A Positive Theory of Social Security Based on Reputation

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We construct a general equilibrium model in which a pay-as-you-go social security system can be adopted and sustained as a political and economic equilibrium. We analyze the welfare implications of this system and compare general equilibrium welfare measures to the commonly used notion of actuarial fairness.

I. Introduction

Why would a society choose to install a pay-as-you-go social security system in which payments to current generations of retirees are financed by payroll taxes levied on working generations? Most candidate answers to this question appeal to some form of altruism between generations, as in Hansson and Stuart (1989) and Tabellini (1991). In this paper we show that a pay-as-you-go system could emerge as a political outcome in a society populated by rational, forward-looking economic agents acting in their economic self-interest. We analyze the political economy of social security in which

individuals get to vote on the system at fairly long time intervals (about 15 years). In our view this is a relevant exercise because it is appropriate to view democratic societies as having a choice over major tax and transfer programs over long horizons, however indirect the mechanism.

The U.S. social security system was created in 1935 and began operating and collecting taxes in 1937. One explanation of why it was introduced in the 1930s is that the Great Depression wiped out a lot of the private savings of households and President Franklin Roosevelt wanted a public pension system to forestall similar problems in the future. The original intent of the Social Security Act was to create a fully funded pension system, with benefits tied to contributions. That intent changed fairly quickly, and by 1939, the initial act was amended in ways that effectively made it a pay-as-you-go social insurance system.

The structure of the U.S. system has remained the same since 1939, but the coverage and the demographic features of the population it serves have changed. Most apparent is the aging of the baby boom generation, which will begin to retire and collect benefits in the early part of the next century. The problems created by this population bulge are compounded by the fact that people are now producing fewer children, living longer, and retiring earlier.[1]

Many studies have shown empirically that the social security system does not treat generations equally, is not "actuarially fair," and was most generous to the initial generations of retirees (see, e.g., Moffitt 1984; Auerbach and Kotlikoff 1987; Leimer 1992a, 1992b). This raises the question of why such a system would be adopted in the first place by forward-looking agents and how it could be sustained if it treats later generations badly. We address these questions by looking at the implementation of social security in an artificial economy in which agents live for four periods. The population in this economy grows at a constant rate, and agents work for the first three periods of their lives and retire during the fourth period. Thus we abstract from the demographic and labor supply issues discussed above.[2] A social security system is simply a schedule for transferring

[1] The fertility rate in the United States has fallen from more than 3.5 children per woman in the 1950s to fewer than 1.9 children per woman in the 1980s. This decline has not been offset by the increase in immigration. The average life span has increased from 66 years in 1935, when social security was created, to 74 years now. The expected life of a person who reaches age 65 has increased even more. Moreover, the labor force participation of men over age 65 has decreased from 54 percent in 1930 to 15 percent in 1991. The implication of these changes is that by 2020 there will be far fewer workers for each social security beneficiary than there were in 1950. These problems are not unique to the United States.
[2] In Cooley and Soares (1996), we study the importance of demographic change for the survival of social security.

income from workers to retirees. The agents in our hypothetical economy are rational and forward-looking, and they must vote for a given level of transfers. Thus an equilibrium with a pay-as-you-go social security system must be both a competitive economic equilibrium and a political equilibrium.

In this economic environment, a social security system is essentially a game between generations.[3] For the system to be sustainable, there must exist some mechanism to support the equilibrium with social security. We show that the threat of collapse of the system, if any generation fails to maintain it, is sufficient to sustain it. It is sustained because the median voters in later generations, treating their past contributions as sunk costs, will still find it in their interest to preserve the system until their retirement, even though they would be better off in an economy without social security.

We calibrate the parameters of this economy to match long-run features of the U.S. economy and compute the equilibrium level of social security benefits that would be chosen by the median voter in the initial period. For reasonable parameter values, we find that the equilibrium replacement rate (the fraction of labor income that is received by a retiree) is about 47 percent. We quantify the effects of this policy on the equilibrium level of the capital stock and on interest rates and wage rates. The equilibrium level of benefits depends on the calibration, so we examine the sensitivity of our findings to the values of the parameters. We also compute the aggregate welfare costs of social security under several different assumptions and show how the costs are borne by different generations.

Much of the existing literature on social security evaluates social security using the partial equilibrium notion of actuarial fairness. This approach constructs tax and benefit streams and compares the tax cost of the coverage to the (expected) level of benefits by computing either the (expected) net present value of benefits or the (expected) internal rate of return. In this paper we show that such partial equilibrium measures would not explain why social security is implemented and sustained. There is a long-standing controversy over whether the U.S. social security system decreases private savings (see Barro 1974; Feldstein 1974, 1996). In the economy studied in this paper, social security decreases private savings and raises the return on capital. It turns out that the choice to implement and sustain a social security system depends crucially on this finding.

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[3] Browning (1975) was the first to consider the political economy of social security in an environment similar to this. He assumes that, once in place, a system will be credible and will be sustained. Sjoblom (1985) shows how treating social security as a dynamic game between generations can lead to its being sustained.

Social security has been studied by other researchers in the context of general equilibrium models similar to the one used in this paper. There is a literature starting with Diamond (1965), following earlier work by Samuelson (1958), that motivated the introduction of social security in a general equilibrium framework as a way of moving the economy from an inefficient equilibrium, characterized by overaccumulation of capital, to an efficient equilibrium by decreasing savings. Modern treatments extend that approach. Auerbach and Kotlikoff (1987) introduce social security into a calibrated deterministic overlapping-generations economy and evaluate its impact on factor supplies and aggregate welfare. They find it to be welfare reducing. Hubbard and Judd (1987) and Imrohoroglu, Imrohoroglu, and Joines (1995) study the role of social security (again in calibrated overlapping-generations economies) as insurance against uncertain lifetimes and individual income risk in stochastic environments with incomplete markets. This paper differs from the previous literature in that we study the political economy of social security in an economy that is not characterized by overaccumulation (is "Diamond efficient") or lifetime uncertainty. We show the connection between the effect that social security has on factor prices and the politico-economic equilibrium.

Social security distorts the savings and labor supply decisions of all agents and affects the aggregate level of capital and the supply of labor in the economy. When each voter chooses her optimal level of benefits, she takes into account that the chosen policy influences factor prices, the wage level, and the interest rate. Positive social security benefits are associated with taxes that will not only decrease each worker's level of consumption and savings but lower the labor supply and decrease the economywide stock of capital for the next period. The drop in next period's capital will increase the interest rate and decrease wages. This will have an indirect positive effect on the share of income from capital.

II. The Economic Environment

We study an economy in which a large number of identical agents are born each period and have a lifetime of four periods. The population grows at a constant rate n so that each generation is $1 + n$ bigger than the preceding one. The number of agents in each cohort relative to the other cohorts is thus stable over time. The share of age i individuals in the population, given by the measure μ_i, $i = 1, 2, 3, 4$, is constant over time, and $\mu_{i+1} = \mu_i/(1 + n)$, with $\sum_{i=1}^{4} \mu_i = 1$. The agents in each generation maximize their discounted lifetime utility: for an agent born in period t this is given by

$$\sum_{i=1}^{4} \beta^{i-1} U(c_{i,\,t+i-1},\, l_{i,\,t+i-1}), \tag{1}$$

where β is the subjective discount factor, $c_{i,\,t+i-1}$ is consumption of an age i individual at period $t + i - 1$, and $l_{i,\,t+i-1}$ is leisure. The "momentary" utility function is assumed to take the constant relative risk aversion form of a Cobb-Douglas consumption-leisure index,

$$U(c_{i,\,t+i-1},\, l_{i,\,t+i-1}) = \frac{(c_{i,\,t+i-1}^{\sigma}\, l_{i,\,t+i-1}^{1-\sigma})^{1-\rho}}{1 - \rho}, \tag{2}$$

where ρ is the coefficient of risk aversion, and σ is the coefficient of consumption on the Cobb-Douglas index.

Agents in this economy accumulate claims on real capital, used in production by firms, to help smooth consumption across time. The budget constraint facing an individual of age i at time t can be written as

$$a_{i+1,\,t+1} = (1 + r_t)a_{i,\,t} + y_{i,\,t} - c_{i,\,t}, \tag{3}$$

where $y_{i,\,t}$ is the real net labor income plus transfers (in terms of the consumption good) of an age i individual at t, $a_{i,\,t}$ denotes the beginning-of-period asset holdings of an age i individual at time t, and r_t denotes the rate of return on these assets. Clearly, an agent will not accumulate any assets in the last period of her life so that

$$a_{5,\,t} = 0 \quad \forall\, t. \tag{4}$$

We choose the construct of four-period-lived agents because, in the United States, current life expectancies and work life expectancies imply that individuals spend somewhere between 3 and 4 years working for every year of retirement. We assume that agents may work the first three periods of their lives but must be retired in the fourth period. Thus we distinguish between workers who are below the exogenous mandatory retirement age 3 and retirees who are above that age. Before their mandatory retirement, age i workers supply $h_{i,\,t}$ hours of labor and earn $w_t h_{i,t} \epsilon_i$, where w_t is the real hourly wage rate (in terms of the consumption good) in period t, and ϵ_i is the efficiency index representing the productivity of an hour of work supplied by an agent of age i. Variations in ϵ_i across generations capture the lifetime efficiency profile of workers. After retirement, the net labor income plus transfers of a retiree is equal to his social security benefits, b_t. The level of benefits is computed by applying a

replacement rate, θ_t, to a base income that we take to be an average of the income of the agents currently employed:

$$b_t = \theta_t w_t \overline{h \epsilon}_t. \tag{5}$$

Under these assumptions the net labor income plus transfers of an individual is given by

$$y_{i,t} = \begin{cases} (1 - \tau_{t,s}) w_t h_{i,t} \epsilon_i & \text{for } i = 1, 2, 3 \\ b_t & \text{for } i = 4. \end{cases} \tag{6}$$

The production technology of the economy is described by a constant-returns-to-scale function

$$Y_t = F(K_t, L_t) = \Psi K_t^{1-\alpha} [L_t(1 + \gamma)^t]^\alpha, \tag{7}$$

where $\Psi \geq 0$, $\alpha \in (0, 1)$ is the labor share of output, and Y_t, K_t, and L_t are the levels of output and of the capital and labor inputs, respectively. We allow for permanent exogenous growth in labor productivity at a constant rate $(1 + \gamma)$. The capital stock is equal to the aggregate asset holdings of the agents in the economy. It depreciates at a constant rate δ and evolves according to the law of motion

$$K_{t+1} = (1 - \delta)K_t + I_t. \tag{8}$$

There is a government in this economy whose role is to implement the transfer schedule chosen by the agents through voting. The government distinguishes only two groups of agents: workers and retirees. Accordingly, the only political decision facing the agents of this economy is to vote for a level of transfers between these two groups. Given the level of transfers chosen by the voters, the government chooses the tax rates so that its budget is balanced supposing that they tax only labor income.

Individuals have two roles in this model: they are economic agents who buy goods, accumulate assets, and supply labor; and they are participants in the political process in which policies are determined. We begin by describing the economic decisions in this economy given a sequence of political decisions. We then describe how the sequence of political decisions is determined. Finally, we define an equilibrium for this economy.

III. Economic Decisions

The economic problem of an age i individual at time t is to choose a sequence of consumption and asset holdings, given a sequence of political outcomes that determine the replacement rate θ and

maximize the expected discounted value of lifetime utility subject to his budget constraints. We write this as

$$V_i(a, A; S) = \max_{c, l, a'} \{U(c, l) + \beta V_{i+1}(a', A'; S')\} \qquad (9)$$

subject to

$$a' = (1 + r)a + y_i - c,$$

$$y_i = \begin{cases} (1 - \tau)wh_i\epsilon_i & \text{for } i = 1, 2, 3 \\ \theta\, \overline{wh\epsilon} & \text{for } i = 4, \end{cases}$$

$$A' = H(A; S) \quad \text{given } S = \{\theta_l\}_{l=t}^{\infty},$$

$$V_5 = 0,$$

where A represents the distribution of capital across agents, and $H(A; S)$ is the law of motion of the distribution of capital. The term S is a given sequence that determines the level of the social security benefits in each period. Hence, we are assuming that, for each period, the level of the social security replacement rate, θ, is given.

A set of decision functions for consumption, labor, and asset holdings $c_i(a, A; S)$, $l_i(a, A; S)$, and $a_i'(a, A; S)$; laws of motion $H(A; S)$; and value functions $V_i(a, A; S_t)$ are obtained for the current state of the economy A.

In our model, competitive firms maximize profits, which are equal to $Y_t - w_tL_t - r_tK_t$, given the wage rate and interest rate. The first-order conditions for the firm's problem determine the following functions for the net real return to capital and the real wage rate:

$$R_t = (1 - \alpha)\Psi\left(\frac{K_t}{L_t}\right)^{-\alpha} - \delta,$$

$$W_t = \alpha\Psi\left(\frac{K_t}{L_t}\right)^{1-\alpha}. \qquad (10)$$

IV. Political Decisions

The political decisions made by agents will determine the sequence $\{S_t\}$ of policies. In this economy each agent has measure zero, so individual voters cannot view their decisions as influencing the aggregate political outcome. To overcome this problem, we assume sincere voting; that is, we assume that everyone votes for his or her most preferred alternative at every stage of the game. Even though the game is sequential, this assumption seems perfectly reasonable. Because each agent has measure zero, the expression of preferences

will not affect the other voters, so there are no strategic gains from misrepresenting preferences. This ensures that each agent will vote as though he were a dictator in the voting period and a "result taker" in the other periods in spite of the fact that the outcome is essentially exogenous to him.

A. The Voting Decision

One of the primary questions addressed in this paper is whether an equilibrium with a social security system can be supported as a political outcome in a democratic voting process. The current-period workers will have to support the costs of any social security benefits without getting any direct current benefits from it. In a one-shot game, that is, in a game played with a one-period horizon, the workers will all oppose any positive level of benefits. This feature of the one-shot game also raises questions about the viability of a social security system in the long run. Even though it might be rational to adopt a social security system, there is always an incentive to deviate from it. Consequently, a policy that might be chosen if the government could make a binding commitment is not credible if it cannot. In other words, social insurance is time-inconsistent because forward-looking rational agents will not believe that it is sustainable.

A number of papers (Verbon 1987; Hansson and Stuart 1989; Jungenfeldt 1991) address the time consistency problem by introducing altruism between generations. Our approach is to use a reputational mechanism represented by a trigger strategy in which the equilibrium of the one-shot game serves as a credible threat to induce more "cooperative" behavior from agents.[4] Social security is a dynamic game that involves repeated interactions between generations. Because of this, reputational considerations can be used to deal with the time inconsistency problem.[5] If the agents expect current deviations to be followed by future deviations, a reputational trade-off is introduced into the agents' decisions. This potential loss of credibility means that the cost of defecting today involves the collapse of the system tomorrow and can motivate the workers to forgo

[4] Because the actions of each agent are unobservable by other agents, individual decisions will be motivated purely out of self-interest. Accordingly, it is not possible to punish agents who deviate from the expected actions. Unobservability also implies that we cannot attribute a reputation to each agent.

[5] Kotlikoff, Persson, and Svensson (1988) address the general problem of time inconsistency for contracts between generations using a mechanism somewhat like the reputational mechanism described here, although they do not describe it as reputational because of the overlapping-generations structure (i.e., because agents are not infinitely lived). Their framework also requires a fixed cost of setting up contracts.

the short-term benefits from deviating in order to secure the gains from having a social security system present when they retire.

Let S_t^* be a rule that specifies the social security system (possibly dependent on the realizations of some state variables). The assumed expectations mechanism is[6]

$$S_{t+1}^e = \begin{cases} S_{t+1}^* & \text{if } S_t = S_t^* \\ 0 & \text{otherwise.} \end{cases} \tag{11}$$

If the social security benefits this period are the ones expected, agents trust the "majority" to perform according to the specified rule for period $t + 1$. But if the workers today vote for "no social security system" when people expected them to vote for a social security system, everyone (including future generations) loses confidence in the sustainability of the system. Instead of viewing this enforcement rule in terms of punishments, it makes more sense to think in terms of rewards: the social security system is "given" to the retirees as a reward for not having deviated from the equilibrium. If the current generations of workers fail to go along, they will not be rewarded in the future.

There is no collusion among agents to punish possible deviators. Instead, any deviation by the majority from the prescribed path triggers a change in the expectations of all agents about future majority decisions; specifically, it causes them to expect the majority of agents (all the workers) to vote against the social security system next period. Hence, each worker will vote against the social security system out of self-interest under our assumption of sincere voting. In this setting, agents do not need any incentives to punish the deviators; given the expectations mechanism, the "punishment" is an endogenous reaction of the economy to a deviation.

When forming expectations for period t, agents know whether the majority will find it worthwhile to defect. If the defection solution is preferable to the rule, then for the expectation $S_t^e = S_t^*$ to be rational, we need $S_t^* = 0$.

It is important to point out that this trigger strategy will support a multiplicity of social security equilibria, and they will not be renegotiation-proof.[7] If the system were to collapse, subsequent generations would find it optimal to put another system in place. All

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[6] The aggregate political outcome is exogenous to the individual agent; i.e., only the collective actions of the agents have an aggregate effect. Any agent who sets his expectations differently from the other agents will not be acting rationally.

[7] This issue is addressed to some extent by Azariadis and Galasso (1995) and Boldrin and Rustichini (1995). The framework of those papers is very different from that considered here.

that is necessary to support social security is the milder assumption that, if the system collapses, it will not be put back in place by the time the generation that defected retires. We adopted the more extreme assumption because it greatly simplifies notation. We have begged the important question of why an initial generation is offered the opportunity to put a system in place—why social security arises when it does. Once an initial generation chooses a social security system, there is a unique equilibrium to our problem.

V.   Equilibrium

The solution to the agents' political problem involves evaluating the utility obtained under the alternative values for the policy parameter. This requires that the agents can correctly predict the future path of the economy under alternative current policies, which in turn requires the ability to predict the corresponding future policies. Therefore, a general equilibrium for this economy requires that agents consider the outcomes of policies that will never be realized, and rationality needs to be maintained in the subgames that would occur when there are any deviations from the equilibrium path.

In the initial period, agents will choose an equilibrium policy sequence with an associated expectations mechanism like the one described by (11).[8] Only policy sequences that are sustainable along the equilibrium path need to be considered. The reason is that rational forward-looking workers would not support the current costs of a social security system if they did not expect to benefit from it in their own retirement. We assume that, once a social security system is implemented, agents in the following periods can vote only for the social security level corresponding to the chosen sequence θ_t^* or against it.

The existence of an equilibrium (or equilibria) in which the agents form expectations according to (11) has to be confirmed. To determine whether θ_t^* is a trigger strategy equilibrium level of the social security system under the reputational mechanism described in (11), it is necessary to consider whether the agents have any incentive to deviate and vote for $\theta_t \neq \theta_t^*$ ($\theta_t = 0$) at any point in time.

The effects of a policy change can be analyzed by finding the future law of motion of the state variable implied by the responses of agents to the new policy. Because of the reputation mechanism, beliefs about the sustainability of a social security system depend in

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[8] In a more general framework, agents would be able to choose a sequence of policy functions $\{\Phi_t\}_{t=0}^{\infty}$ that in each period would determine the level of the social security replacement rate as a function of the state of the economy, $\theta_t = \Phi_t(\lambda_t)$.

every period on the political outcome for the preceding period. This means that the realization of θ in each period will affect the decisions of the agents in the subsequent periods, and it has to be included as a state variable, along with the distribution of capital.

To keep this problem tractable, we restrict the set of possible sequences of policy functions to be a sequence of constant policy functions. Agents in the initial generation vote for a level of benefits given by the replacement rate θ. This determines the constant level of this policy parameter. Once a social security system is implemented, agents in subsequent periods will vote only for the social security system—represented by the chosen level θ^*—or against it.

The aggregate policy for next period will depend on the political outcome for the current period:

$$\theta_{t+j} = \begin{cases} \theta^* & \text{if } \theta_{t+j-1} = \theta^* \text{ for } j \geq 1 \\ 0 & \text{otherwise.} \end{cases} \tag{12}$$

With the foregoing assumption, we can define the function P describing the political outcome as

$$P(\theta_{-1}, \theta^*) = \begin{cases} 1 & \text{if } \theta_{-1} = \theta^* \\ 0 & \text{otherwise,} \end{cases} \tag{13}$$

and we can now formulate the problem of the age i agent in the following way:

$$\tilde{V}_i(a, A, \theta; \theta^*) = \max_{c, l, a'} \{U(c, l) + \beta V_{i+1}(a', A'; P(\theta, \theta^*)\theta^*)\} \tag{14}$$

subject to

$$a' = (1 + r)a + y_i - c,$$

$$y_i = \begin{cases} (1 - \tau)wh_i\epsilon_i & \text{for } i = 1, 2, 3 \\ \theta w\overline{h\epsilon} & \text{for } i = 4, \end{cases}$$

$$A' = H_\theta(A, \theta; \theta^*), \quad \theta \in \{0, \theta^*\},$$

$$\tilde{V}_5 = 0.$$

A set of decision functions for consumption, labor, and investment $c_{\theta i}(a, A, \theta; \theta^*)$, $l_{\theta i}(a, A, \theta; \theta^*)$, and $a'_{\theta i}(a, A, \theta; \theta^*)$; laws of motion $H_\theta(A, \theta; \theta^*)$; and value functions $\tilde{V}_i(a, A, \theta; \theta^*)$ are obtained for the current state of the economy (A, θ), where θ is the chosen level for the social security benefits for the current period. Next period's decisions for consumption, labor, and investment are given by the

functions $c_i(a', A'; P(\theta, \theta^*)\theta^*)$, $l_i(a', A'; P(\theta, \theta^*)\theta^*)$, and $a'_i(a', A'; P(\theta, \theta^*)\theta^*)$ from the individual's economic problem (9).

Note that, after the initial level of the social security replacement rate, θ^*, is chosen by the first-period agents, age i agents need only compare $\tilde{V}_i(a, A, 0; \theta^*) = \max_{c, l, a'} \{U(c, l) + \beta V_{i+1}(a', A'; 0)\}$ to $\tilde{V}_i(a, A, \theta^*; \theta^*)$ in order to decide whether to vote for or against the implemented social security level.

A.   Aggregation of Preferences

Once the social security system is implemented, agents will choose between the given level of social security θ^* and no social security. Because there are only two possible values for the chosen parameter, the majority rule aggregator is easily applicable.

LEMMA. The optimal political outcome for an agent of generation i with an asset stock a_i when the aggregate state is A, given the expectation mechanism (11) with $\theta_t^* = \theta^*$ for all t, is

$$\Theta_i(a, A; \theta^*) = \underset{\theta \in \{0, \theta^*\}}{\operatorname{argmax}} \tilde{V}_i(a, A, \theta; \theta^*). \tag{15}$$

LEMMA. The political outcome for the state of the economy A and given the expectation mechanism (11) with $\theta_t^* = \theta^*$ for all t is

$$\Theta_{ag}(A, \theta^*) = \underset{\theta \in \{0, \theta^*\}}{\operatorname{argmax}} \sum_{\{i: \Theta_i(a, A; \theta^*)=\theta\}} \mu_i$$

$$= \theta^* M\left(\frac{\sum_{i=1}^{I} M(\Theta_i(a_i, A; \theta^*) = \theta^*)}{I} > .5\right), \tag{16}$$

where $M(\cdot)$ is simply a majority rule function that delivers the value one if the argument is true and zero otherwise.

DEFINITION. Given the expectation mechanism (11) with $\theta_t^* = \theta^*$ for all t, if the replacement rate, θ^*, is a political outcome in every period along the equilibrium path and in any period of the corresponding steady state, then it is *sustainable*.[9]

DEFINITION. An equilibrium is a set of value functions, $V_i(a, A; \theta^*)$ and $\tilde{V}_i(a, A, \theta_t; \theta^*)$; decision rules for consumption, labor, and asset holding, $c_i(a, A; \theta^*)$, $c_{\theta i}(a, A, \theta; \theta^*)$, $l_i(a, A; \theta^*)$, $l_{\theta i}(a, A, \theta; \theta^*)$, $a'_i(a, A; \theta^*)$, and $a'_{\theta i}(a, A, \theta_t; \theta^*)$, for $i = 1, \ldots, 4$; laws of motion for the distribution of capital, $H(A; \theta^*)$ and $H_\theta(A, \theta; \theta^*)$; a pair of

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[9] We need consider only policy functions that are sustainable along the equilibrium path. Each level for the replacement rate can be presumed sustainable and then tested for deviations along the path.

relative factor price functions $\{W(A), R(A)\}$; a function for the level of capital per capita $\hat{K}(A)$;[10] and a replacement rate θ^*: (1) These functions satisfy the individual's dynamic programs (9) and (14). (2) These functions satisfy the first-order conditions of the firm's problem (10). (3) Factor markets clear:

$$\hat{K}_t(A_t) = \sum_{i=1}^{4} \mu_i a_{i,t},$$

$$\hat{L}_t = \sum_{i=1}^{3} \mu_i h_{i,t} \epsilon_i.$$

(17)

(4) The commodity market clears:

$$\sum_i \mu_i [\, c_i\,(a, A; \theta^*) + a_i'(a, A; \theta^*)] = \hat{F}(\hat{K}, \hat{L}) + (1 - \delta)\hat{K},$$

(18)

$$\sum_i \mu_i [\, c_{\theta i}\,(a, A, \theta; \theta^*) + a_{\theta i}'(a, A, \theta; \theta^*)] = \hat{F}(\hat{K}, \hat{L}) + (1 - \delta)\hat{K}.$$

(5) The laws of motion for the distribution of capital are generated by the decision rules of the agents:

$$H(A; \theta^*) = [a_1'(A_1, A; \theta^*), \, a_2'(A_2, A; \theta^*), \, a_3'(A_3, A; \theta^*)],$$

$$H_\theta(A, \theta, \theta^*) = [a_{\theta 1}'(A_1, A, \theta; \theta^*), \, a_{\theta 2}'(A_2, A, \theta; \theta^*),$$

(19)

$$a_{\theta 3}'(A_3, A, \theta; \theta^*)].$$

(6) The social security system is self-financing:

$$\tau_t = \frac{\mu_4 b}{\displaystyle\sum_{i=1}^{3} \mu_i w h_{i,t} \epsilon_i} = \theta \mu_4.$$

(20)

(7) The consumer problems (9) and (14) are consistent (for all i):[11]

$$H(A; \theta^*) = H_\theta(A, \theta^*; \theta^*),$$

$$V_i(a, A; \theta^*) = \tilde{V}_i(a, A, \theta^*; \theta^*),$$

$$c_i(a, A; \theta^*) = c_{\theta i}(a, A, \theta^*; \theta^*),$$

(21)

$$l_i(a, A; \theta^*) = l_{\theta i}(a, A, \theta^*; \theta^*),$$

$$a_i'(a, A; \theta^*) = a_{\theta i}'(a, A, \theta^*; \theta^*).$$

[10] A circumflex indicates that the variable is expressed in per capita terms corrected for technological change to ensure stationarity.

[11] The sequence of policy functions θ^* is the one preferred by agents when they expect θ^* to be the political outcome for the next period. If the agents believe that the system will be sustained, their decision functions will be the same as though they take the whole sequence of policy decisions as given (see problem [9]).

(8) The replacement rate $\theta*$ is the political outcome:

$$\theta* = \Theta_{ag}(A, \theta*). \tag{22}$$

B. Implementation of $\theta*$

Once the set of the sustainable sequences of policy functions is determined, we can consider the problem facing the agents who are alive when social security is first proposed. These agents will choose the equilibrium sequence of policy functions that will be implemented jointly with the associated expectations mechanism described by (11). They will vote only for sustainable levels of θ.

The problem of the age i agent in the period in which social security is first proposed is

$$\overline{V}_i(a, A; \theta*) = \max_{c, l, a'} \{U(c, l) + \beta V_{i+1}(a', A'; \theta*)\} \tag{23}$$

subject to

$$a' = (1 + r)a + y_i - c,$$

$$y_i = \begin{cases} (1 - \tau)wh_i\epsilon_i & \text{for } i = 1, 2, 3 \\ \theta\,\overline{wh\epsilon} & \text{for } i = 4, \end{cases}$$

$$A' = H_{\theta*}(A; \theta*), \quad \theta* \in \Omega(A),$$

$$\overline{V}_5 = 0,$$

where $\Omega(A)$ is the set of sustainable replacement ratios for the current state of the economy. A set of decision functions $c_{\theta*i}(a, A; \theta*)$, $l_{\theta*i}(a, A; \theta*)$, and $a'_{\theta*i}(a, A; \theta*)$; laws of motion $H_{\theta*}(A; \theta*)$; and value functions $\overline{V}_i(a, A; \theta*)$ are obtained for this problem.

The problem of a generation i agent in the initial period can also be described by (23) with the following objective function:

$$\overline{V}_i(a, A; \theta*) = \max_{c, l, a'} \{U(c, l) + \beta V_{i+1}(a', A', \Theta_{ag}(A', \theta*))\},$$

where the aggregator $\Theta_{ag}(A', \theta*)$ replaces the sustainability constraint $\theta* \in \Omega(A)$. For any nonsustainable $\theta*$, next period's political outcome will be $\Theta_{ag}(A', \theta*) = 0$, and current workers will end up paying for a system that would never benefit them. For sustainable $\theta*$'s, $\Theta_{ag}(A', \theta*) = \theta*$, and they will get the benefit level corresponding to $\theta*$.

In the first period, as agents vote for the social security system policy parameter $\theta*$, there is a continuum of possible transfer levels

from which to choose. In this context, where there are more than two possible choices, the majority rule is not a well-defined aggregator. But if preferences over the possible policies are single-peaked, the median voter theorem can be used to obtain the aggregated political outcome.

Black's median voter theorem says that, with a majority rule, if the number of agents is odd, there is a unique outcome equal to the best outcome for the individual whose best outcome constitutes the median of the set of best outcomes.

LEMMA. Let m be the generation in which the median voter is located. Then the aggregate choice will be determined according to

$$\Theta_{ag}(A) = \Theta_m(a_m, A) = \operatorname*{argmax}_{\theta} \overline{V}_m(a_m, A, \theta). \qquad (24)$$

C. Welfare

Social security affects social welfare by altering aggregate consumption levels and lifetime consumption profiles. We construct a measure of the welfare costs based on the Hicks compensation principle. Using the steady-state equilibrium of the economy without social security as a reference, we compute the extra income required to make all the agents able to attain the same level of lifetime utility in the economy with the social security system as in an economy without social security. The compensation scheme that results is one that, being optimally allocated between consumption and savings, maintains the reference level of utility in each period.

The compensation to be given to an age i agent endowed with a level of assets $a_{i,t}$ in an economy with a social security system described by S and an aggregate state described by A_t is $x_{i,t}$ such that $V(a_{i,t} + x_{i,t}, A_t; S) = V_{i,t}$, where $V_{i,t}$ would be the lifetime utility level of that agent in the economy if the social security system was never implemented.

To compute the welfare costs, we need only calculate the compensation to be given to the young agents from the implementation period on and then add the compensation to be given to the older agents (second through fourth generations) in the initial period.

The welfare cost corresponding to period t is $\mu_1 x_{1,t}$, and the total discounted welfare cost, where we use discount factor β, is

$$SW = \sum_{t=0}^{\infty} \beta^t \mu_1 x_{1,t} + \mu_2 x_{2,0} + \mu_3 x_{3,0} + \mu_4 x_{4,0}.$$

Our measure of welfare costs is then $SW(1 + r)/Y$, where r and Y are, respectively, the real interest rate and the output per capita in the reference steady state.

VI.   Calibration

We develop the quantitative implications of this model economy for the nature and welfare consequences of social security by assigning values to the parameters of preferences and technology and computing the equilibrium paths for the economy. We calibrate the model to match long-run features of the U.S. economy. Agents in our model are assumed to be born as workers at age 21 living 55 years to a real-life age of 75. Therefore, a period in the model will correspond to 55/4 years.

   We set the population growth to be 1.2 percent per year, the average population growth rate in the United States since 1954. For the four-generation model, this translates to a growth rate of $n = .18$.[12]

A.   Preferences

In our benchmark model we set the intertemporal elasticity of substitution to .67, which implies a coefficient of risk aversion ρ equal to 1.5. We set the discount rate β to yield a value of the capital/output ratio that is close to three. This gives a value close to the equivalent in the four-generation model of the value (.9852) used by Auerbach and Kotlikoff (1987) in their 55-generation model.

   We calibrate the coefficient of consumption in the utility function, σ, to .235. This value implies that the hours of work supplied by each agent in our model match the average hours worked by the agents in the Current Population Survey March demographic files for 1989–91; that is, about 23.14 percent of their time is allocated to market activities.[13]

B.   Technology

The share of labor in the production function is set to be .6 following Cooley and Prescott (1995). The parameter A is normalized to one. The age-specific endowments of efficiency units are constructed to

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   [12] Browning (1975) points out that it may be important to distinguish the portion of population growth that is due to increased longevity because that will tend to increase the age of the median voter. We do not address that issue here.
   [13] We assume that individuals have a total of 365×16 yearly hours to allocate between labor and leisure.

TABLE 1

LABOR SUPPLY

h_1	h_2	h_3	ϵ_1	ϵ_2	ϵ_3
.2569	.2691	.1681	.9043	1.1828	1.1873

TABLE 2

BENCHMARK CALIBRATION: FOUR GENERATIONS

n	ρ	β^{*a}	σ	α	δ	γ	ϵ_1	ϵ_2	ϵ_3
.1782	1.5	.7575	.235	.6	.6823	.2008	.9043	1.1828	1.1873

[a] This discount rate corresponds to an effective discount rate of $\beta^* = \beta(1 + \gamma)^{\sigma(1-\rho)} = .7937$.

provide a realistic age distribution of earnings using data from the Current Population Survey. We compute these indexes as the ratio between the average hourly wage for each age group and the average hourly wage of all the age groups (see table 1).

Finally, we set the depreciation rate and the exogenous growth rate to be, respectively, 8 percent and 1.34 percent on an annual basis. The parameter choices are summarized in table 2.[14]

VII.   Findings

In this economy the utility levels of the agents alive in the initial period (when social security is first proposed) are single-peaked over the policy parameter, θ. Figure 1 shows how the utility of each initial generation varies with θ. The utility of the youngest agents alive at that time is strictly decreasing over positive values of θ, and the utility of retirees is strictly increasing. The utilities of the middle-aged agents (generations 2 and 3) have interior maxima. The third-generation agents always prefer higher levels of benefits than the second generation, but the median voter belongs to the second generation. Having established single-peakedness for the benchmark economy and having located the median voter, one can determine the equilibrium level of the replacement rate.

As noted previously, the equilibrium level of θ must be sustainable. To avoid the burden of determining all the sustainable values for this parameter, it is more efficient to check first whether the equilibrium unconstrained level of θ for the median voter is sustainable. The

[14] An appendix describing details of the computational procedure is available on request from the authors.
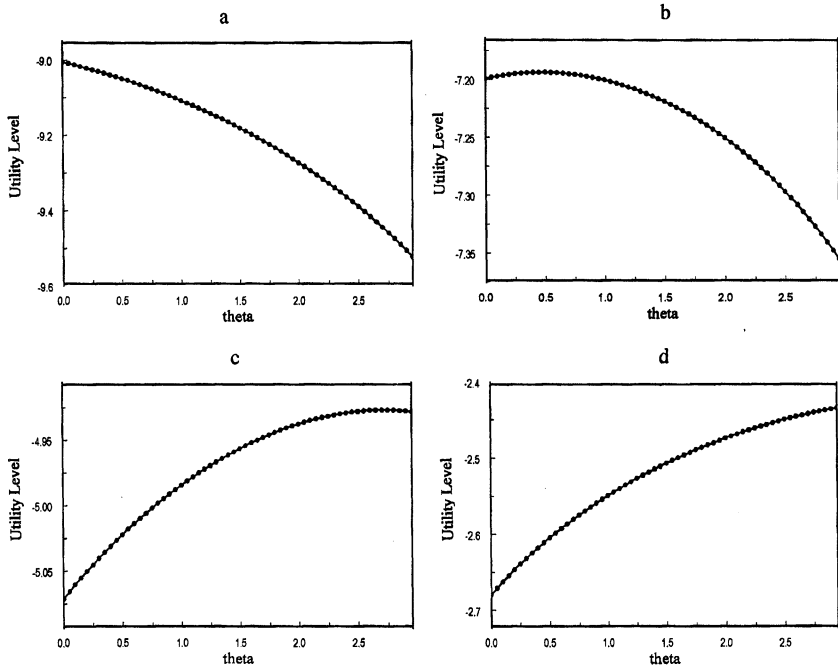
a

b

c

d

FIG. 1.—Present discounted utility of the agents when social security is introduced. a, First-generation agents; b, second-generation agents; c, third-generation agents; d, fourth-generation agents.

level of the policy parameter that maximizes the utility level of the median voter is $\theta^* = .4723$. The benefit level is sustainable, so it will be a political equilibrium. The corresponding implied tax rate on labor income is $\tau^* = .0908$. This implication of the model seems reasonable: Aaron, Bosworth, and Burtless (1989) estimate the replacement rate for an average earner retiring at age 65 to be .30, or 30 percent in 1950. In the 1990s they estimate the replacement rate to be above 40 percent, but they project that it will decline in the early part of the next century. Also, Halter and Hemming (1987) found the average social security tax rate to be approximately 9.4 percent.

The equilibrium replacement rate is very sensitive to the assumed generational structure and the location of the median voter. The median voter in this artificial economy is located in the second generation, and this is robust: it holds for any positive value of the population growth rate. Given the four-generation structure, this would be a person between 34 and 48 years of age. The median voter in recent U.S. elections is about 44 years old.

TABLE 3

STEADY STATES

	No Social Security: $\theta = 0$	With Social Security: $\theta = .4723$
K_{ss}/Y_{ss}	3.3011	3.099
L_{ss}	.2154	.2012
r_{ss}	.0511	.0552
w_{ss}	.2318	.2222

Table 3 shows the equilibrium capital/output ratio K_{ss}/Y_{ss}, the effective labor supply L_{ss}, the interest rate r_{ss}, and the wage rate w_{ss} in the absence of a social security system ($\theta = 0$) and for the optimal replacement rate ($\theta = \theta^*$). Here we see the most important general equilibrium effects on the economy: the equilibrium levels of the assets for each generation and the aggregate capital/output ratio as well as the labor supply decrease with the introduction of a pay-as-you-go social security system. The real rate of return on private savings increases and the wage rate decreases.

For comparison, consider that the capital/output ratio in the United States for the period 1929–40 (a period in which output was abnormally low because of the Depression), before social security was in place, was 5.13. For the period 1929–49, which includes periods of abnormally low output and abnormally high output, the ratio was 4.12. For the period 1970–89, the capital/output ratio was 2.93.[15]

The benchmark economy without social security is dynamically Diamond efficient in the sense that there is no overaccumulation of capital in the steady state. The introduction of social security decreases the aggregate level of capital and labor per capita and redistributes resources away from the workers, bringing down average utility for both the agents alive in the initial period and those not yet born. This occurs because the median and older voters in the initial period are offered the opportunity, by voting on social security, to tax younger and unborn generations. These results show that, even in a dynamically efficient economy, a social security system can be an equilibrium outcome of a voting process.

Figure 2 shows the net benefits (the present value of contributions minus the present value of benefits) for each of the initial genera-

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[15] Capital data are taken from *Fixed Reproducible Tangible Wealth in the United States, 1929–1990,* and the output series are taken from the *National Income and Product Accounts,* both published by the Bureau of Economic Analysis, U.S. Department of Commerce.
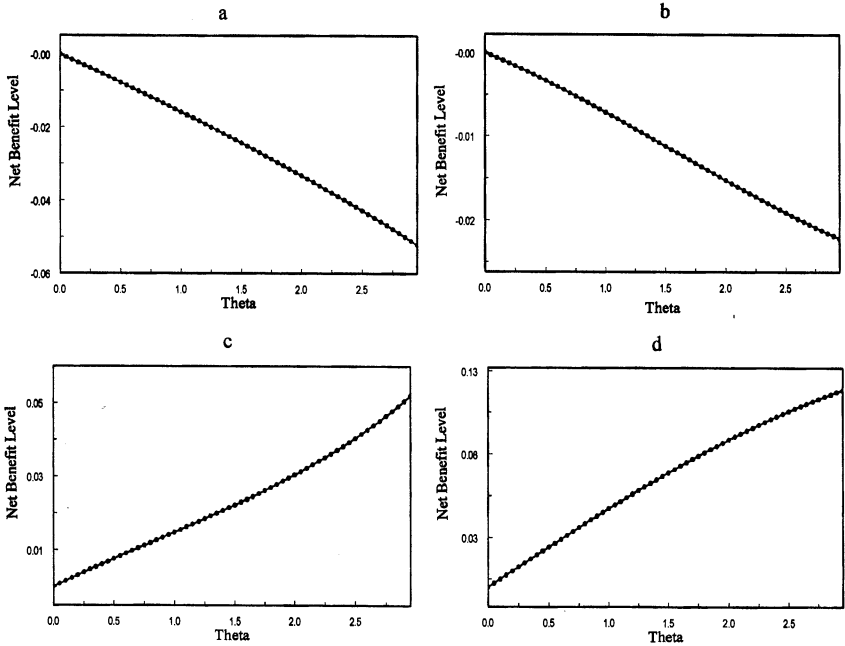
FIG. 2.—Present value of net benefits when social security is introduced. a, First-generation agents; b, second-generation agents; c, third-generation agents; d, fourth-generation agents.

tions as a function of θ. Even for the median voter, these benefits are negative for positive values of θ. But the median voter prefers the economy with social security because of the general equilibrium effects on the capital stock, labor supply, and factor prices.[16]

Figure 3 shows the evolution of the capital/output ratio, the effective labor supply, the interest rate, and the wage rate along the transition path from a steady state without social security to a steady state with $\theta = \theta^*$. Although the transition appears fairly rapid, it is important to recall that the periods here are generations, that is, 55/4 years long. Note the immediate response of the factor prices to the

[16] The returns to social security include both the return to agents' contributions and the general equilibrium effects of the system. Note also that, because we are working with transitional dynamics, the rate of return of the social security system is not identical to the population growth rate. The newly born agent has to pay $\tau h(w_t + w_{t+1})$ in taxes to get $\theta h w_{t+2}$, and as the capital stock and the effective labor supply levels will decrease with an increase in the replacement rate, he will also get a higher return on his assets and will face a decrease in his wages after the implementation period in which they will increase.
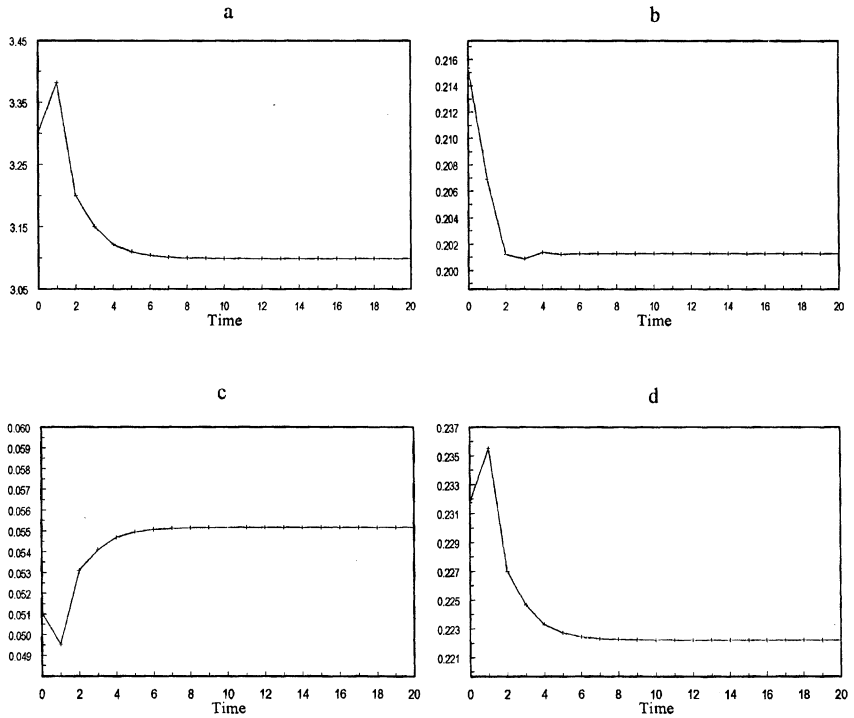
a

b

c

d

FIG. 3.—Transition path. a, Capital/output ratio; b, effective labor supply; c, interest rate; d, wage rate.

introduction of the social security system due to the decrease in the labor supply.

A. Sensitivity Analysis

Table 4 shows the sensitivity of the steady-state features of this economy and equilibrium level of social security benefits to variations in the intertemporal elasticity of substitution, labor's share, the population growth rate, the rate of technological progress, and the discount factor.

Increasing the intertemporal elasticity of substitution $(1/\rho)$ makes workers more willing to delay consumption because they care less about consumption smoothing. Moreover, agents will also reallocate more consumption through the social security system to the later periods of their lives, which leads to a higher replacement rate.

When the labor supply is more elastic, the higher decrease in the labor input due to the introduction of a social security system leads

TABLE 4

SENSITIVITY ANALYSIS

Model	Benchmark	$\sigma = .3$	$\rho = 2$	$\alpha = .64$	$n = .1$	$\gamma = 0$	$\beta = .92$[a]
a_2/y $(\theta = 0)$	2.3215	2.2133	2.1345	1.9241	2.0934	3.0516	2.9097
a_3/y $(\theta = 0)$	5.9635	5.5977	5.4146	5.5056	5.6812	7.5765	6.8436
a_4/y $(\theta = 0)$	6.9233	6.8646	6.4384	6.9798	6.9175	8.5473	7.4759
K/Y $(\theta = 0)$	3.3011	3.1781	3.0337	3.1022	3.3829	4.1735	3.7637
L $(\theta = 0)$	.2154	.2714	.2092	.2196	.2111	.2157	.2249
$r_{(\text{annual})}$ $(\theta = 0)$	.0511	.0535	.0566	.0483	.0495	.0364	.0428
θ^*	.4723	.3582	.2238	.501	.1256	.5471	.9277
τ^*	.0908	.0689	.043	.0963	.0271	.1052	.1783
a_2/y $(\theta = \theta^*)$	2.6485	2.4056	2.2579	2.3578	2.2033	3.4698	3.4644
a_3/y $(\theta = \theta^*)$	6.0167	5.5838	5.4075	5.5982	5.7058	7.6124	4.3069
a_4/y $(\theta = \theta^*)$	5.3565	5.723	5.7328	5.1467	6.4705	6.3635	6.8415
K/Y $(\theta = \theta^*)$	3.0993	3.0068	2.9294	2.8865	3.321	3.8734	3.302
L $(\theta = \theta^*)$	.2013	.2593	.2028	.2046	.20711	.1993	.195
$r_{(\text{annual})}$ $(\theta = \theta^*)$	.0552	.0571	.0589	.0529	.0507	.041	.0511
Welfare cost	.0613	.0513	.0352	.0572	.0181	.0708	.5147

[a] This discount factor corresponds to an effective discount factor of .9.

to a smaller impact on the rate of return to capital. Consequently, the equilibrium level of the replacement rate is lower.

With higher discount rates, agents have a greater incentive to defer consumption to the future. Accordingly, the steady-state level of the capital stock in the economy without social security is higher and the interest rate is lower. A lower market interest rate means that the relative return of social security assets is higher, leading to a higher equilibrium level of the replacement rate θ. It is also worth noting that for high values of the discount factor, we get an interior peak for the utility of the first generation in the initial period. Because the economy without social security is "less dynamically efficient" than the benchmark economy, the gains to the youngest workers of implementing a low level of social security benefits more than offset the costs (increase in taxes and reduction in wages).

The replacement rate is very sensitive to labor's share of output, α. Increasing labor's share lowers the steady-state capital/output ratio and the interest rate. The higher share leads to a higher equilibrium replacement rate.

Economies with lower population growth or labor-augmenting technical change ($n = 0.1$, $\gamma = 0$) have higher initial steady-state stocks of capital per capita than the benchmark economy and therefore lower interest rates. The lower population growth rate lowers the return of the social security system, lowering the equilibrium level of θ that voters would choose. When there is no population growth, there will be no social security in equilibrium. This does not occur when labor is inelastically supplied because the impact of so-

cial security on factor prices is higher and labor taxation is nondistortionary.

The lower exogenous growth in labor productivity also lowers the direct return of the social security system, but it increases the effective discount factor, leading to a higher equilibrium level for the replacement rate.

B.   How the Generations Value Social Security

To assess how different generations fare under a social security system, we use an approach similar to the one we used to calculate the welfare costs. We construct a measure of benefits from social security based on the Hicks compensation principle. We compute the increment to income required to make the agent as well off in terms of utility with and without social security. The resulting compensation can be optimally allocated between consumption and savings to maintain the reference level of utility in each period.

The compensation to be given to an age i agent endowed with a level of assets $a_{i,t}$ in an economy without social security and an aggregate state described by A_t is $x_{i,t}$ such that $V(a_{i,t} + x_{i,t}, A_t; 0) = V(a_{i,t}, A_t; S)$, where $V(a_{i,t}, A_t; S)$ is the utility level of that agent in an economy with a social security system described by S.

The value of the compensation as a fraction of per capita output and the value of net benefits (the present value of contributions minus the present value of benefits) are shown in figure 4. They are shown along the transition path from a steady state without social security to a steady state with $\theta = \theta^*$. The net benefits are computed for each generation, with past contributions treated as sunk costs. An important attribute of the equilibrium is that the net benefits are always negative along the path for the successive median voters. But the second and older generations would require a significant increment to income to be as well off without social security once their contributions have been made. This illustrates that it is the general equilibrium effect of social security on the level of capital in the economy and on the rate of return that is necessary for the system to continue to be sustained even though the net benefits are negative for the two youngest generations.

VIII.   Concluding Comments

With some notable exceptions, much of the literature on social security evaluates it using partial equilibrium measures of welfare.[17] But

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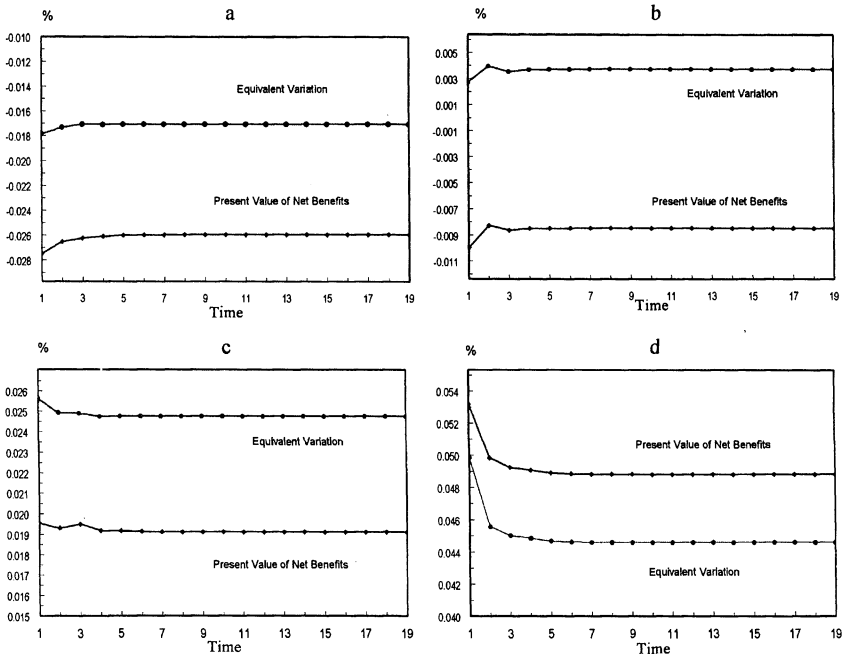[17] Among the exceptions are Leimer and Petri (1981), Auerbach and Kotlikoff (1987), and Leimer (1992a, 1992b).

FIG. 4.—Equivalent variation and present value of net benefits on the transition path. a, First-generation agents; b, second-generation agents; c, third-generation agents; d, fourth-generation agents.

in most discussions the general equilibrium effects of social security are ignored, implicitly because they are thought to be small, or the focus is placed on the analysis of steady states. The approach commonly used is to construct tax and benefits streams and compare the tax cost of the coverage to the (expected) level of benefits by computing either the (expected) net present value of benefits or the (expected) internal rate of return. Both are based on the concept of actuarial fairness. The net present value of expected benefits is computed using a market real interest rate, and the internal rate of return is the rate of discount that equates the expected present value of benefits with the expected present value of taxes. Individual equity is generally equated with actuarial fairness, and most evaluations of social security are based on this idea.

Many current discussions of the problems with social security compare the return on funds contributed to the system with the returns that would have been earned had the funds been invested in the U.S. stock market. The findings of this paper suggest that such comparisons may be seriously misleading. Social security has a sizable

effect on the level of the capital stock and the rate of return to private savings. Without these effects, social security would not be implemented and sustained as a political equilibrium.

It is important to acknowledge that there are many important extensions of the economic environment that might moderate our findings. We consider only a closed economy. In an open economy, social security might not have such an important impact on the rate of return. We also abstract from altruism and from connections between generations that could change our findings in important ways. Finally, we rely on the construct of the median voter, whereas political pressure groups may play an important role in deciding the future of social security. These caveats notwithstanding, our results do suggest the importance of considering the political economy of important policy choices like social security.

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