents vote on hypothetical social security reforms. We find that the role of a pay-as-you-go social security system as a partial insurance and redistribution device significantly reduces political support for a transition to an economy with a fully funded system. We conclude that the status quo bias in favor of an unfunded social security system is stronger in economies in which agents of similar age differ significantly with respect to labor earnings and wealth because of idiosyncratic income uncertainty. *Journal of Economic Literature* Classification Numbers: H55, E62, H3 © 1999 Academic Press

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1. INTRODUCTION

In this paper we explore the effects that idiosyncratic uncertainty within generations has on the result of majority voting on social security reforms. In the presence of uninsured idiosyncratic risk with respect to individual

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labor productivity, a pay-as-you-go social security system has a role as a partial insurance device. This partial insurance role comes from two sources: on one hand, it substitutes for missing annuity markets; on the other hand, it is partial insurance against idiosyncratic income uncertainty. Ex-post, if social security benefits are imperfectly linked to contributions, the system redistributes between individuals with different realizations of the stochastic productivity process. Therefore, in a model with idiosyncratic income uncertainty, a transition to a fully funded system may have less political support than in the benchmark model in which we abstract from the existence of heterogeneity within generations. In our model, agents are ex-ante identical, and the only source of heterogeneity within generations derives from the individual realizations of the labor productivity shock. We find that a bias in favor of the status quo (the pay-as-you-go system) can arise or be stronger than in the case without heterogeneity.

The framework used also allows us to explore what the effects of a social security reform are for the labor-leisure decision. The payroll tax to finance social security payments distorts the labor-leisure decision. Removing this distortionary taxation has an income and a substitution effect for labor supply. Our quantitative analysis shows that the substitution effect dominates and average hours worked increase slightly. At the same time, the age profile of hours worked changes: removing the unfunded social security system decreases hours worked for younger generations and increases them for older generations.

Our paper builds on the tradition of analyzing transitional dynamics in overlapping generations economies with pay-as-you-go social security systems, as first analyzed by Auerbach and Kotlikoff (1987).[1] Our focus, though, is on the political implementability of a transition from the status quo system to a fully funded system.

In recent quantitative studies İmrohoroğlu *et al.* (1995, 1998) have analyzed the question of the optimal replacement rate in an unfunded system. In these papers the authors find that the replacement rate that maximizes expected utility of an agent born into the steady state is 0%, i.e., a fully funded system.[2] Our model is very similar to the one studied by İmrohoroğlu *et al.* (1995), and we find that a newborn agent would prefer to be born into a steady state with no social security system rather than

[1] A more recent study is the transition between different social security systems in Huang *et al.* (1997).

[2] This is true as long as the time discount factor β is smaller than 1, the economy is growing, or land is introduced as a fixed production factor. Feldstein (1985) analyzes a two-period overlapping generations model in which he can characterize the optimal steady-state replacement rate analytically and finds that for a wide range of parameter values the optimal rate is zero. Huggett and Ventura (1998) study the steady-state welfare consequences of the social security reform proposed by Boskin (1986).

into a social security system with an empirically plausible replacement rate of 50%.

This raises the question of why we do not observe more countries with a fully funded system or countries in transition to such a system.[3] It is our hypothesis that along the transition from one system to another, sizable redistribution between generations and between agents with different wealth positions within one generation occurs. A majority of current voters would lose along the transition and therefore favor the status quo.[4]

Most studies on the political economy of social security reform[5] rely on median voter arguments that abstract from the existence of intracohort heterogeneity. Our analysis shows quantitatively how this type of analysis can substantially overestimate political support for a potential social security reform.

The paper is organized as follows. In Section 2 we present the model. Section 3 explains the policy experiments we consider. Section 4 discusses the calibration of the model. In Section 5 we discuss the results. Section 6 presents a sensitivity analysis with respect to the specification of idiosyncratic uncertainty. Section 7 concludes. Details of the computational procedure are contained in the Appendix.

2. THE MODEL

We consider a discrete time overlapping generations model. The economy is populated by a continuum (with given mass growing at a constant rate n) of ex-ante identical individuals. Each agent faces a positive probability of death in every period. Therefore, even in the absence of altruistic bequest motives, in our economy a fraction of the population leaves accidental bequests. These are distributed as lump-sum transfers, denoted as Tr, uniformly over agents currently alive. At a certain age agents retire[6] and receive social security payments at an exogenously specified replacement rate b of current average wages. Social security payments are financed by proportional labor income taxes τ. Labor is supplied elasti-

[3] Chile, for example, has carried out such a transition. See Diamond and Valdés-Prieto (1994) for a detailed discussion of this case.

[4] In our framework, resistance to policy reforms and status quo bias is expected to be higher in the presence of intracohort heterogeneity. A similar result has been derived by Fernandez and Rodrik (1991) for the issue of trade liberalization reform in a model with idiosyncratic uncertainty.

[5] See, for example, Cooley and Soares (1996, to appear).

[6] Retirement at this age is mandatory. Therefore, we are abstracting from the effects of social security on the retirement decision of individuals. See Gruber and Wise (1997) and Rust and Phelan (1997) for a more detailed analysis of this issue.

cally. Agents of different ages differ in their labor productivity. In addition, workers of the same age face idiosyncratic uncertainty about their individual labor productivity. We assume that workers cannot insure against this uncertainty by trading contingent contracts. Moreover, annuity markets are assumed to be missing and agents are assumed to be borrowing constrained. However, agents can use one-period uncontingent bonds as a partial insurance device against the risk of low labor productivity in the future.[7]

Individuals are indexed by type (a_t, η_t, j), where a_t is asset holdings, η_t is labor productivity status at date t, and j is age. $\Phi_t(a_t, \eta_t, j)$ is the measure of agents of type (a_t, η_t, j) at date t. Each agent dies with probability 1 at age J. Let ψ_j denote the probability of being alive at period $j+1$, conditional on being alive at period j. Agents retire at age jr and receive social security benefits SS while alive. Individuals are endowed with one unit of time and enter the economy with zero assets.

Preferences over consumption and leisure $\{c_j, (1 - l_j)\}_{j=1}^{J}$ are assumed to be representable by a standard time-separable utility function:

$$E\left\{ \sum_{t=1}^{\infty} \beta^j \frac{\left(c_j^{\gamma}(1 - l_j)^{1-\gamma}\right)^{1-\sigma}}{1 - \sigma} \right\}, \tag{2.1}$$

where β is the time discount factor and σ is the coefficient of relative risk aversion. The instantaneous utility of being dead is normalized to zero.

Labor productivity (measured in efficiency units of labor) of an agent of type (a_t, η_t, j) is given by $\epsilon_j \eta_t$, where $\{\epsilon_j\}_{j=1}^{J}$ is the deterministic age profile of average labor productivity and η_t is the stochastic labor productivity status of the agent. For retired agents, $\epsilon_j = 0$. The stochastic process for labor productivity status is identical and independent across agents and follows a finite-state Markov process with stationary transitions over time, i.e.,

$$Q_t(\eta, E) = Prob(\eta_{t+1} \in E | \eta_t = \eta) = Q(\eta, E). \tag{2.2}$$

Let Π denote the invariant probability measure associated with Q, which we assume to be unique.

[7] In our model financial markets are incomplete in an ad hoc fashion, as in Aiyagari (1994). Cole and Kocherlakota (1998), in a much simpler model, provide some justification for this assumption.

We assume that the aggregate technology can be represented by a standard Cobb–Douglas production function, so that the aggregate resource constraint is given by

$$C_t + K_{t+1} - (1-\delta)K_t \leq \theta K_t^{\alpha} N_t^{1-\alpha}, \tag{2.3}$$

where K_t, C_t, and N_t represent aggregate capital stock, aggregate consumption, and aggregate labor input (measured in efficiency units) in period t. The depreciation rate for physical capital is denoted by δ. As usual with constant returns to scale technologies, in equilibrium the number of firms is indeterminate, and we can assume, without loss of generality, the existence of a single representative firm.

We use the following timing conventions: at the beginning of the period agents' labor productivity status is revealed, and they receive transfers from accidental bequests. Then individuals supply labor and capital to the firm. Production takes place and households receive factor income. Next agents make their consumption–savings decision. Finally the uncertainty about early death is revealed.

2.1. *Definition of a Competitive Equilibrium*

Let $a \in \mathrm{R}_+$, $\eta \in \mathrm{E} = \{\eta_1, \eta_2, \ldots, \eta_n\}$, $j \in J = \{1, 2, \ldots, J\}$, and let $\mathrm{S} = \mathrm{R}_+ \times \mathrm{E} \times \mathrm{J}$. Let $\mathrm{B}(\mathrm{R}_+)$ be the Borel σ-algebra of R_+ and $\mathrm{P}(\mathrm{E}), \mathrm{P}(\mathrm{J})$ the power sets of E and J, respectively. Let $\mathscr{S} = \mathrm{B}(\mathrm{R}_+) \times \mathrm{P}(\mathrm{E}) \times \mathrm{P}(\mathrm{J})$, and let M be the set of all finite measures over the measurable space $(\mathrm{S}, \mathscr{S})$.

DEFINITION. Given a sequence of replacement rates $\{b_t\}_{t=1}^{\infty}$, and initial conditions K_1 and Φ_1, a competitive equilibrium is a sequence of individual functions for the households $\{v_t, c_t, a'_t, l_t\colon \mathrm{S} \to \mathrm{R}_+\}_{t=1}^{\infty}$, sequences of production plans for firms $\{N_t, K_t\}_{t=1}^{\infty}$, prices $\{w_t, r_t\}_{t=1}^{\infty}$, government policies $\{\tau_t, SS_t\}_{t=1}^{\infty}$, a sequence of transfers $\{Tr_t\}_{t=1}^{\infty}$, and a sequence of measures $\{\Phi_t\}_{t=1}^{\infty}$, $\Phi_t \in M$, such that for all t, the following hold.

1. Given prices, policies, transfers, and initial conditions, v_t is the solution to the following programming problem (with c_t, a'_t, and l_t as associated policy functions):

$$v_t(a, \eta, j) = \max_{c, a', l} \left\{ u(c, l) + \beta \psi_j \int v_{t+1}(a', \eta', j+1) Q(\eta, d\eta') \right\}, \tag{2.4}$$

subject to

$$c + a' = I(j) w_t (1 - \tau_t) \epsilon_j \eta l + (1 + r_t)(a + Tr_t) + (1 - I(j)) SS_t, \tag{2.5}$$

where

$$I(j) = \begin{cases} 1 & \text{if } 1 \leq j < jr \\ 0 & \text{if } jr \leq j < J \end{cases} \tag{2.6}$$

$$a' \geq 0 \tag{2.7}$$

$$c \geq 0 \tag{2.8}$$

$$0 \leq l \leq 1. \tag{2.9}$$

The functions $\{v_t, c_t, a'_t, l_t\colon \mathrm{S} \to \mathrm{R}_+\}_{t=1}^{\infty}$ are measurable with respect to $\mathscr{S}$.

2. The prices w_t and r_t satisfy

$$r_t = \theta\alpha\left(\frac{N_t}{K_t}\right)^{1-\alpha} - \delta \tag{2.10}$$

$$w_t = \theta(1-\alpha)\left(\frac{K_t}{N_t}\right)^{\alpha}. \tag{2.11}$$

3. The government policies satisfy

$$SS_t = \frac{b_t w_t N_t}{\int \Phi_t(da \times d\eta \times \{1, \dots jr - 1\})} \tag{2.12}$$

$$\tau_t w_t N_t = SS_t \int \Phi_t(da \times d\eta \times \{jr, \dots J\}). \tag{2.13}$$

4. Transfers are given by

$$Tr_{t+1} = \frac{\int (1-\psi_j) a'_t(a, \eta, j) \Phi_t(da \times d\eta \times dj)}{\int \Phi_{t+1}(da \times d\eta \times dj)}. \tag{2.14}$$

5. Market clearing:

$$K_{t+1} = \int a'_t(a, \eta, j) \Phi_t(da \times d\eta \times dj) \tag{2.15}$$

$$N_t = \int \eta \epsilon_j l_t(a, \eta, j) \Phi_t(da \times d\eta \times dj) \tag{2.16}$$

$$\int c_t(a, \eta, j) \Phi_t(da \times d\eta \times dj) + K_{t+1} = \theta K_t^{\alpha} N_t^{1-\alpha} + (1-\delta) K_t. \tag{2.17}$$

6. Law of motion for Φ_t:

$$\Phi_{t+1} = H_t(\Phi_t). \tag{2.18}$$

The function H_t can be written explicitly as

a. For all $\mathscr{J}$ such that $1 \notin \mathscr{J}$:

$$\Phi_{t+1}(A \times E \times \mathscr{J}) = \int P_t((a, \eta, j); A \times E \times \mathscr{J}) \Phi_t(da \times d\eta \times dj), \tag{2.19}$$

where

$$P_t((a, \eta, j); A \times E \times \mathscr{J}) = \begin{cases} Q(e,E)\psi_j & \text{if } a'_t(a, \eta, j) \in A, j + 1 \in \mathscr{J}, \\ 0 & \text{else.} \end{cases} \tag{2.20}$$

b.

$$\Phi_{t+1}(A \times E \times \{1\}) = \begin{cases} \Pi(E) & \text{if } 0 \in A, \\ 0 & \text{else.} \end{cases} \tag{2.21}$$

A steady-state equilibrium is an equilibrium such that N_t, K_t, and the measure of all agents grow at rate n, and all other elements of the equilibrium are constant over time.

Several elements of the equilibrium definition deserve some comments. The borrowing constraint appears in Eq. (2.7). The fact that transfers earn interest is due to our timing convention. Otherwise, the functional equation for the household is standard, as are the marginal conditions for the representative firm. Equation (2.12) indicates that social security payments are a fraction b_t of average wages. Equation (2.13) ensures period-by-period budget balance of the social security system. Per capita transfers are defined in (2.14): total accidental bequests next period are equal to total assets that agents dying at the end of this period saved for next period. Dividing by the total number of agents alive next period gives next period's per capita transfers. Market clearing in the capital, labor and goods market are captured in Eqs. (2.15), (2.16), and (2.17), respectively. The explicit formulation of the law of motion for the aggregate state has to be divided into two parts in order to capture the assumption that newborn agents start their lives with zero assets (see (2.21)).

3. POLICY EXPERIMENTS

As our benchmark we take the model without heterogeneity and a pay-as-you-go social security system with an empirically plausible replacement rate of $b = 0.5$ (we will discuss this in the Calibration section). We assume that in period 1 the economy is in a steady state with this system.

We consider three different potential policy reforms and voting on reform vs. no reform only. Voting takes place at the beginning of period 2, after the idiosyncratic productivity shock has been realized, but before any economic choices have been made. If a reform is supported, the economy enters the transition path; if not, it stays in the initial steady state. We assume that, once a reform is implemented, the government is committed to it. The three potential reforms are

- Policy Reform A: Beginning with period 2 the replacement rate is set equal to 0 and stays there forever, i.e., $b_1 = 0.5$, $b_t = 0$, $\forall t > 1$. This reform terminates the social security system immediately and does not honor entitlements to social security payments.
- Policy Reform B: The replacement rate, 50%, is linearly reduced by one percentage point yearly over 50 periods, i.e., $b_t = 0.5 - 0.01(t-1)$, $t = 1, 2 \ldots, 50$, $b_t = 0$, $\forall t > 50$. This reform terminates the social security system gradually so that entitlements are partially honored and payroll taxes are accordingly reduced to finance progressively smaller benefits.
- Policy Reform C: The replacement rate is fixed for 20 years at 50% and set at 0 thereafter, i.e., $b_t = 0.5$, $t = 1, 2, \ldots, 20$, $b_t = 0$, $\forall t > 20$. Therefore, all individuals retired or about to retire keep their social security benefits, but future retirees anticipate that they will receive only part or no social security benefits. This reform allows agents to readjust their plans for the anticipated reform in 20 years.

In order to quantify the welfare effects of different policies for different individuals, we will use a consumption equivalent variation measure. We quantify the welfare change of a given policy reform for an individual of type (a, η, j) by asking by how much (in percent) this individual's consumption has to be increased in all future periods and contingencies (keeping leisure constant) in the old steady state so that his expected future utility equals that under a specific policy reform. Given the form of the utility function, welfare measures are easily computed as

$$EV(a, \eta, j) = \left(\frac{v_2(a, \eta, j)}{v_1(a, \eta, j)} \right)^{1/\gamma(1-\sigma)}. \tag{3.1}$$

We use a similar criterion to compare welfare between steady states and denote by

$$EV^{SS} = \left(\frac{\Sigma_{\eta \in E} \Pi(\eta) v_T(0, \eta, 1)}{\Sigma_{\eta \in E} \Pi(\eta) v_1(0, \eta, 1)} \right)^{1/\gamma(1-\sigma)} \tag{3.2}$$

the consumption equivalent variation of an agent about to be born into the new as compared to the old steady state.[8]

For example, an $EV(a, \eta, j)$ of 1.1 implies that if the given policy reform is put into place, then an individual of type (a, η, j) will experience an increase in welfare due to reform equivalent to receiving 10% higher consumption in the initial steady state (in all future nodes of her event tree) with leisure constant at the initial steady-state choice.

4. CALIBRATION

The parameters of the model have been calibrated so that the initial steady state for the economy without intracohort heterogeneity (our benchmark economy) replicates selected observations of the U.S. economy. We consider 66 generations with the retirement age at period 46. Therefore, the model is interpreted as one in which the maximum age is 85, and individuals become economically active at age 20 and retire at age 65. The probabilities of surviving $\{\psi_j\}_{j=1}^J$ have been taken from Faber (1982). We consider a yearly population growth of 1.1%. Together, these values imply that the ratio of retired people to active population (the dependency ratio) is equal to 21.6%. This number matches the ratio of population older than 65 over population between 20 and 65 from the 1990 Population Census for the United States. Notice that, given our specification, payroll taxes to finance social security payments are equal to the replacement rate times the dependency ratio. We choose the replacement rate so that the payroll tax matches its empirical counterpart. Social security payroll taxes in the U.S. data are 15.3%. However, given that the focus of our exercise is solely on retirement benefits, we subtract the part corresponding to Medicare and disability insurance. Therefore, we choose the OASI (Old-Age and

[8] Ideally, one would like to compute the percentage increase in labor efficiency units necessary for an individual to obtain the same expected future utility as under a reform (or the final steady state). This, however, would require repeated computations of the whole dynamic consumer problem (for each type), which is quite costly.

Survivors Insurance) rate, 10.7%.[9] This implies a replacement ratio of 50% in our benchmark economy.

As technology parameters we chose $1 - \alpha = 0.64$ to match the labor share of output. The depreciation rate is set at $\delta = 0.06$. The values chosen for preference parameters are a yearly discount factor $\beta = 0.97$ and coefficient of relative risk aversion of $\sigma = 2$.

These parameters have been jointly calibrated to match an interest rate of 6% and an investment–output ratio of 21% for the initial steady state without heterogeneity, and they imply a capital–output ratio of 3.[10]

The share parameter of consumption in the utility function is set at $\gamma = 0.42$. This value implies that in the initial steady state hours worked average 33% of the time endowment. This number is consistent with the microeconomic evidence that households allocate about one-third of their discretionary time to market activities.[11]

The labor earnings age profile $\{\epsilon_j\}$ has been taken from Hansen (1993).

Labor services in our model are homogeneous, so there is a single wage for one efficiency unit of labor. Individuals differ in their endowment of labor efficiency units according to their age and the realization of the stochastic process.

We will analyze and compare two different specifications for the stochastic component of labor productivity. The first uses directly Survey of Consumer Finances (SCF) data on labor earnings differentials and social mobility, as reported by Diaz-Jimenez *et al.* (1997), to calibrate the stochastic component of labor productivity. The second uses an AR(1) process estimated by Storesletten *et al.* (1998) from Panel Study of Income Dynamics (PSID) data and approximates this process by a finite Markov chain, following the method proposed by Tauchen and Hussey (1991). In the next section we will restrict ourselves to two-state Markov processes, leaving for Section 6 the discussion of robustness of these results to different specifications.

For the first specification, we choose a two-state Markov process with values $\eta_1 = 0.5$ and $\eta_2 = 3$ and persistence probabilities of the states $\pi_1 = 0.9811$ and $\pi_2 = 0.9261$, respectively. Hence, the expected value of the stochastic component of labor productivity has been normalized to 1,

[9] The OASI rate includes survivors insurance. One might interpret this as a retirement benefit because it includes mainly payments to widow(er)s of age 60 or older. Thus, in a model where the decision unit is the household, survivors insurance payments are also transfers from working households to retired households.

[10] Ríos-Rull (1996) discusses the effects of choosing different (β, σ)-pairs on the age profile of labor supply, given that a capital–output ratio of 3 is reproduced by the model economy.

[11] See Ghez and Becker (1975) and Juster and Stafford (1991).

as 80% of agents in each generation are in state 1. The value of η_2 has been chosen so that the top quintile of the labor earnings distribution make three times the average labor earnings as in the data. The transition probabilities, π_1, π_2, have been selected so that the model replicates the mobility facts of the distribution of labor earnings as reported by Diaz-Jimenez *et al.* (1997), who report that after 5 years 69% of households initially in the top quintile remain there and 92% of households initially in the bottom four quintiles remain there after 5 years (see their Table 8). As a result, the model implies a coefficient of variation of labor earnings of 1.3 and a coefficient of variation of wealth of 1.7 for the initial steady state. Diaz-Jimenez *et al.* (1997) report that for the U.S. economy these two values are 4.19 and 6.09, respectively.

Notice that the spread in both labor income and wealth is much smaller in the model than in the data,[12] even though we are choosing a highly asymmetric and persistent process exactly for the purpose of increasing the spread in labor earnings and hence wealth. With such a specification we generate an important fraction of the population whose income comes mainly from labor income. On the other hand, we have a small fraction of the population whose income consists mainly of asset returns. This will be important in terms of assessing the general equilibrium effects of a social security reform, since the first (and more numerous) group is mainly concerned with payroll taxes and retirement pensions, and the second (small) group is mainly concerned with the effects on asset returns, since retirement pensions are a smaller fraction of their income when they are retired.

For the second parameterization we draw on results from Storesletten *et al.* (1998). They used PSID data to estimate the following process for the stochastic component of (the log of) labor efficiency units, $u_t = \log(\eta_t)$:

$$\begin{aligned} u_t &= z_t + \varepsilon_t, & \varepsilon_t &\sim N(0, \sigma_\varepsilon^2) \\ z_t &= \rho z_{t-1} + \nu_t, & \nu_t &\sim N(0, \sigma_\nu^2), \end{aligned} \tag{4.1}$$

obtaining estimates for $\rho = 0.935$, $\sigma_\varepsilon^2 = 0.017$, $\sigma_\nu^2 = 0.061$.

Then, we use the Tauchen procedure to approximate this process by a two-state Markov chain. The values obtained are $\eta_1 = 0.73$ and $\eta_2 = 1.27$,

[12] As argued by Quadrini and Ríos-Rull (1997), life-cycle models with uninsured idiosyncratic risk but no bequest motive cannot replicate the large spread of wealth found in the U.S. economy, unless stochastic discount factors are introduced as in Krusell and Smith (1998) or Heathcote (1998).

TABLE I
Preference Parameters

Parameter	Value
σ	2.00
β	0.97
γ	0.42

TABLE II
Demographics

Parameter	Value
J	66
jr	46
ψ_j	Faber [11]
n	0.011

with persistence probabilities $\pi_1 = \pi_2 = 0.82$.[13] Notice that this procedure by construction generates a symmetric Markov chain with two groups of equal size, with smaller difference between their labor efficiency units and less persistence. Hence, compared to the previous specification, the coefficient of variation of labor earnings and hence wealth are even smaller, 0.71 and 0.92, respectively.

The parameters of the model are summarized in Tables I–IV.

5. RESULTS

All potential reforms start from the same initial steady state and end in the final steady state with no social security. So we first discuss the quantitative properties of these steady states, both in the model with and without heterogeneity. Then we will turn to the properties of the potential transitions, voting outcomes and welfare analysis, separately for each of the three reforms considered.

[13] Heaton and Lucas (1996) estimate a slightly different specification of the stochastic component of labor productivity:

$$u_t = \rho u_{t-1} + \varepsilon_t, \qquad \varepsilon_t \sim N(0, \sigma_\varepsilon^2)$$

and they find $\rho = 0.53$ and $\sigma_\varepsilon^2 = 0.063$. The Tauchen procedure implies $\eta_1 = 0.665$ and $\eta_2 = 1.335$ with $\pi_1 = \pi_2 = 0.74$. We do not report results for this specification, since they do not differ substantially from the results derived from the estimates of Storesletten *et al.* (1998).

TABLE III
Technology Parameters

Parameter	Value
α	0.36
δ	0.06
θ	1

TABLE IV
Individual Productivity

Parameter	Diaz-Jimenez *et al.*	Storesletten *et al.*
η_1	0.5	0.73
η_2	3.0	1.27
π_1	0.9811	0.82
π_2	0.9261	0.82
ε_j	Hansen [16]	Hansen [16]

5.1. *Initial and Final Steady State*

Table V summarizes the main quantitative features of the initial and final steady states for the models with and without intracohort heterogeneity. From here on we refer to the specification that follows Storesletten *et al.* (1998) as the "symmetric case" and to the specification that uses the data reported by Diaz-Jimenez *et al.* (1997) as the "asymmetric case." Note that y is output per capita and h denotes average hours worked. As measures of income and wealth dispersion, we report the coefficient of variation of both labor earnings and wealth, $cv(lab)$ and $cv(weal)$, respectively. We will quantify welfare changes using the consumption equivalent variation (EV^{SS}) of a newborn.

By construction, and independently of the specification of heterogeneity, the replacement rate drops from 50% to 0% and the tax rate from 10.7% to 0%. As a result, social security benefits as a fraction of output per capita drop from around 39% to 0%. As mentioned in the previous section, the dispersion of labor income and wealth, measured by the respective coefficients of variation, is significantly higher in the asymmetric specification of heterogeneity than in the symmetric specification, but still significantly smaller than in the data. In Section 6 we discuss whether specifications of the labor productivity process that include more states or permanent individual fixed effects can generate higher dispersion in labor income and wealth in our model.

TABLE V
Steady-State Results

Var.	No heterogeneity In. St.St.	No heterogeneity Fi. St.St.	Het. (sym. case) In. St.St.	Het. (sym. case) Fi. St.St.	Het. (asym. case) In. St.St.	Het. (asym. case) Fi. St.St.
b	50%	0%	50%	0%	50%	0%
r	6.0%	4.9%	5.5%	4.3%	3.4%	2.0%
w	1.18	1.25	1.21	1.30	1.36	1.49
h	32.8%	34.5%	31.3%	33.2%	29.4%	31.0%
K/Y	2.98	3.30	3.12	3.51	3.84	4.49
y	1.04	1.17	1.08	1.22	1.31	1.51
SS/y	38.9%	0	38.9%	0	38.9%	0
$cv(lab)$	0.52	0.51	0.71	0.68	1.39	1.38
$cv(weal)$	0.81	0.93	0.92	0.94	1.17	1.58
EV^{SS}	—	12.7%	—	12.8%	—	11.2%

From Table V we see that both with and without heterogeneity, a switch from an unfunded to a fully funded social security system leads to higher capital accumulation in the steady state. The capital–output ratio increases by 11% in the benchmark model, while this increase is 12% for the symmetric case and 17% for the asymmetric case. Individuals who have to provide for their retirement by private savings and are not subject to payroll taxes accumulate a larger amount of assets. Hence the capital stock is higher in the final steady state. Moreover, in the presence of idiosyncratic uncertainty, precautionary savings motives imply even higher asset (and capital) accumulation and hence lower interest rates.[14] This effect is stronger the more pronounced the uninsured idiosyncratic risk with respect to labor productivity (compare the symmetric with the asymmetric specification). As a result of an increase in asset accumulation (and only modest increases in labor supply), wages increase and interest rates drop, by 1.1, 1.2, and 1.4 percentage points, respectively, in our three specifications. Notice, however, that even in the asymmetric case the economy is not dynamically inefficient in the final steady state.

Average hours worked increase by 5.2% in the case of homogeneous individuals, 6.1% and 5.4% in the symmetric and asymmetric cases, respec-

[14] See Huggett (1997) for a proof of this result for an economy with infinitely lived agents. The same intuition applies to our model.

tively, with a policy reform. Note that average hours supplied are smaller the higher the degree of heterogeneity in the specification. At the same time, aggregate labor supply in efficiency units (not reported here, but see Fig. 3) increases with the degree of idiosyncratic uncertainty. These facts are reconciled by noting that high-productivity agents decide to work significantly more than low-productivity agents.

Output per capita increases, because of capital deepening and (modestly) increasing labor supply, by 12.5% in the economy without intracohort heterogeneity, by 13% in the case of modest heterogeneity and by 15% in the case of significant heterogeneity. This increase in available resources for consumption is also reflected in the welfare consequences of a social security reform. An agent to be born into the steady state of an economy with a pay-as-you-go system would have to receive 11–13% (depending on the specification of heterogeneity) higher consumption in each future contingency to be as well off as to be born into the steady state without a social security system. These welfare benefits, on which a major fraction of the existing literature has focused, derive mainly from higher per capita consumption. On the other hand, the social security system acts as a partial insurance device against idiosyncratic labor productivity risk and substitutes for missing annuity markets. These beneficial features of the system reduce the welfare benefits from a reform, this effect being stronger the more uninsured idiosyncratic risk is present in the economy. This explains why, even though output and consumption per capita show the biggest increase in the asymmetric case, the welfare benefits from a reform are smaller in this specification.

Figure 1 shows the age profile of hours worked in both the initial and the final steady state. For the economies with and without intracohort heterogeneity, the termination of the pay-as-you-go system induces a shift in the age pattern of labor supply: young agents work less and old agents work more than in the initial steady state, reflecting the fact that in the absence of an unfunded system, agents by themselves have to save for their retirement. In the steady state, two main sources determine the labor–leisure decision for an agent of age j: the asset position and individual labor productivity of this agent, relative to (expected) labor productivity in the future. Older agents have higher age-specific labor productivity (ε_j equals 1 for age 20, peaks at 2 at age 50, and falls to 1.64 at age 65) but higher asset holdings. The higher the asset position of individuals, ceteris paribus, the lower is individual labor supply. Higher labor productivity has ambiguous effects, because income and substitution affect work in different directions. Overall, labor supply tends to decline with age. This is especially true in the model with asymmetric heterogeneity, since the degree to which agents face lifetime labor income uncertainty is decreasing in age.

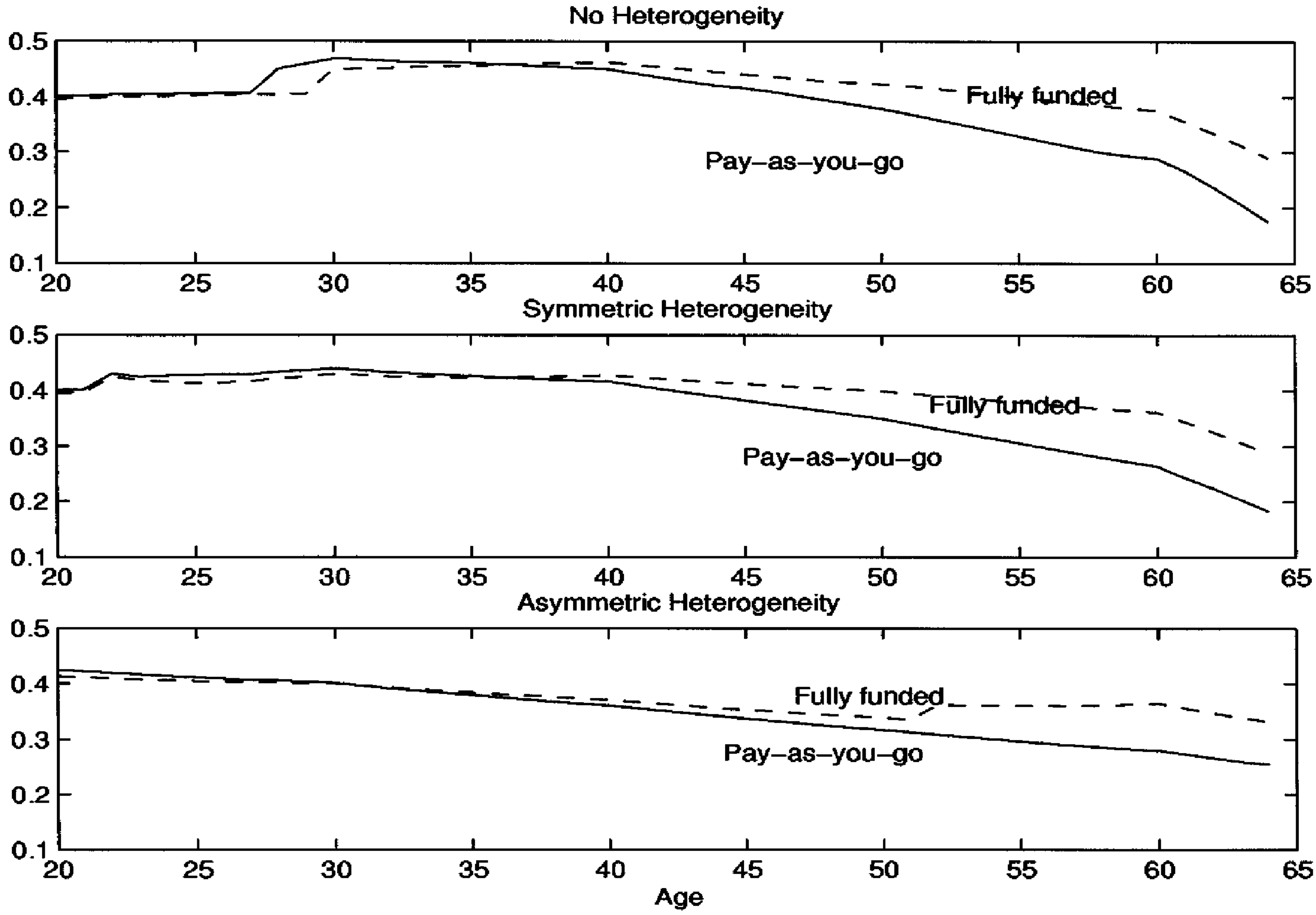

FIG. 1. Age profile of average hours worked.

Therefore young agents tend to work more in order to insure themselves against this uncertainty by accumulating assets.[15]

Figure 2 shows average asset holdings by generation. Asset holdings are always higher in the fully funded system for all generations than in the unfunded system, deriving from the fact that workers cannot rely on retirement payments from the social security system. Notice that the highest level of asset holdings is reached in the latest active periods of a worker in the steady state without a social security system, with assets being decumulated thereafter. Moreover, in the case with no heterogeneity, workers start saving only after their productivity reaches a certain point (after age 27). The same is true in the case of symmetric heterogeneity

[15] We observe a small, sudden increase in average hours worked at age 27 (30 in the final steady state) in the specification without intracohort heterogeneity. At this age agents start to save, and the nonnegativity constraint on assets stops binding. To finance positive savings, agents have to increase their work effort. The same effect occurs with heterogeneity when the low-productivity agents start saving.

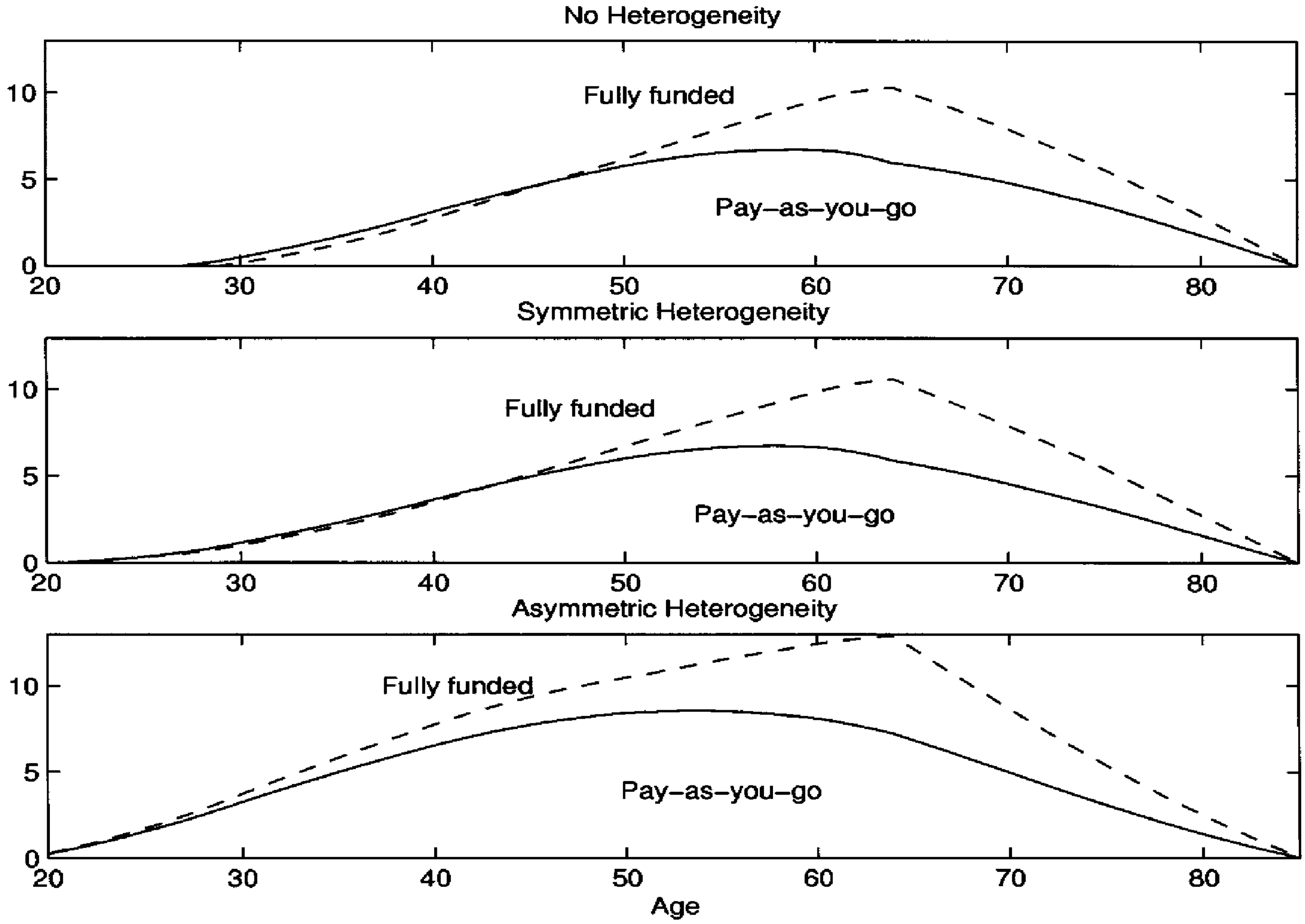

FIG. 2. Age profile of average asset holdings.

(where the starting age is 22). However, in the asymmetric heterogeneity case the young, more productive workers start saving from the earliest age on, which explains why average asset holdings are positive for all age groups. We also observe that in the presence of a pay-as-you-go system, the difference in asset accumulation between economies with no and with substantial heterogeneity are smaller than in a fully funded system. Under the pay-as-you-go system an agent retires with 17% higher average asset holdings in the presence of (asymmetric) heterogeneity, while in a fully funded system this number amounts to 23%.[16]

5.2. *Transition Paths*

In this subsection we turn to the discussion of transitional dynamics, voting results, and welfare analysis. In our model we can distinguish five

[16] This might be interpreted as a first indication of the partial insurance role of the pay-as-you-go system, in the absence of which precautionary savings are significantly higher.

effects that determine the welfare consequences of potential reforms as well as the voting decisions of individuals:

1. Intergenerational redistribution. Depending on the reform, older agents lose part of their entitlements or younger agents contribute more than they will eventually receive.

2. Intragenerational redistribution. Payroll taxes are proportional and social security benefits are not tied to contributions in our model.[17] Hence, the social security system redistributes from agents with high labor earnings (high productivity agents) to agents with low labor earnings.

3. Social security as a partial insurance device. In the absence of annunity markets and insurance against idiosyncratic uncertainty, the social security system partially substitutes for these missing markets. Note that it is ex-post (after uncertainty is revealed) intragenerational redistribution that generates ex-ante insurance against idiosyncratic uncertainty among ex-ante identical individuals. For agents that are already born, these two effects are therefore hard to distinguish.

4. General equilibrium effects. Along the transition path wages and interest rates change. Agents with higher accumulated wealth receive a higher fraction of their income from interest payments and a lower fraction from labor income.

5. Elimination of tax distortions. With an endogenous labor–leisure decision, the payroll tax to finance social security payments is a distortionary tax. Removing this distortion is one of the benefits of a transition to a fully funded system.

We will now attempt to disentangle the quantitative importance of these effects for each reform separately, where we note that the fifth effect unambiguously increases support for a reform and the third effect (to the extent that it can be distinguished from the second) unambiguously decreases support for a reform.

5.3. *Policy Reform A*

Policy Reform A represents an extreme social security reform, in which workers who have contributed to the social security system will not receive any retirement pension. We consider this reform to be a benchmark for

[17] In the U.S. social security system individual benefits are linked to individual monthly earnings (indexed and averaged over the working lifetime). The replacement rate, however, is a decreasing function of monthly earnings, so that the actual system also contains a substantial redistributive component. Ignoring the earnings–benefit linkage overstates the distortion of the labor–leisure decision induced by the pay-as-you-go system. This might bias our results *in favor* of a reform.

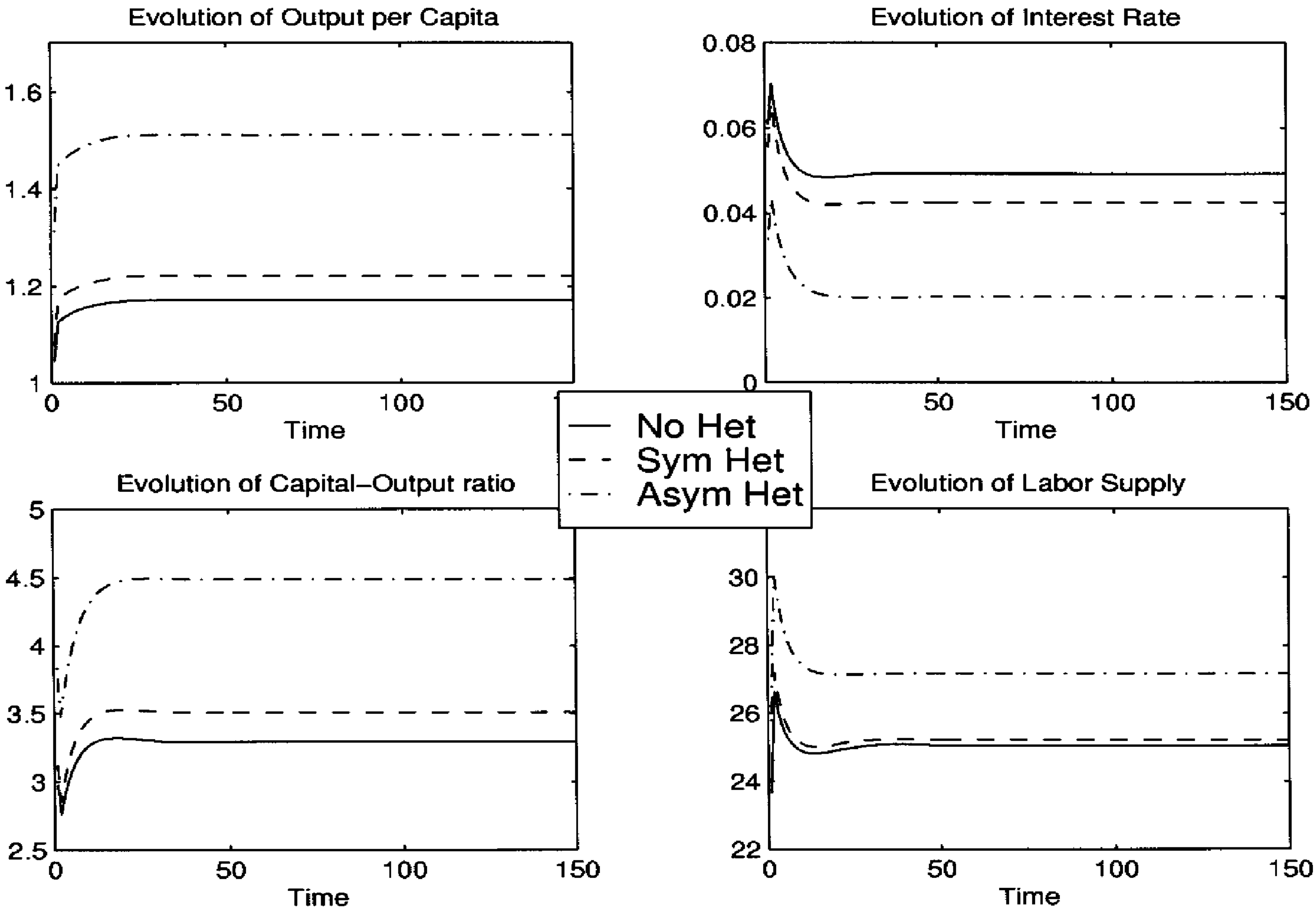

FIG. 3. Evolution of macroeconomic aggregates: reform A.

comparison with reforms that phase out the social security system more gradually. Figure 3 shows the evolution of macroeconomic aggregates if this reform were to be implemented.

Under this reform the economy reaches its final steady state after about 30 years. The elimination of payroll taxes makes working more attractive. Therefore, directly after the reform is implemented there is a sharp increase in hours worked and hence aggregate labor supply. Since the aggregate capital stock is predetermined from the period before the reform,[18] the capital–labor ratio drops sharply, resulting in a substantial initial increase in the real interest rate and a decrease in the real (pretax) wage as well as the capital–output ratio. Because of the response in labor supply, about 60% (in all three cases) of the increase in per capita output

[18] We assume that neither a reform nor even a vote on a reform was expected in period 1, where the economy is in the initial steady state with a pay-as-you-go system. For anticipation effects of a potential reform see the discussion of reform C, or, for a detailed investigation, see Bütler (1998).

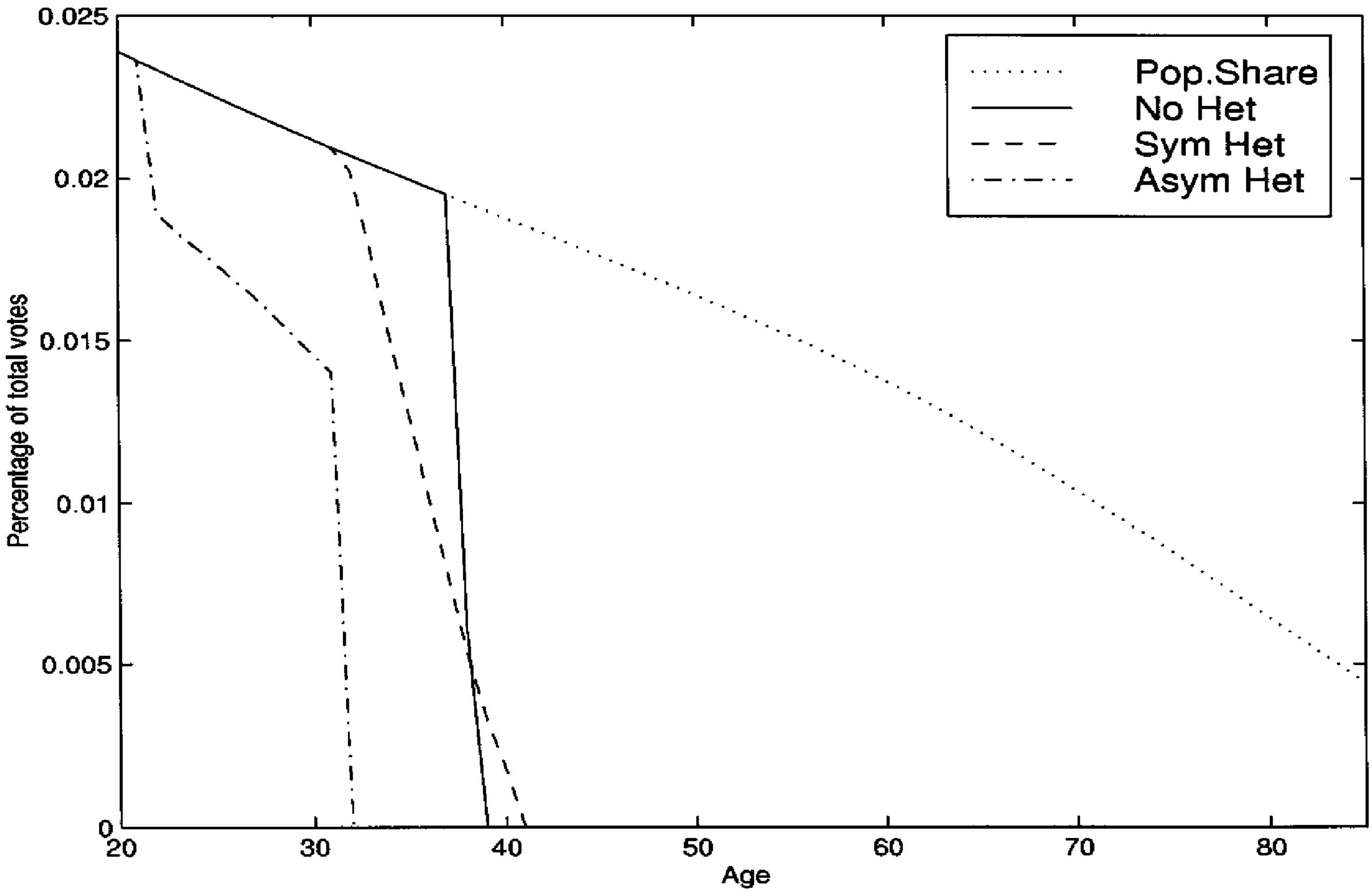

FIG. 4. Votes in favor of reform A.

is realized already in the initial period of the reform.[19] In subsequent periods higher capital accumulation sets in, which leads to further increases in output per capita, even though labor supply decreases gradually to its new steady-state value. After the initial overshoot, interest rates fall and wages rise because of an increasing capital–labor ratio.

Even though the transition paths look alike for the three specifications of heterogeneity, the welfare consequences for different individuals and their willingness to adopt the reform differ significantly across specifications of intracohort heterogeneity. In the case of no heterogeneity, 40% of individuals alive in period 1 would favor the reform, while support is smaller in the presence of heterogeneity (36% in the symmetric case and 21% in the asymmetric case), i.e., the more heterogeneity introduced in the model, the less support for a reform.

Figure 4 shows how political support for the reform depends on age. The effect of intergenerational redistribution is strong. In the absence of

[19] Notice the importance of allowing for elastic labor supply in this type of analysis. With exogenous labor supply in the second period, output per capita would not change at all.

heterogeneity everybody of age 37 or younger votes for the reform, and everybody of older age votes against it.[20] For young agents, the prospect of earning untaxed wages for the rest of their lives outweighs the cost of having contributed for some time to the social security system without getting any benefits, whereas for the older population (with less time remaining to provide for retirement on their own) the reverse is true. It is remarkable that agents who are already 37 years old prefer to forgo all acquired entitlements in exchange for 29 years of (higher) wages that are not subject to distorting payroll taxes.

With intracohort heterogeneity some generations are split in votes, with labor productivity status and asset position determining support or opposition. For the specification with modest heterogeneity, all agents up to age 32 support the reform, generations 33–41 are split, and all older generations oppose the reform, whereas the specification with substantial heterogeneity yields critical ages of 23 and 33.

In order to further analyze the voting decision of different individuals it is instructive to investigate the welfare changes induced by the potential reform. In Figs. 5–7 we show how the welfare effects of the reform, measured by consumption equivalent variation, vary with asset position and labor productivity status for selected generations.

We can see, as already discussed, that, ceteris paribus, young agents would benefit from a reform, with gains for newborns with no assets of about 5–10% in equivalent consumption (depending on the specification of heterogeneity). Old agents are the big losers of the reform, with agents of age 60 losing about 20–60% (for reasonable asset holdings). The situation is even worse for agents who are already retired.

For young individuals welfare gains are decreasing in their asset position. The rationale for that is that a young poor agent relies substantially on labor earnings as the main source of income, especially if she is currently unproductive and will therefore not be able to accumulate assets for the near future (as the productivity shocks are highly persistent). Thus, the realized gain in welfare from removing the payroll tax is substantial, even more so considering the increase in wages due to general equilibrium effects. However, young wealthy individuals are negatively affected by a reform that decreases the return to their assets. Furthermore, young agents do not receive social security payments until far in the future, the point at which the redistributive character of the system materializes. It appears that for young individuals the removal of the payroll tax, together

[20] Bohn (1998) finds, in a different, partial equilibrium model context, a cutoff age of exactly 37, with agents of age 38 and older benefitting from the current social security system. Although he does not include survivor benefits in his benchmark analysis whereas we do, we find the similarity in our results remarkable.

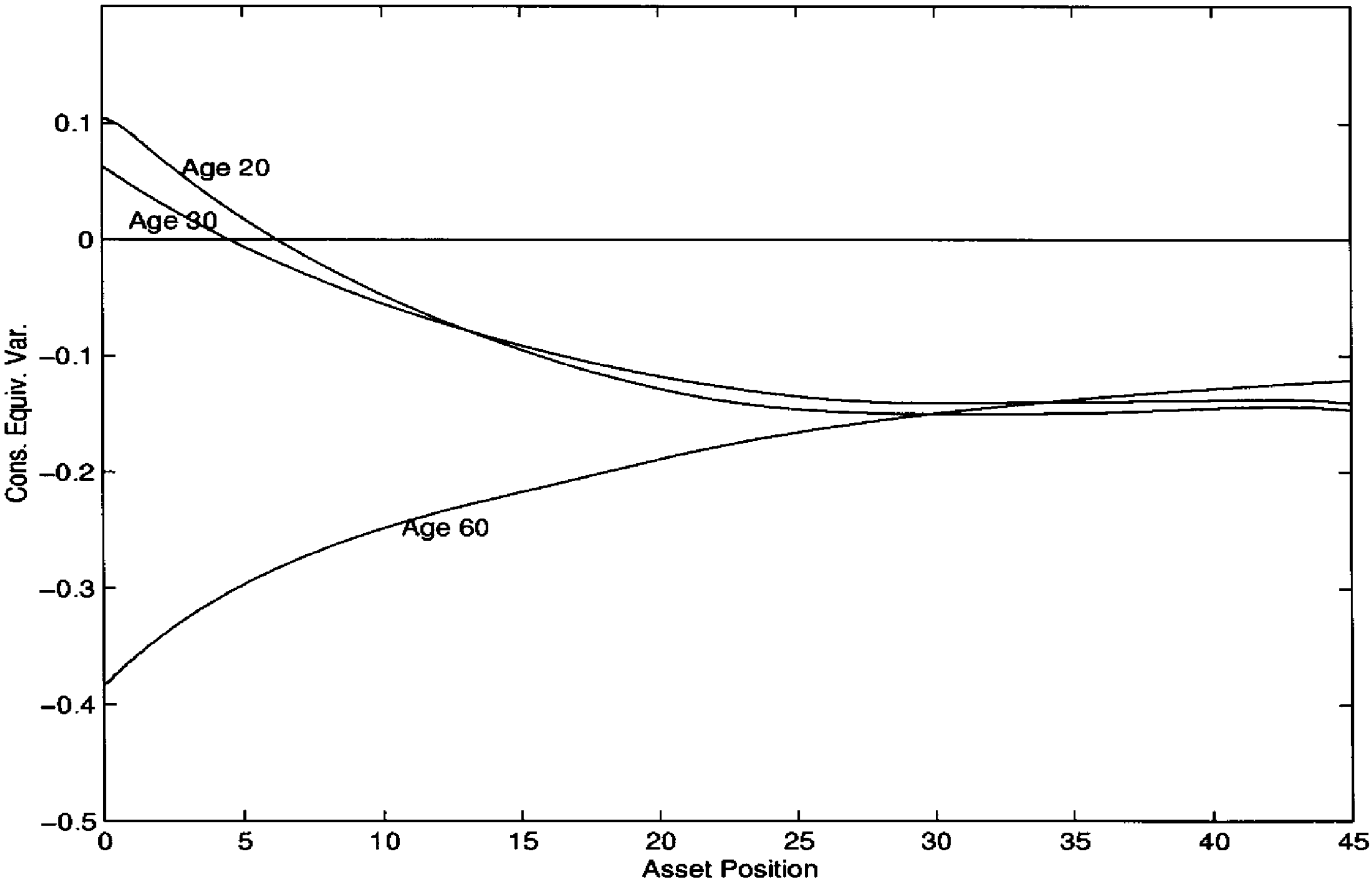

FIG. 5. Welfare effects of reform A: no heterogeneity.

with the general equilibrium effects, dominates the redistributive effects, so that, holding age constant, poor unproductive agents benefit (more) from a reform and wealthy productive agents lose. This explains why for the young generations in which votes are split, wealthy agents vote *against* the reform.

However, for older individuals the welfare change is increasing in asset positions, and agents with the high productivity shock are less affected by the reform. Agents of age 60 have 4 years of their working life left and therefore are not strongly affected by the general equilibrium effects of changing factor prices. They do not use asset holdings so much as a source of generating interest income, but rather consume the principal in their retirement years. Furthermore, if these agents happen to be unproductive today, there is a large probability that they will stay unproductive for the rest of their working life. These agents strongly value the redistributive nature of the pay-as-you-go system, the extent of the value varying with the degree of intracohort heterogeneity, as can be seen from Figs. 6 and 7. In the case of modest heterogeneity, unproductive agents with zero asset holdings experience a welfare loss of 45% compared to 37% for productive

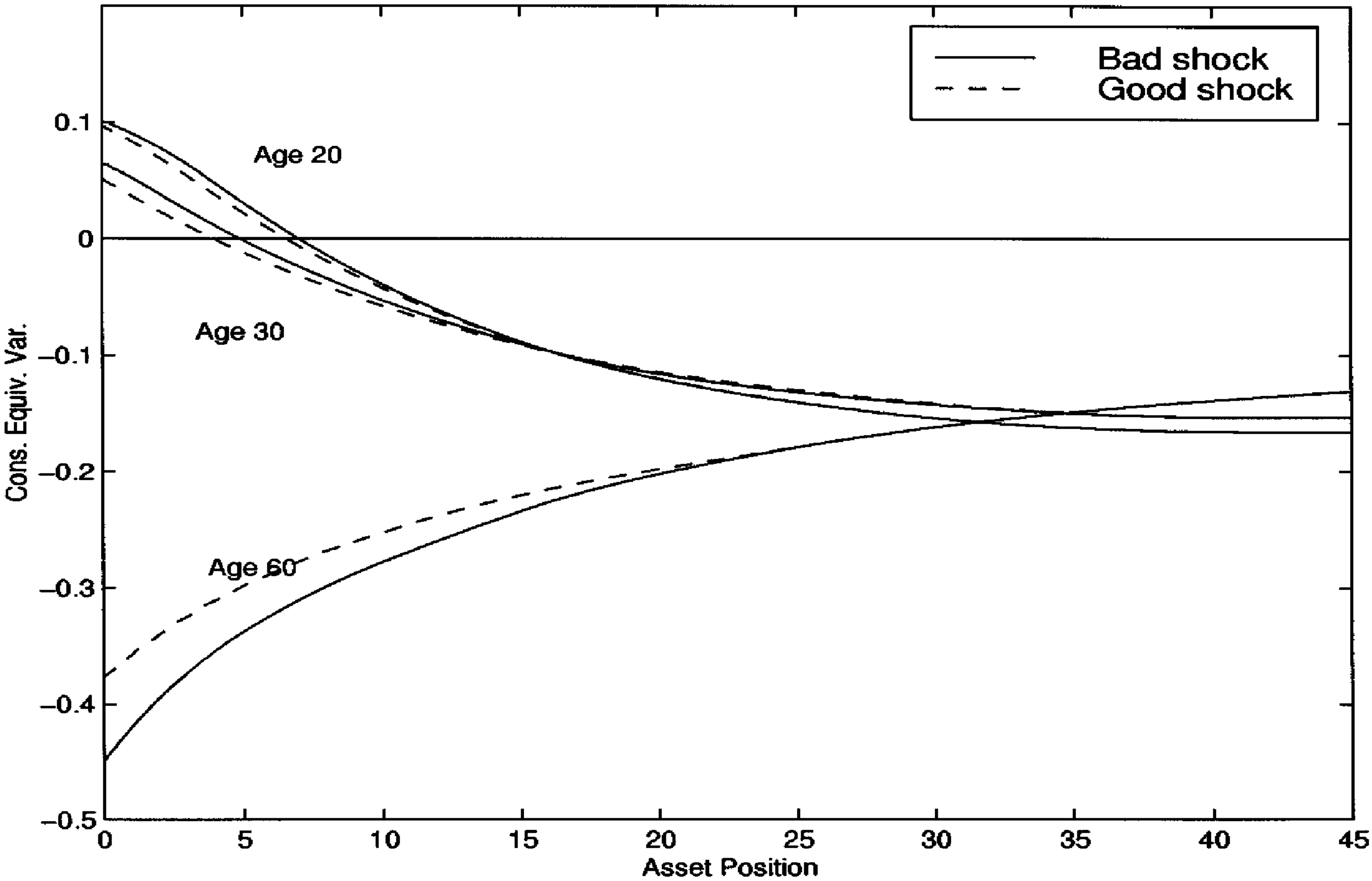

FIG. 6. Welfare effects of reform A: symm. heterogeneity.

agents, whereas in the specification with substantial heterogeneity, in which shocks are very persistent, these numbers amount to 62% and 28%. We also observe, however, that for agents with a very high level of asset accumulation (agents that have almost perfectly self-insured against idiosyncratic uncertainty), welfare consequences of the reform do not depend on the current realization of the productivity shock.

In order to evaluate the importance of general equilibrium effects we perform the following exercise: we computed individual decision rules and voting and welfare changes for reform A under the assumption that interest rates, pretax wages, and transfers stay unchanged at their initial steady-state values. Thus, a reform only implies not paying the payroll tax and giving up future social security payments. Figure 8 shows the welfare changes for such an experiment for the specification of substantial heterogeneity.[21]

[21] For young generations, consumption equivalent variation is still a decreasing function of asset holdings, because the beneficial removal of payroll tax is more important for agents whose income is mainly composed of labor income.

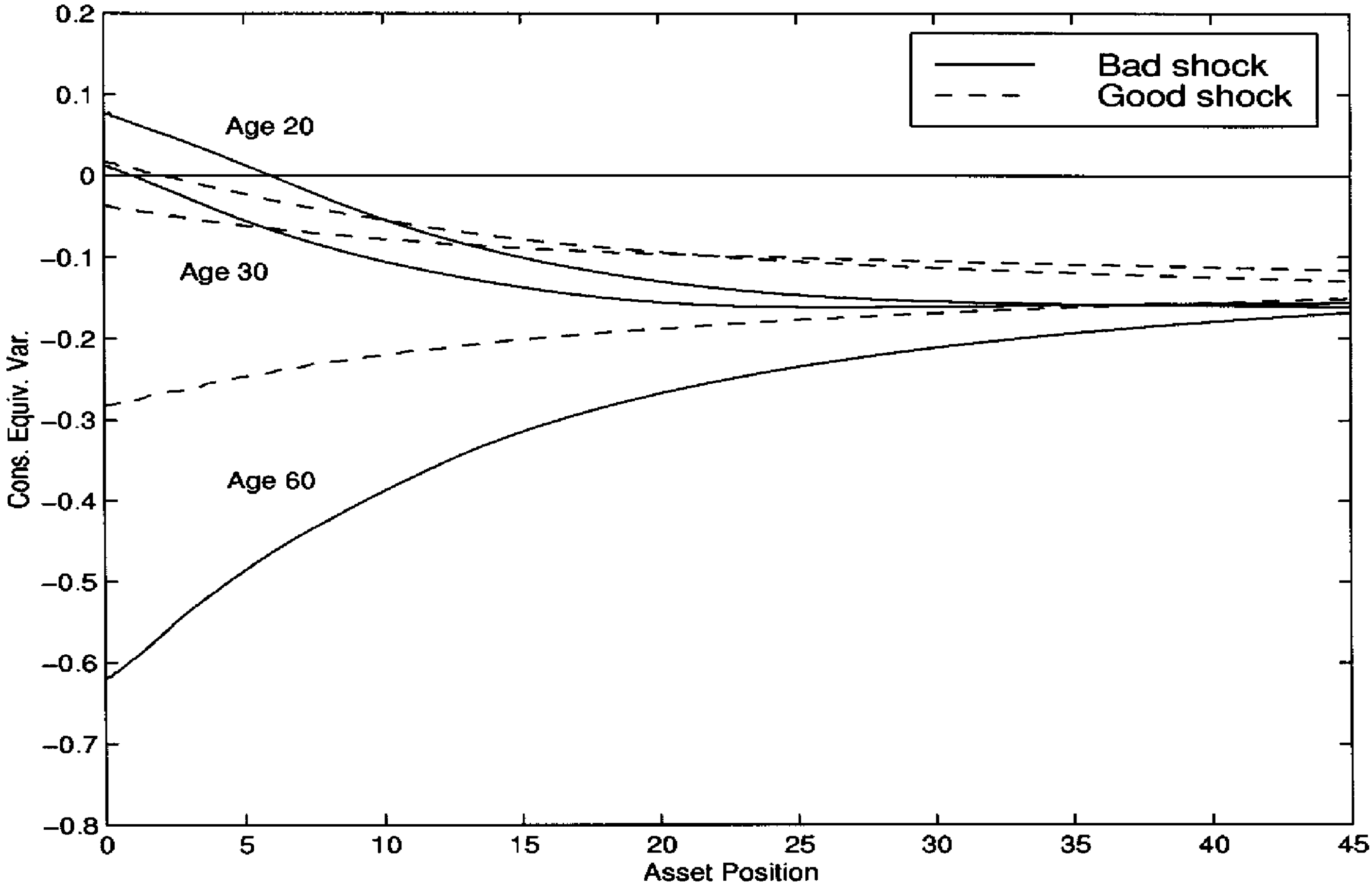

FIG. 7. Welfare effects of reform A: asymm. heterogeneity.

We argued above that young, poor, low-productivity agents benefit from the reform mainly via rising wages, whereas young, high-productivity agents, able to accumulate assets in the future, are also adversely affected by falling interest rates. Holding factor prices fixed, we see that now low-productivity agents are less favored by a reform, and young *high*-productivity agents are the major beneficiaries of the reform, which supports our previous hypothesis. Another important observation from this exercise is that for agents with a high amount of accumulated assets, the reform is more favorable (less hurtful) if interest rates stay constant, so that wealthier agents now support the reform.[22] We conclude that the general equilibrium effects, mainly the decline in interest rates, makes young, wealthy, and highly productive agents reject a reform that could potentially

[22] Voting results for reform A with fixed factor prices are as follows: 46% support with no heterogeneity, 43% in the symmetric case, and 15% in the asymmetric case. Notice that with low (or no) heterogeneity, considering fixed prices would increase support, whereas in the asymmetric case total support is smaller. Support in generations which are split comes from the high-productivity agents (only 20% of each generation in the asymmetric case, 50% in the symmetric case).

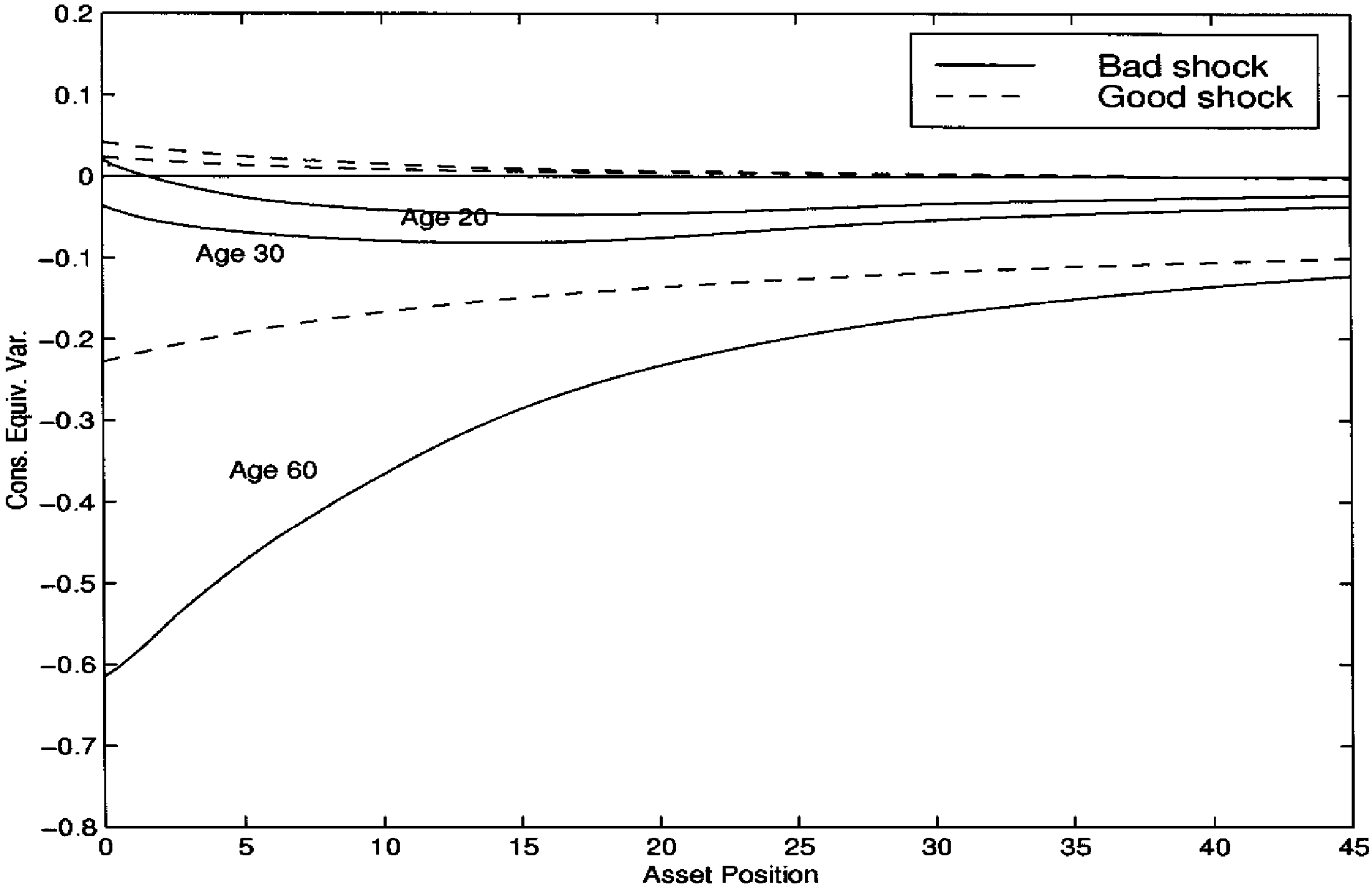

FIG. 8. Welfare effects of reform A: asymm. het., fixed prices.

favor them because it reduces the burden of intragenerational redistribution they have to bear.

5.4. *Policy Reform B*

Policy reform B represents a more gradual transition to a fully funded system. Still, older generations lose part of their social security entitlements. Therefore, currently older agents are not affected as much by the transition as before. On the other hand, young agents contribute more to the system than they will eventually receive. Furthermore, the transition to the new steady state is much slower, and therefore currently young agents will not enjoy all of the benefits from a steady state with higher wages and zero taxes on labor income in the near future, as shown in Fig. 9. Convergence to the new steady state now takes about 70 years.

Now a majority vote between status quo and reform yields 21% support for a reform in the model without intracohort heterogeneity. With heterogeneous agents, the reform is supported by 17% in the specification with modest heterogeneity and by 2% in the specification with substantial

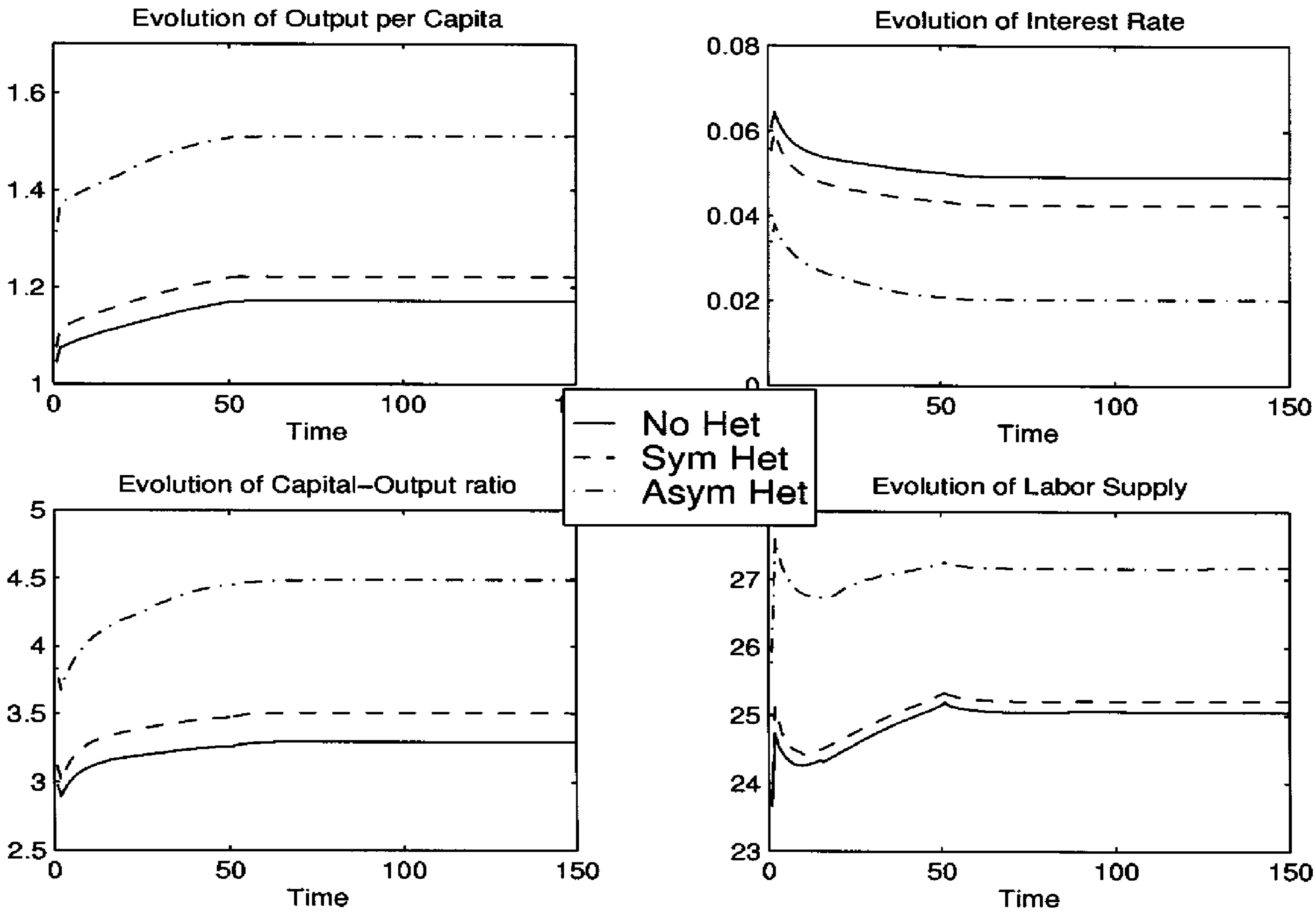

FIG. 9. Evolution of macroeconomic aggregates: reform B.

heterogeneity. Again political support in favor of a reform is a decreasing function of the degree of intracohort heterogeneity.

In Fig. 10 we graph support for the reform against the age of voters. Supporters of the reform can be found among the very oldest and youngest generations. Figure 11 depicts the welfare effects of the reform for selected generations, as a function of asset holdings, for the asymmetric specification of heterogeneity. We chose to depict generation 81, as this generation is split in votes. The oldest generations favor the reform, at least when they have accumulated a certain wealth. This occurs because of general equilibrium effects. With this reform these generations face minor reductions in their social security benefits, but experience higher interest rates for the rest of their lives. As can be seen from Fig. 9, interest rates overshoot on impact and then drop significantly. For this reform, interest rates are above their initial steady-state level for four periods into the reform. The increase in income derived from asset accumulation outweighs the small losses in social security payments for generations 81–85 and is

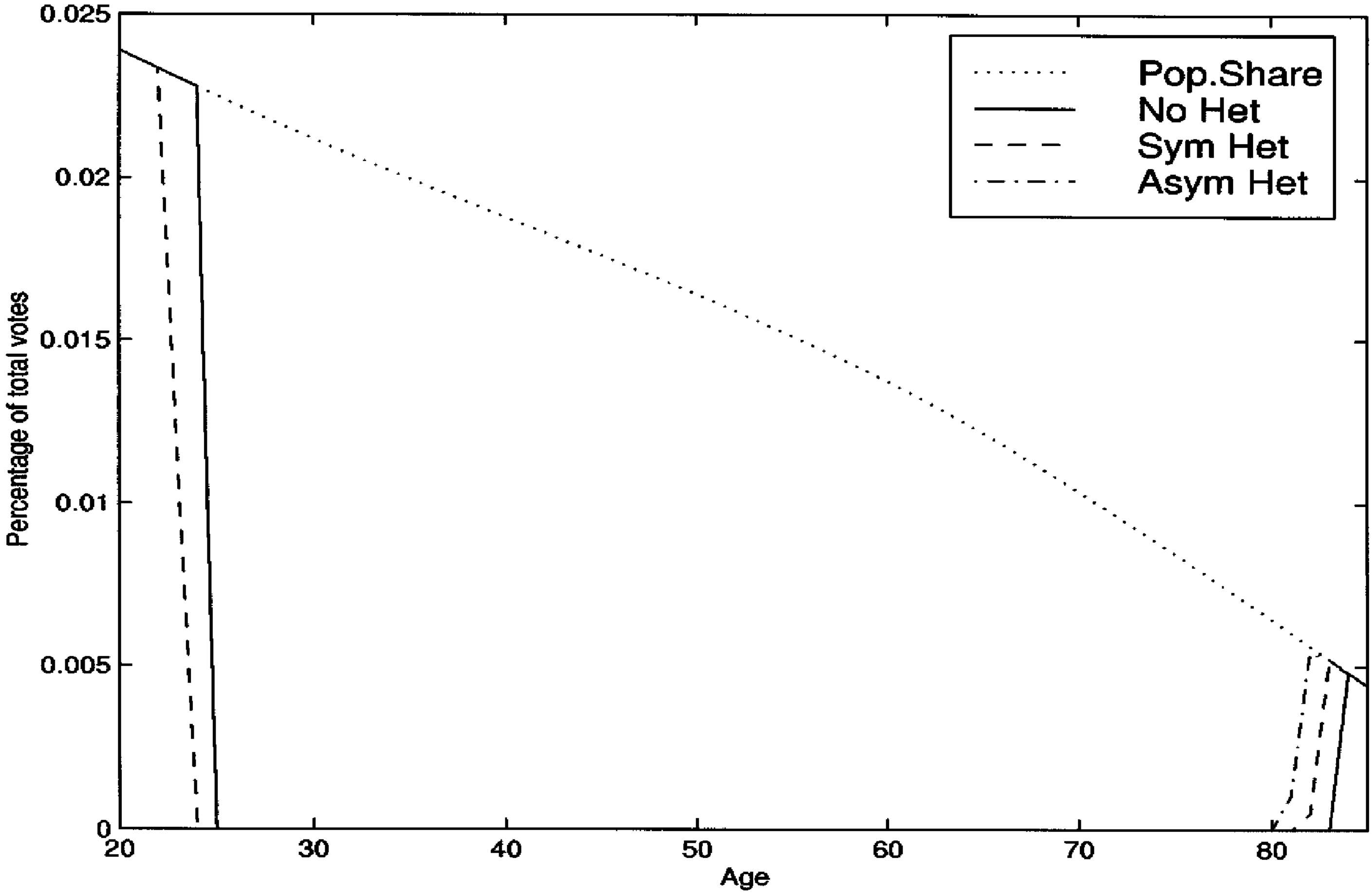

FIG. 10. Votes in favor of reform B.

sufficient for these agents to support the reform. As we can see, the welfare gains from a reform for these agents are rather small, amounting to about 0.5% in consumption equivalent variation. For the specification with modest or no intracohort heterogeneity, interest rates are back to the initial steady-state value in three periods, reducing the number of older generations to support the reform.

Middle-aged agents and younger retirees are the unambiguous losers of reform B. Younger retirees lose a significant portion of their acquired benefits and suffer from (eventually) lower returns on their savings. For example, an agent who just retired and has average asset holdings for this generation suffers a welfare loss of 6.5–7.5%, depending on the specification. Agents in their middle ages, say of age 45, under the reform still have to pay a significant amount of payroll taxes but will receive only a minor fraction of social security benefits. Welfare losses for these agents, with average asset holdings for this generation, are between 5.5% and 13%. Welfare losses are lowest in the no-heterogeneity case and highest for the unproductive agents in the asymmetric heterogeneity case, reflecting the fact that unproductive agents of this age start to value the redistributive

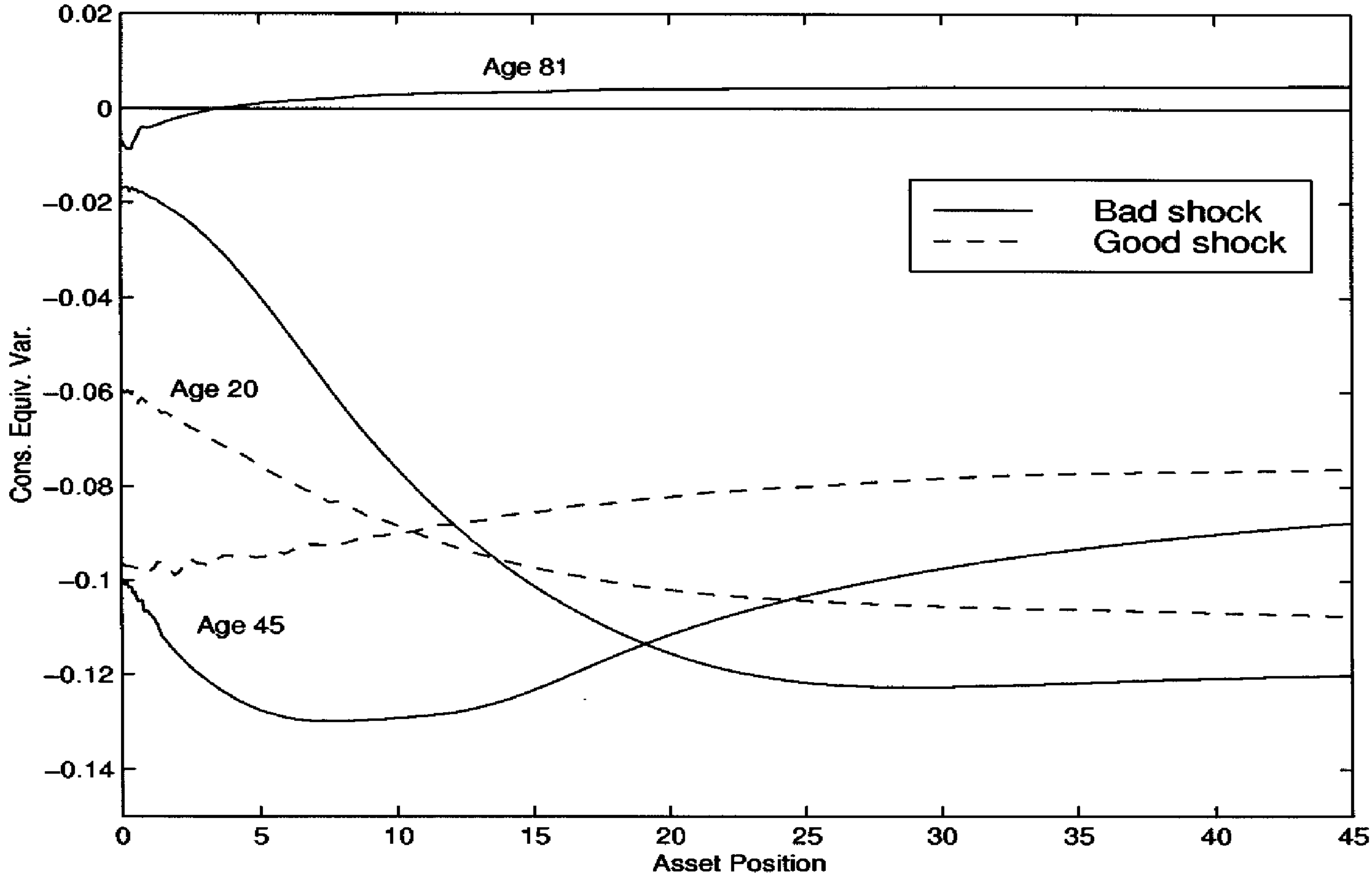

FIG. 11. Welfare effects of reform B: asymm. heterogeneity.

character of the pay-as-you-go system, especially if the process for individual productivity is highly persistent and dispersed.

Under reform B, young agents face a substantial reduction of taxes over their lifetime, lose all social security benefits, and face significant changes in factor prices during their working lives. Welfare effects and voting decisions for these agents depend on the quantitative importance of these effects. Qualitatively, for these agents the welfare effects are similar to those in reform A, and the same intuition applies to the results. However, since the reduction of payroll taxes and increasing wages take more time in this reform than in reform A, only the youngest generations vote for the reform, and only in the case of modest or no heterogeneity (see Fig. 10). The welfare consequences of transition B in general are more modest: gains of 1% at most for newborn agents (facing no idiosyncratic uncertainty) and welfare losses of 13% at most for agents in their middle ages who are currently unproductive.

It is remarkable to compare these results with what the voting outcome would be if factor prices were to remain unchanged: 57% support for reform B with no heterogeneity, 53% with moderate heterogeneity, and

23% for the asymmetric case.[23] With fixed prices only young individuals vote for the reform, since the oldest generations do not benefit from a higher return on their savings in the first periods of the reform. Compared to the other specifications, in the asymmetric heterogeneity case, only the highly productive agents favor the reform for a large number of generations (generations 26–55), whereas in the other cases fewer generations, but most of their members can be won for the reform.

5.5. *Policy Reform C*

Is it possible to design a transition in which the social security system balances its budget in every period and that is approved by a majority of voters? A possible candidate is a transition that keeps the benefits of all retired agents untouched (and hence wins their votes) and cuts taxes sufficiently rapidly to win support from young generations. Transition C explores this possibility by keeping all benefits untouched for 20 years (i.e., for all agents already retired) and then abolishing the unfunded system immediately. Figure 12 shows aggregate variables along this potential reform. Qualitatively, after period 20, in which the pay-as-you-go system is terminated, the paths look similar to those of transition A. Note that all agents are fully informed of this event in advance. Optimizing agents react to a tax cut in the future by intertemporal reallocation of the time spent in market activities. Initially, labor supply increases, then drops in the periods prior to the tax cut and increases sharply in period 21. The same is true with asset accumulation. The capital stock in period 21 is determined by asset accumulation decisions in period 20. Hence, the capital–labor ratio and therefore the capital–output ratio fall sharply in period 21 and the real interest rate rises. After this period, the economy converges to the new steady state as rapidly as in transition A. This pattern holds, regardless of the presence of intracohort heterogeneity.

Is this transition successful in attracting a sufficient number of voters? In the economy with homogeneous agents, 28% of the individuals vote for the reform, whereas with heterogeneous agents this number is reduced to 24% and 17%, respectively, for the symmetric and asymmetric specification of heterogeneity. Figure 13 shows how political support differs by age. As expected, this reform attracts current retirees. These individuals benefit from higher pensions (as labor earnings increase in the first 20 periods of the transition), which more than compensates for the loss of interest income due to declining interest rates.

[23] Cooley and Soares (1996) find, in a similar framework, that ignoring general equilibrium effects can reverse the outcome of a majority voting on *implementing* a pay-as-you-go social security system.

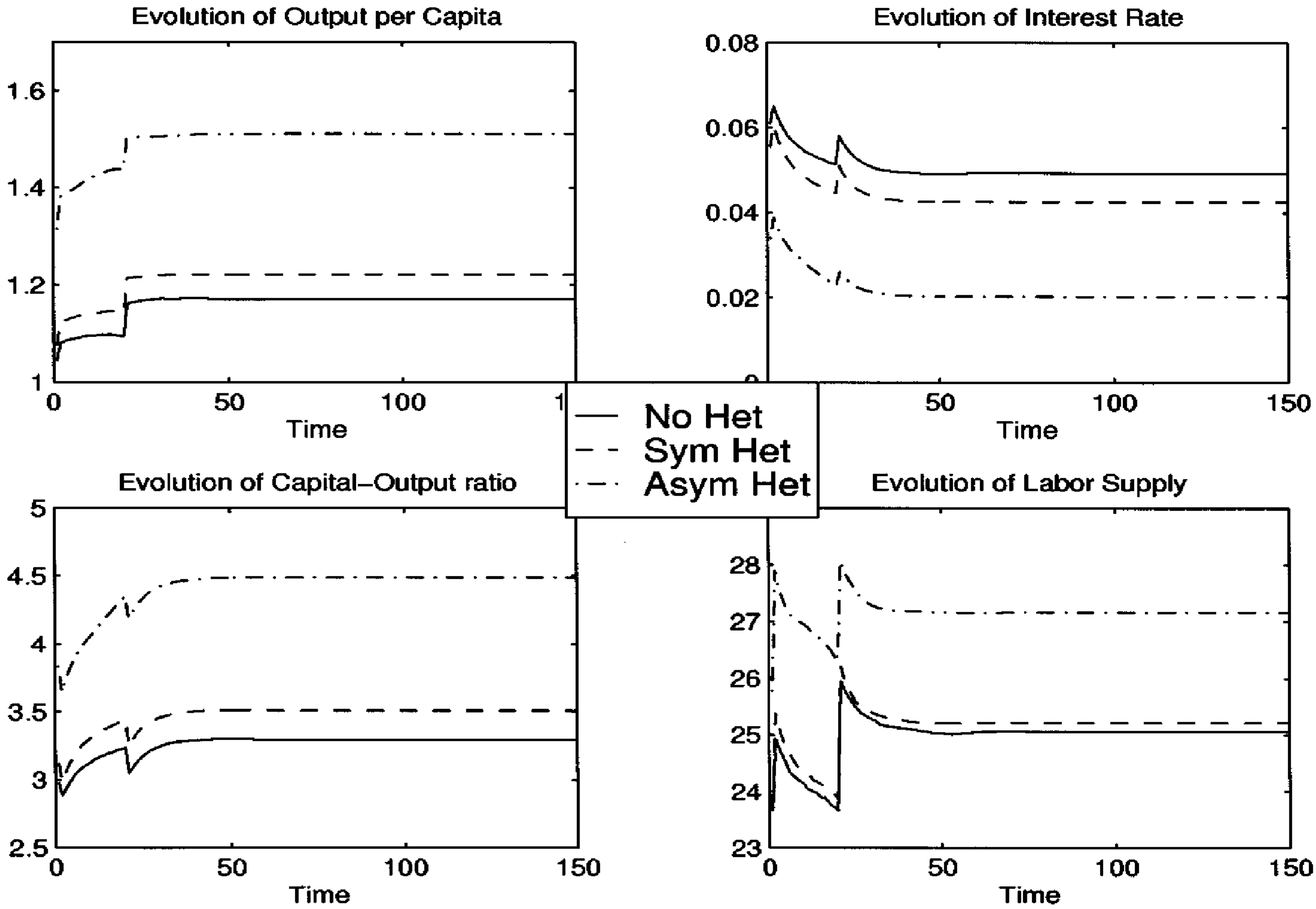

FIG. 12. Evolution of macroeconomic aggregates: reform C.

However, the youngest generations show insufficient support for this reform. Only the first five generations vote for the reform in the homogeneous case. Paying taxes for 20 years without acquiring any social security benefits is not offset by higher and tax-free wages in the future for middle-aged agents. If, in addition, agents face uncertainty about their labor productivity, the removal of the unfunded social security system as a partial insurance/income redistribution device only finds support among the three youngest generations when they face moderate labor productivity risk and no support among the young when they face substantial risk.[24]

The welfare consequences for agents who are already retired or still young are similar to those for reform B. Middle-aged generations are especially harmed by the reform, as they pay full taxes for the rest of their working lives and will not receive any benefits. For example, for an agent who is 45 years old and has average asset holdings, the welfare losses

[24] For fixed factor prices the voting outcome is as follows: 55%, 48%, and 24% support for the reform.

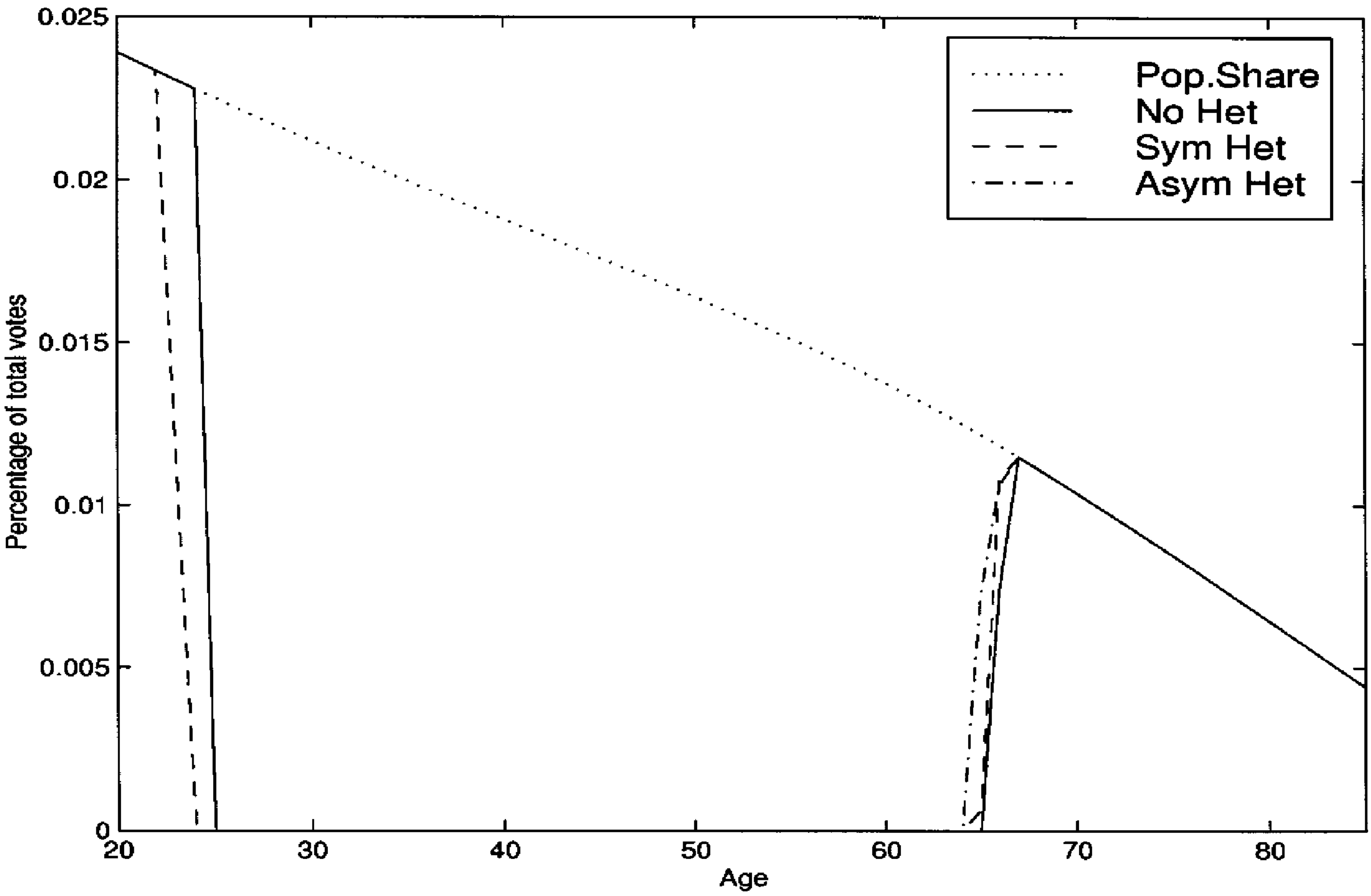

FIG. 13. Votes in favor of reform C.

amount to 13–25% in consumption equivalent variation, with the highest loss for unproductive agents in the asymmetric case.

6. SENSITIVITY ANALYSIS

Given that the focus of our study is on the effects of intracohort heterogeneity, in this section we investigate the sensitivity of our results to alternative specifications of the Markov process governing individual labor productivity.

6.1. *Increasing the Number of States in the Markov Chain*

The specification of labor productivity as a two-state Markov process may seem restrictive. In this subsection we report results for specifications with more than two states. We focus on reform A as, qualitatively, increasing the number of states has the same effect for all three reforms.

In the previous section we observed that the symmetric specification of heterogeneity, following Storesletten *et al.* (1998) and using the Tauchen

TABLE VI
Dispersion of labor earnings, wealth, votes for reform A

	Sym, 2 states	Sym, 3 states	Sym, 5 states	Asym, 2 states
$cv(lab)$	0.71	0.81	0.92	1.39
$cv(weal)$	0.92	1.00	1.13	1.71
Votes	36.4%	33.8%	30.4%	21.3%

procedure, yielded substantially less dispersion in labor earnings and wealth than the asymmetric specification. We therefore ask whether the introduction of more states into the specification following Storesletten *et al.* yields results that are closer to those obtained with the two-state asymmetric specification. Specifically, we used the same procedure described in Section 4 to discretize the AR(1) process estimated by Storesletten *et al.* (1998) into a three-state and a five-state Markov chain. Measures of dispersion of labor income and wealth (for the initial steady state), as well as votes in favor of reform A, are reported in Table VI.

Increasing the number of states does increase the spread between levels of individual labor productivity an agent could face. As a consequence, the dispersion of labor earnings and hence wealth increases with the number of states. Votes in favor of a reform are declining in the number of states, which supports our finding from Section 5 that political support for a reform decreases as the extent of idiosyncratic uncertainty with respect to individual labor productivity increases. The results in this subsection indicate that this is true regardless of whether the stochastic process is symmetric.[25] We conclude that the two two-state specifications used in Section 5 can serve as benchmarks, with richer specifications generating a degree of intracohort heterogeneity somewhere between these polar cases.

6.2. *Permanent Differences in Labor Productivity*

So far the specification of individual labor productivity did not allow for deterministic differences over and above those captured by the deterministic age component. Storesletten *et al.* (1998) argue that a significant fraction of intracohort differences in labor earnings and wealth is due to permanent, individual-specific differences in labor productivity.[26] In this

[25] We also repeated our exercise with Markov chains based on the data of Diaz-Jimenez *et al.* (1997), but with more states. The results did not change significantly, compared to the two-state specification.

[26] Given that in our model agents start to live at the age of 20, these permanent differences might be due to unmodeled economic choices made before that age, e.g., differences in educational choices. In a related paper, Kotlikoff *et al.* (1998) study the effects of privatizing the social security system under the assumption that intracohort heterogeneity arises purely from permanent deterministic differences.

TABLE VII
Dispersion of Labor Earnings, Wealth, Votes for Reform A

	Sym, 2 states	Sym, 2 type 2 st	Sym, 3 types 2 st
$cv(lab)$	0.71	0.64	0.68
$cv(weal)$	0.92	0.96	1.06
Votes	36.4%	37.8%	37.4%

section we explore how our results change if we allow for individual-specific fixed effects.

Following Storesletten *et al.* (1998), the age-independent component of individual i's labor productivity, $u_{i,t} = \log(\eta_{i,t})$, is specified as

$$\begin{aligned} u_{i,t} &= \alpha_i + z_{i,t} + \varepsilon_{i,t}, \qquad \varepsilon_{i,t} \sim N(0, \sigma_\varepsilon^2), \quad \alpha_i \sim N(0, \sigma_\alpha^2) \\ z_{i,t} &= \rho z_{i,t-1} + \nu_{i,t}, \qquad \nu_{i,t} \sim N(0, \sigma_\nu^2). \end{aligned} \tag{6.1}$$

The authors obtain as estimates from PSID data $\sigma_\alpha^2 = 0.326$, $\rho = 0.98$, $\sigma_\varepsilon^2 = 0.005$, $\sigma_\nu^2 = 0.019$.[27] In order to discretize this process we consider specifications with two and three deterministic types of individuals and a two-state Markov process for the stochastic component of each type in both cases. We pick $\alpha_1 = -0.43\sigma_\alpha$, $\alpha_2 = 0.43\sigma_\alpha$ for the two-type specification and $\alpha_1 = -0.675\sigma_\alpha$, $\alpha_2 = 0$, $\alpha_3 = 0.675\sigma_\alpha$ for the three-type specification.[28] In both cases, an equal fraction of the population belongs to each type. For a given α_i we then use the Tauchen procedure to construct a two-state Markov chain for individual i's labor productivity, fluctuating around the unconditional mean α_i.

We present the results for the specification with permanent differences in labor productivity in Table VII. We note that with permanent differences the dispersion in labor earnings is smaller, but the dispersion in wealth is bigger than without permanent differences. For a specific individual, labor productivity is less fluctuating with permanent differences (com-

[27] These are their estimates when they choose to match the cross-sectional variance of labor earnings of the youngest cohort. The authors provide alternative estimates when choosing to match the average cross-sectional variance across cohorts. For further details about the advantages of both approaches, see their paper.

[28] Note that $-0.43\sigma_\alpha$ is the 33.3 percentile of a normal distribution with zero mean and standard deviation of σ_α, and $-0.675\sigma_\alpha$ is the 25 percentile.

pare the estimates for σ_ε and σ_ν with and without permanent differences), and hence there is less substitution in hours worked between states. Given the nature of preferences, permanent differences in productivity do not induce significant differences in hours worked across types. Hence, the dispersion in labor earnings is smaller with permanent effects. However, permanent differences in labor productivity create fatter tails in the wealth distribution and hence a higher coefficient of variation of wealth.

Macroeconomic aggregates show the same qualitative behavior along a transition with or without permanent effects. Voting outcomes are similar to the specification without permanent differences, as well. The welfare consequences of a potential reform are also quite similar to those reported in Fig. 6, with the additional feature that, ceteris paribus, agents with permanently higher productivity benefit more (lose less) from a reform than agents with permanently low labor productivity (see Fig. 14). This is mostly due to the fact that with (only) permanent productivity differences,

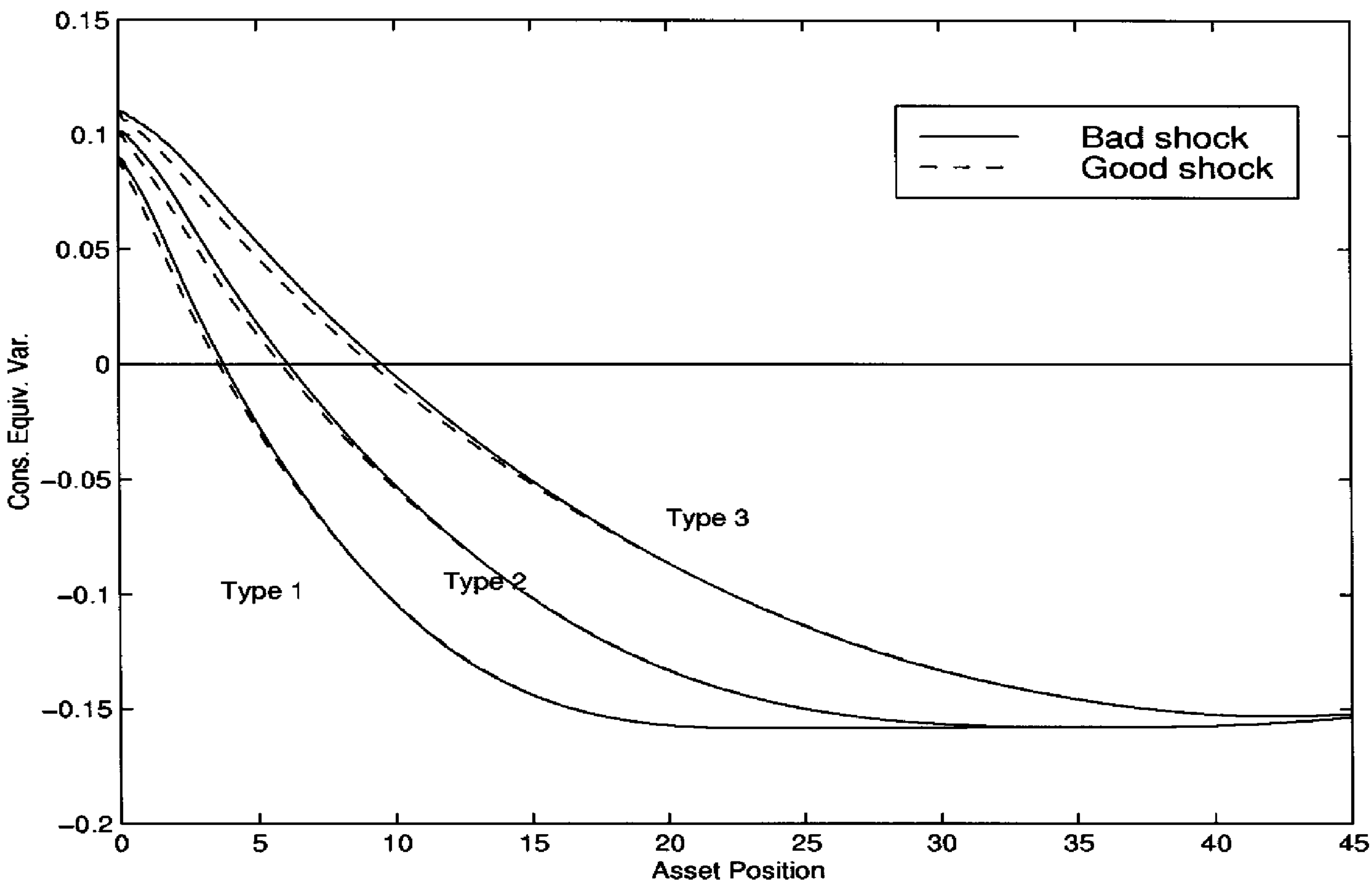

FIG. 14. Welfare effects of reform A with permanent effects.

the social security system is a pure redistribution scheme from more to less productive agents.

Overall, the results in this subsection seem to indicate that the exclusion of permanent differences in labor productivity is not an important omission in our analysis. Essentially, we obtain the same results as in the symmetric case without permanent differences.

7. CONCLUSION

We constructed and computed an overlapping generations economy with intracohort heterogeneity with respect to labor income and endogeneous labor–leisure choice to analyze the welfare effects and potential political support for different hypothetical social security reforms. We considered three different policy reforms: immediately eliminating the social security system (reform A), eliminating it gradually over 50 years (reform B), or announcing the elimination of the system 20 years in advance (reform C). Our main findings are that: (a) none of the reforms proposed gain majority support; (b) reforms like B and C that phase out the social security system more gradually than reform A may have less political support; and (c) political support for a transition from a pay-as-you-go to a fully funded system is significantly weaker if agents face idiosyncratic uncertainty. These results are obtained in a model in which a newborn would (in an ex-ante sense) prefer to be born into an economy with a fully funded rather than a pay-as-you-go system, regardless of the presence of intracohort heterogeneity.

Our analysis also shows the importance of general equilibrium effects in determining welfare consequences (measured by consumption equivalent variation) for different individuals. We find that abstracting from the general equilibrium effect of factor price changes can reverse voting decisions of a significant fraction of the population.

We restricted ourselves to three budget balanced reforms, leading to a full privatization of the social security system. There is, however, a wide range of possible reforms that are currently discussed in the political debate, ranging from complete to partial privatization to modifying the existing tax-benefit scheme or using alternative ways to finance current and future social security entitlements. The analysis of the dynamic response of the economy to these alternative types of reform goes beyond the scope of this work, and future research needs to show what the macroeconomic consequences and welfare effects of these alternative reforms are, in order to assess their political implementability.

A. APPENDIX: COMPUTATIONAL METHOD

We discretize the state space by choosing a finite grid for assets, $A = \{0, \ldots, a_{na}\}$. However, we do not restrict optimal choices to lie in the grid by using linear interpolation (see below). The joint measure over assets, labor productivity status, and age, Φ_t, can then be represented as a finite-dimensional array. After making the economy stationary (by taking care of population growth using the standard transformations), the structure of the algorithm used to compute the equilibrium is as follows:

- Compute initial steady state.

  1. Guess r, N, Φ and compute K, w, τ, SS, Tr.
  2. Solve backward for value and policy functions by using $v(\cdot,\cdot, J+1) \equiv 0$.
  3. Use decision rules to compute new N, Φ, and r.
  4. Update, r, N, Φ.
  5. Iterate on r, N, Φ until convergence.

- Compute final steady state (same as before).
- Compute the transition path.

  1. Assume that transition is completed after $T-1$ periods, where in period T the economy is in the final steady state and in period 1 the economy is in the initial steady state. Choose T so large that by increasing T the transition path is unaltered.
  2. Guess $\{r_t, N_t, \Phi_t\}_{t=2}^{T-1}$ and compute $\{K_t, w_t, \tau_t, SS_t, Tr_t\}_{t=2}^{T-1}$.
  3. Working backward, compute value functions and policy functions for all generations for all transition periods by using $v_T(\cdot)$ from the final steady state.
  4. Using the initial steady-state distribution Φ_1, use the decision rules to compute new N, Φ, and r for $t = 2, \ldots, T-1$.
  5. Iterate on $\{r_t, N_t, \Phi_t\}_{t=2}^{T-1}$ until convergence is achieved.

- Compute welfare measures and voting outcomes.

Voting takes place at the beginning of period 2, after the idiosyncratic productivity shock has been realized, but before any economic choices have been made. The voting decision of an individual with state (a, η, j) is determined as follows: if $v_2(a, \eta, j) > v_1(a, \eta, j)$, then this individual votes in favor of the reform, otherwise in favor of the status quo.

We now describe the step of solving for optimal policy functions in more detail. After substituting out the budget constraint and using the intratemporal first-order condition for the labor leisure choice (subject to $0 \leq l \leq$

1), a typical household problem can be written as

$$v_t(a,\eta,j) = \max_{a' \geq 0}\Big\{u(c(a;a'),l(a;a')) + \beta\psi_j \sum_{\eta' \in E} v_{t+1}(a',\eta',j+1)Q(\eta,d\eta')\Big\}.$$

This is a one-dimensional maximization problem. The recursive structure of the problem guarantees that the function v_{t+1} is known when solving this problem. We restrict v_{t+1} to lie in the class of piecewise linear functions, so that for given η' and $j+1$, $v_{t+1}(\cdot,\eta',j+1)$ can be represented as an na-dimensional vector. By linear interpolation of v_{t+1} the function

$$u(c(a;a'),l(a;a')) + \beta\psi_j \sum_{\eta' \in E} v_{t+1}(a',\eta',j+1)Q(\eta,d\eta')$$

is well defined on all of $\Re_+$, and standard constrained-maximization techniques (as, for example, supplied by FORTRAN) can be used to solve for $a'_t(a,\eta,j)$ and hence $v_t(a,\eta,j)$, $l_t(a,\eta,j)$, $c_t(a,\eta,j)$. Note that $a'_t(a,\eta,j)$ is not constrained to equal a point in the finite grid. Since we store the joint distribution Φ_{t+1} only on the finite grid points for assets, an individual with choice $a'_t(a,\eta,j) \in (a_k, a_{k+1})$ is interpreted to choose asset holdings a_k with probability κ and asset holdings a_{k+1} with probability $1-\kappa$, where κ solves $a'_t(a,\eta,j) = \kappa a_k + (1-\kappa)a_{k+1}$.

In our computations the number of grid points was chosen to be $na = 102$. Experiments with larger grid sizes yielded results that were virtually indistinguishable from the ones reported in the text. Taking into account the concavity of the problem, we chose a grid in which the spacing between grid points increases with asset levels. Following Huggett and Ventura [21], we chose $a_1 = 0$:

$$a_k = b(k^c), \qquad k = 2,\ldots na.$$

The parameter c controls the spacing between grid points and was chosen to be $c = 3$, whereas b controls the scale of the grid and was chosen so that the implied upper bound for asset holdings was never binding ($b = 55$ was sufficient for this). With these choices a program with a two-state Markov process takes about 120–150 minutes on a Pentium 266.

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