Economics Working Paper 150

Altruism, Uncertain Lifetime, and the Distribution of Wealth[*]

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December 1995

Keywords: Altruism, accidental bequests, wealth distribution, social security.

Journal of Economic Literature classification: D30, E21, H55.

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[*] This paper is based on the first chapter of my doctoral dissertation. I am indebted to Jordi Caballé for his advice and encouragement during this work. I thank helpful comments of Subir Chattopadhyay and Rodolfo Manuelli. Financial support from the *Instituto de Estudios Fiscales* and the *Ministerio de Educación y Ciencia* (grant FU94-21471056) of Spain is acknowledged. Special thanks to the Department of Economics of the University of Minnesota for its kind hospitality.

Abstract

This paper studies the dynamics of the distribution of wealth in a general equilibrium framework. It considers an overlapping generations model with production and altruistic preferences in which individuals face an uncertain lifetime and annuity markets do not exist. This paper focuses on the role that accidental bequests, voluntary bequests, and non–negativity constraints on bequests play in the dynamics of the distribution of wealth. It is proved that the equilibrium interest rate is lower than the one that satisfies the modified golden rule. In this economy, a social security system not only plays an insurance role, but also prevents capital overaccumulation. In fact, this paper shows that a pay–as–you–go social security system decentralizes the social planner solution as a competitive equilibrium.

1 Introduction

This paper is a study of the dynamics of the distribution of wealth in a general equilibrium framework. The literature on the distribution of wealth typically assumes that heterogeneity across individuals' wealth is generated by uninsurable shocks that affect individuals' income (for example, Laitner (1979)), ability (Loury (1981)), or preferences (Lucas (1980) and (1992)). In this paper, heterogeneity arises because uninsurable shocks affect the lifetime of individuals.[1] Since individuals can not buy annuities, they hold wealth if they die young. This wealth is passed on to their heirs and constitutes an accidental bequest. Individuals differ in the inheritance that they receive. Many economists have pointed out that intergenerational transfers are important for explaining the dynamics of the distribution of wealth. This paper, by introducing accidental bequests in a model with dynasties, considers two motives for bequest which generate unexplored dynamics in the distribution of wealth.

I consider an overlapping generations model with production (Diamond (1965)) and altruistic preferences (Barro (1974)) in which individuals live at most two periods and can live only one period with a positive probability. There are two sources of inefficiency in this economy. The first source is the absence of annuity markets. A second source of inefficiency is that negative bequests are not allowed. In fact, this paper shows that at the stationary

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[1] Friedman and Warshwsky (1990) show that a bequest motive and yield differentials between individual lifetime annuities and alternative investments can account for the thinness of the private annuity market in the U.S. economy. Moreover, an adverse selection problem could explain the incompleteness of the annuities markets. There are several papers that focus on the efficient allocations and on the dynamics of the efficient distribution of wealth in environments with asymmetric information. Atkenson and Lucas (1992) consider incentive compatible allocations, Aiyagari and Alvarez (1995) study the problem of efficient monitoring in a dynamic insurance economy. Both contain excellent reviews of the literature.

equilibrium, there is overaccumulation of capital with respect to the modified golden rule. This paper also shows that the intertemporal allocation of capital that satisfies the modified golden rule is the efficient allocation chosen by a social planner. The welfare function of this planner is the discounted sum of utilities of all generations' consumptions beginning with the initial old (see Samuelson (1967) and (1968)). The stationary efficient allocations maximize the welfare function subject to feasibility constraints. This allocations can be decentralized as a competitive equilibrium by a social security system. In this economy, a social security system not only plays the role of insurance, but also prevents capital overaccumulation.

This paper focuses on the dynamics of the distribution of wealth at the stationary equilibrium. To this end, I investigate how wealth evolves at the individual level. A first finding is that, for a wide class of preferences, the individual's decision problem has a unique solution. The proof relies on a related partial equilibrium literature, in particular, on Schechtman and Escudero (1977). Some mathematical properties of the individuals' optimal policy functions are studied. These properties are useful for proving the existence and uniqueness of an invariant distribution of bequests at the stationary equilibrium. Proofs related to the equilibrium invariant distribution of wealth follow theorems of Doob (1953).

The existence of an invariant distribution is not a common feature of all models where the heterogeneity is driven by shocks on preferences.[2] In Lucas (1992) and in Atkenson and Lucas (1992) the distribution of wealth degenerates to an ever increasing inequality. In this paper, the poverty trap is precluded because the non-negativity constraint on bequests imposes a lower bound on the accumulation of wealth. This lower bound on the accumulation of wealth is also present in Escolano (1992), where shocks affect individuals' altruism. A key difference between Escolano (1992) and this paper, is that in Escolano the way that shocks affect preferences implies that the non-negativity constraint on bequest

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[2] In this model, lifetime uncertainty can be interpreted as a shock on preferences as in Alvarez (1994).

is binding, while in this paper the lower bound on bequests is a property of the optimal bequest that arises at equilibrium.

In section 2, I describe the model and prove some mathematical properties of the optimal policy functions. In section 3, I define a stationary equilibrium in this framework and prove the existence and uniqueness of the invariant distribution of wealth at the stationary equilibrium. I also demonstrate that the interest rate at equilibrium is lower than the correspondent to the modified golden rule. In section 4, I characterize a social security system which decentralizes the planner's optimal stationary allocation as a competitive equilibrium. In section 5, I conclude with some comments. The appendix contains some of the proofs.

2 A Model

Consider an economy with overlapping generations that uses physical capital and labor to produce a single good. The technology is represented by a neo-classical production function that exhibits constant returns to scale. The output per worker in period t is $y_t = f(k_t)$, with $k_t = K_t/N_t$, where K_t is capital, and N_t is labor. The production function is twice continuously differentiable, positive, increasing, and strictly concave: $f(k) > 0$, $f'(k) > 0$, $f''(k) < 0$, for all $k > 0$ and $f(0) = 0$, and satisfies the Inada conditions, that is, $\lim_{k\to\infty} f'(k) = 0$ and $\lim_{k\to 0} f'(k) = \infty$. At the end of each period, capital depreciates a constant rate $\delta \in [0, 1]$.

Firms hire capital and labor services to produce. Competitive profit maximization by firms leads to the following conditions:

$$R_t = 1 + f'(k_t) - \delta, \tag{1}$$

$$\omega_t = f(k_t) - k_t f'(k_t), \tag{2}$$

where R_t is the net interest factor and ω_t is the wage.

At the beginning of each period, a generation which consists of a continuum of individuals is born. The measure of young individuals grows at an exogenous rate $n-1>0$. Individuals can live one or two periods. With probability, $p \in (0,1)$, an individual dies at the end of his first period of life. This probability is constant across individuals.

2.1 The Individuals' Decision Problem

Young individuals are endowed with one unit of labor. They supply inelastically this unit of labor to firms in exchange of the competitive wage ω_t at period t. At the beginning of the period, young individuals receive an inheritance from their parents, b_t. During this period, individuals can also consume, c_t^1, and/or save, s_t. The budget constraint of a young individual at period t is thus

$$\omega_t + b_t = c_t^1 + s_t. \tag{3}$$

With probability $(1-p)$ an individual survives and, then, receives the return of the savings accumulated when young. An old individual is retired, so that his only source of income is the return of his savings. During this last period of life, an individual consumes, c_{t+1}^2, and leaves voluntarily a bequest to each of his n children, b_{t+1}^V. Therefore, the budget constraint of an old individual is

$$R_{t+1}s_t = c_{t+1}^2 + nb_{t+1}^V. \tag{4}$$

With probability p, an individual dies at the beginning of his second period of life and, then, the return of his savings are distributed to his n children which constitutes an accidental bequest, b_{t+1}^A,

$$R_{t+1}s_t = nb_{t+1}^A. \tag{5}$$

A young individual does not know the bequest that he will leave to his children because of the lifetime uncertainty. With probability p, an individual will die early and he will leave an accidental bequest which is equal to the return of his savings. With probability $(1-p)$, an individual will leave a voluntary bequest. I adopt Barro's (1974) formalization of the bequest motive: parents care about their children's utility. I assume that utility is separable, both intertemporally and intergenerationally. The preferences of an individual born in period t are represented by

$$E_t\left\{\sum_{i=t}^{\infty}\beta^{i-t}\left(u(c_i^1)+\rho(1-p)u(c_{i+1}^2)\right)\right\}, \tag{6}$$

where $\rho \in (0,1)$ is the intertemporal discount factor, $\beta \in (0,1)$ is the intercohort discount factor, the function $u : \Re_+ \rightarrow \Re$ is continuous, twice differentiable, strictly increasing, strictly concave, and satisfies the Inada condition at the origin, that is, $\lim_{c^i \to 0} u'(c^i) = \infty$ with $i = 1, 2$.[3]

Because I assume one-sided altruism, only from parents to children, there will be no institutions which permit parents to force their children to give them gifts. Moreover, since old individuals do not receive labor income nor gifts from their children, they can not obtain credit. Therefore, I will impose non-negativity constraints on bequests, that is,

$$b_{t+1}^V \geq 0, \text{ and } b_{t+1}^A \geq 0. \tag{7}$$

The decision problem at period t of a young individual who belongs to any cohort is to choose a plan $\left\{c_i^1, c_{i+1}^2, b_{i+1}^V, b_{i+1}^A\right\}_{i=t}^{\infty}$ such that maximizes (6) subject to the constraints (3), (4), (5), and (7).

The goal of this subsection is to prove the existence of a solution of the individual's problem. This proof is restricted to a situation where interest rate and wage remain constant from period to period since this paper focuses on the analysis of the stationary equilibrium. Furthermore, I will assume that the interest factor satisfies $R < n/\beta$. This assumption simplifies the proof of existence of a solution of the individual's problem and the analysis of the dynamics of the distribution of wealth. The main reason for this

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[3] Note that lifetime uncertainty can be interpreted as a shock on the intertemporal discount factor because $\rho = 0$ if an individual dies early and $\rho > 0$ otherwise.

restriction is that the equilibrium interest factor is, in fact, lower than n/β. This property of the equilibrium interest factor will be shown in the next section.

If $\left\{\widehat{c}_i^1, \widehat{c}_{i+1}^2, \widehat{b}_{i+1}^V, \widehat{b}_{i+1}^A\right\}_{i=0}^{\infty}$ is an optimal plan given b_0, the function

$$v^*(b_0) \equiv E_0 \sum_{i=0}^{\infty} \beta^i \left(u(\widehat{c}_i^1) + \rho(1-p)u(\widehat{c}_{i+1}^2)\right)$$

is the indirect utility function of an individual that receives a bequest b_0.

Lemma 1 *If $v^*(\cdot)$ exists, it is increasing and concave.*[4]

If the indirect utility function exists, by Theorem 4.2 in Stokey and Lucas with Prescott (1989) the indirect utility function satisfies the functional equation

$$\begin{aligned} v^*(b) \quad = \quad & \underset{\{c^1, c^2, b^V, b^A\}}{Max} \quad u(c^1) + \rho(1-p)u(c^2) + \beta\left[pv^*(b^A) + (1-p)v^*(b^V)\right] \\ & s.t. \\ & \omega + b = c^1 + \frac{n}{R}b^A, \\ & nb^A = c^2 + nb^V, \\ & b^V \geq 0 \; b \text{ and } b^A \geq 0. \end{aligned} \tag{8}$$

Moreover, by Theorem 4.4 in Stokey and Lucas with Prescott (1989), the optimal plan $\left\{\widehat{c}_i^1, \widehat{c}_{i+1}^2, \widehat{b}_{i+1}^V, \widehat{b}_{i+1}^A\right\}_{i=0}^{\infty}$ is generated from the optimal policy functions $c^1(b_i)$, $c^2(b_i)$, $\phi_V(b_i)$, and, $\phi_A(b_i)$ defined by

$$v^*(b_i) = u(c^1(b_i)) + \rho(1-p)u(c^2(b_i)) + \beta\left\{pv^*(\phi_A(b_i)) + (1-p)v^*(\phi_V(b_i))\right\},$$

where $c^1(b_i) = \widehat{c}_i^1$, $c^2(b_i) = \widehat{c}_{i+1}^2$, $\phi_V(b_i) = \widehat{b}_{i+1}^V$, and $n\phi_A(b_i) = c^2(b_i) + n\phi_V(b_i)$. The functions $c^1(b)$, $c^2(b)$, $\phi_V(b)$, and $\phi_A(b)$ satisfy the first order conditions of the maximization

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[4] For a proof see Levhari and Srinivasan (1969).

problem (8) which are the following:

$$\frac{n}{R}u'(\omega + b - \frac{n}{R}b^A) = np(1-p)u'(nb^A - nb^V) + \beta p v^{*\prime}(b^A), \qquad (9)$$

$$npu'(nb^A - nb^V) \geq \beta v^{*\prime}(b^V), \text{ with equality if } b^V > 0. \qquad (10)$$

Using the envelope theorem, it follows that

$$v^{*\prime}(b) = u'(\omega + b - \frac{n}{R}\phi_A(b)), \qquad (11)$$

for all b.[5] The above conditions are necessary for a policy function to be optimal. These conditions are sufficient if the policy functions and the derivative of the indirect utility function satisfy the following transversality condition:

$$\lim_{t\to\infty} \beta^t E v^{*\prime}(b_t)b_t = 0.$$

The necessary conditions imply that the optimal policy functions have the following properties:

Proposition 1 *The function ϕ_A is strictly increasing with respect to b and ϕ_V is non-decreasing with respect to b. The consumption of both periods is strictly increasing with respect to b.*

Proof. See the appendix.

The next proposition shows that if the interest factor is not greater than n/β and the bequest received is sufficiently small and positive, the non-negativity constraint on voluntary bequests is binding.

Proposition 2 *If $R \leq n/\beta$, then i) $\phi_V(b) < b$, for all $b > 0$ and ii) there exists a $\underline{b} > 0$ such that $\phi_V(b) = 0$ for all $b \leq \underline{b}$.*

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[5] From this relation it follows that the indirect utility function is increasing with respect to the bequest received given that $u' > 0$.

Proof. See the appendix.

2.1.1 Existence of Solution of the Individuals' Problem

I will prove that the individuals' problem has a solution when $R < n/\beta$. The proof follows Schechtman and Escudero (1977) and consists in finding a candidate of solution, $\{c^1(b), c^2(b), \phi_V(b), \phi_A(b)\}$ and a function $v^{*\prime}$ and showing that they satisfy conditions (9), (10), (11), and the transversality condition.[6]

Following Schechtman and Escudero (1977), the candidate solution of the individuals' problem is the limit as $t \to \infty$ of the optimal policy functions that solve the equivalent finite horizon problem,

$$\begin{aligned} v_t^*(b) &= \underset{\{b^A, b^V\}}{Max}\ u(c_t^1) + \rho(1-p)u(c_{t+1}^2) + \beta\left[pv_{t-1}^*(b^A) + (1-p)v_{t-1}^*(b^V)\right] \\ &\quad s.t. \\ &\quad \omega + b_t = c_t^1 + \frac{n}{R}b_{t+1}^A, \\ &\quad nb_{t+1}^A = c_{t+1}^2 + nb_{t+1}^V, \\ &\quad b_{t+1}^V \geq 0 \text{ and } b_{t+1}^A \geq 0. \end{aligned} \tag{12}$$

This finite horizon problem has a unique solution represented by the pair of functions $(\phi_{At}(b), \phi_{Vt}(b))$. The limit of these functions as $t \to \infty$ (from now on, limiting policies) are possible solutions to the individuals' problem. Schechtman and Escudero (1977) explain that if an upper bound for $v_t^{*\prime}$ is found, then there exists a function $v^{*\prime}(b) = \lim_{t\to\infty} v_t^{*\prime}(b)$ and the limiting policies satisfy the necessary conditions (9), (10), and (11). Hence, to show that the limiting policies are a solution of the individual's problem, it is sufficient to show that the transversality condition is satisfied. The next lemma shows that there exists an

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[6] It is possible to show that the individual's problem has a solution when $R \geq n/\beta$. The proof is available upon request and it follows Sotomayor (1984). This proof assumes that the marginal utility has an asymptotic exponent different from zero. However, such situation is impossible in a stationary equilibrium, as it will be shown.

upper bound for $v_t^{*\prime}$.

Lemma 2 *Let* $v_t^{c'}$ *be the derivative of the indirect utility function of the decision problem (12) setting* $p = 0$. *Then,* $v_t^{*'}(b) \leq v_t^{c'}(b)$, *for all* t.

Proof. See the appendix.

The next step is to prove that the limiting policies and the derivative of the indirect utility function satisfy the transversality condition.

Proposition 3 *The limiting policies are the unique solution of the individual's problem (8).*

Proof. It is sufficient to show that $\lim_{t\to\infty} \beta^t E v^{*\prime}(b_t) b_t = 0$. From Lemma 2, we know that $v_t^{*\prime}(b) < v_t^{c'}(b) \leq u'\left(c_t^{c1}(0)\right)$, for all t and $b > 0$. It is straightforward to show that $u'\left(c_t^{c1}(0)\right) \leq \overline{u}$, where $\overline{u} \equiv \max\left\{u'\left(\frac{R\omega}{R+1}\right), \frac{n\rho}{\beta} u'\left(\frac{R\omega}{R+1}\right)\right\}$. An upper bound of the bequest is the sum of the incomes of the dynasty, that is,

$$b_t < \sum_{i=0}^{t} \left(\frac{R}{n}\right)^i \omega + \left(\frac{R}{n}\right)^t b_0.$$

Then, if $R \geq n$, $\lim_{t\to\infty} \beta^t E v^{*\prime}(b_t) b_t \leq \lim_{t\to\infty} \beta^t \overline{u} \left(\frac{R}{n}\right)^t \left(\omega \sum_{i=0}^{t} \left(\frac{n}{R}\right)^i + b_0\right) = 0$. On the other hand, if $R < n$, the bequest has a finite upper bound and, then, it follows that the transversality condition is satisfied. ■

3 Stationary Equilibrium

The capital market clears when aggregate saving is equal to the firms' aggregate demand for capital. In order to calculate the aggregate savings of the economy, it is necessary to know the distribution of bequests across young individuals. Let ψ denote the distribution function of bequests across young individuals at the beginning of a period. Therefore, $\psi(B)$ is the fraction of young people who receives a bequest b that belongs to a set $B \in \varphi$, where φ is the Borel σ-algebra of subsets of the state space S.

Given that there is a continuum of individuals, the law of large numbers applies and capital market clears at a stationary equilibrium when

$$\frac{1}{R}\int \phi_A(b)d\psi(b) = k. \tag{13}$$

At a stationary equilibrium, the distribution of bequests, the interest rate, and the wage are invariant from period to period. Therefore,

$$\psi(b') = p\int_{B_1(b')} d\psi(b) + (1-p)\int_{B_2(b')} d\psi(b), \tag{14}$$

where $B_i(b') = \{b \geq 0 : \phi_i(b) \leq b'\}$, i = 1,2 and b' is the next period bequest received by each of the n children of an individual.

Definition 1 *A stationary equilibrium is characterized by a per capita capital* $\widehat{k}$, *the continuous functions* $\{c^1(b), c^2(b), \phi_V(b), \phi_A(b)\}$, *and the distribution function of bequests* $\psi^*(b) : \Re_+ \rightarrow [0,1]$ *such that, (i)* $\{c^1(b), c^2(b), \phi_V(b), \phi_A(b)\}$ *solves the individual's problem for each* b, *(ii)* $\widehat{R}$, $\widehat{\omega}$, *and* $\widehat{k}$, *satisfy (1) and (2), (iii)* ϕ_A, ϕ_V, *and* $\widehat{k}$ *satisfy (13), (iv)* ϕ_A, ϕ_V, *and* ψ^* *satisfy (14).*

The concept of stationary equilibrium involves that the distribution of wealth remains unchanged from period to period so that the aggregate macroeconomic variables remain constant. In the next subsection, I will focus on the dynamics of the distribution of wealth in a stationary equilibrium. For this end, I assume that the economy has reached a stationary equilibrium and, therefore, the aggregate macroeconomic variables remain constant from period to period. Input prices are also assumed to be constant with the interest factor satisfying $\widehat{R} < n/\beta$. I will then demonstrate that there exists a unique invariant distribution of wealth at equilibrium. At the end of this section, I will show that at a stationary equilibrium the interest rate is strictly lower that the correspondent to the modified golden rule.

3.1 The Equilibrium Wealth Distribution

In this subsection I focus on the dynamics of the distribution of wealth across young individuals. A newly born individual is endowed with one unit of labor and receives an inheritance. I define wealth in this environment as the bequest that an individual receives because heterogeneity across individuals' wealth is driven by differences in the bequests that they receive. I do not include in this concept of wealth the labor income because individuals earn the same labor income since they inelastically supply labor to firms.

Given $(\hat{\omega}, \hat{R})$, the following equation describes the evolution of any individual's policy bequest:

$$b' = \begin{cases} \phi_A(b) & \text{with probability } p, \\ \phi_V(b) & \text{with probability } 1-p. \end{cases}$$

This transition rule defines a Markov chain in a discrete and numerable state space S.[7] The transition probability of this process is, for $b \in S$ and $B \in \wp$,

$$P(b, B) = p\chi_B\left(\phi_A(b)\right) + (1-p)\chi_B\left(\phi_V(b)\right),$$

where $\chi_B\,(i)$ is an indicator function such that, $\chi_B\,(i) = 0$ if $i \notin B$ and $\chi_B\,(i) = 1$ if $i \in B$. The number $P(b, B)$ records the probability that, in a given dynasty, the bequest moves from the state b to some state in the Borel subset B of $\wp$ during one unit of elapsed time. I define the operator T associated with the transition function by

$$\left(T\psi\right)(B) = p\sum_{b\in S}\chi_B\left(\phi_A(b)\right)d\psi(b) + (1-p)\sum_{b\in S}\chi_B\left(\phi_V(b)\right)d\psi(b).$$

Note that the distribution of bequests along time of a dynasty, ψ, coincides with the distribution of bequests at a point in time across young individuals of different dynasties.

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[7] The state space is discrete because individuals' lifetime is affected by a discrete shock.

Because shocks are identically and independently distributed across individuals and time, all dynasties have the same distribution of bequests along time. Since there is a large number of dynasties at any period, the distribution of bequests along time of a representative dynasty coincides with the distribution of bequests at a point in time across young individuals that belong to different dynasties.

I will prove that there exists a unique solution ψ^* to the functional equation $T\psi = \psi$, which is the stationary distribution that satisfies equation (14). The proof uses the Theorem 5.7 in Doob (1953), which shows that the probability measure $\psi^*(\cdot)$ exists if the transition function P satisfies Doeblin's condition in Doob (1953, condition D, p. 192) and that it is unique if the state space S has one ergodic set. In order to define an ergodic set, it is necessary to introduce two concepts. A set E is a consequent of $b \in S$ if $P(b, E) = 1$ for all $N \geq 1$. A set which is a consequent of every one of its members is an invariant set. Finally, an ergodic set is an invariant set containing no other invariant subsets of smaller measure.

Lemma 3 (Doeblin Condition.) *There is a finite measure π on (S,φ) an integer $N \geq 1$, and a number $\varepsilon > 0$, such that if $B \in \varphi$ and $\pi(B) \leq \varepsilon$, then $P^N(b, B) \leq 1 - \varepsilon$, for all $b \in S$.*

Proof. Let us suppose, without loss of generality, that $1 - p \geq p$. Let $\pi(b_{i,N}) = p^i(1-p)^{N-i}$ for all $b_{i,N} \in S$, where the subindex i indicates the number of ancestors that die at the end of the first period of their lifetime, and $N - i$ is the number of ancestors that are alive in the second period of their lifetime. Therefore, for any $B \in \varphi$, $\pi(B) = \sum_{b_{i,N} \in B} \pi(b_{i,N})$. Let $\varepsilon = \min(p^i(1-p)^{N-i}), i = 0, 1, ..., N$. Then, $1 - p \geq p$ implies $\varepsilon = p^N$. Let B be a set such that $\pi(B) \leq \varepsilon \leq p$, then B contains at most one element so that, for all b, $P(b, B) \leq 1 - p \leq 1 - \varepsilon$, since the altruistic bequest and the accidental bequest are different. ☐

Lemma 3 has shown that the transition function P satisfies the Doeblin condition for some triple (π, N, ε) which implies that there exists at least one ergodic set and at most a finite number of ergodic sets. The next lemma proves that there exists a unique ergodic set in S for the transition function P and, then a unique probability measure $\psi^*(\cdot)$.

Lemma 4 *If $R \leq n/\beta$, then the state space S has a unique ergodic set E.*

Proof. Let's suppose that E and E^* are two ergodic sets for the transition function P. If I prove that there exists a subset $a \in E \cap E^*$ such that $\pi(a) > 0$, then E and E^* are not distinct ergodic sets. That is, if $P(a, E) = 1$ and $P(a, E^*) = 1$ then E is equal to E^*. This proof follows three steps:

1. By Proposition 2, we know that: *i)* $b > \phi_V(b)$ if $\widehat{R} \leq n/\beta$ and *ii)* there exists a $\underline{b} > 0$ such that $\phi_V(\underline{b}) = 0$ and $\phi_V(b) > 0$ for all $b > \underline{b}$.
2. Using 1, it is easy to prove that inf $\{b \in E\} = 0$. The proof follows by contradiction. Assume that inf $\{b \in E\} = b^*$ and $\phi_V(b^*) > 0$ which implies that $b^* > \underline{b}$. By step 1, we know that $\phi_V(b^*) < b^*$. In that case, $P(b^*, E) < 1$, which contradicts the initial assumption of the ergodicity of E. Therefore, $\phi_V(b^*) = 0$. If E is an ergodic set of S and $b^* \in S$, then $P(b^*, E) = 1$ which implies that $0 \in E$, and, by the initial assumption $b^* = 0$. If E^* were another ergodic set of S, using the same argument we get that $0 \in E^*$. Thus, $0 \in E \cap E^*$.
3. The last step is to prove that $\pi(0) > 0$. In the proof of Lemma 3, I defined the measure $\pi(b_{iN}) = p^i(1-p)^{N-i}$, where i is the number of ancestors that die at the end of their first period of life. Let $i = 0$, given that $\phi_V(b) < b$ for $b > \underline{b}$ and $\phi_V(b) = 0$ for $b \leq \underline{b}$, the altruistic bequest received by an individual who belongs to this family is equal to zero for an enough large N. Therefore, $\pi(0) \geq \pi(b_{0N}) = (1-p)^N > 0$. ■

Proposition 4 *If $R \leq n/\beta$, then there exists a unique solution ψ^* to the equation (14).*

Proof. By Lemmas 3 and 4, it follows from Doob (1953, Theorem 5.7). □

The above proposition shows that there exists a unique wealth distribution at the stationary equilibrium. If the ergodic set contains cyclically transferring subsets, the distribution of bequests does not converge to the limit distribution. In order to rule out cyclically moving subsets within the ergodic set I follow also Doob (1953, pp. 202-203):

Lemma 5 (Doob (1953).) *Let E be the unique ergodic set. Consider $C \subseteq E$ with $\pi(C) > 0$ be such that*

$$\inf_{\xi,\eta \in C} P^{\gamma}(\xi, \eta) > 0, \text{ for some integer } \gamma.$$

Let $I(C)$ be the set of integer numbers γ such that C satisfies the above property and let $d(C)$ be the greatest common denominator of $I(C)$. Then, if $d(C) = 1$, the unique ergodic set E does not contain two or more cyclically transferring subsets.

Proposition 5 *If $R \leq n/\beta$, then the unique ergodic set E does not contain two or more cyclically transferring subsets.*

Proof. I use Lemma 5 from Doob (1953). The set C is $\{0\}$. I next show that $\{0\}$ satisfies the properties that C has in Lemma 5. Lemma 4 proved that $0 \in E$. Given that there are non-negativity constraints on altruistic bequests, at the stationary state the following holds: $\phi_V(0) = 0$ and therefore, $P(0,0) = 1 - p > 0$. Moreover, by the proof of Lemma 4, we know that $\pi(0) > 0$. Finally, $d(0) = 1$, so that the unique ergodic set E does not contain two or more cyclically transferring subsets. □

The above propositions have shown that there is a unique invariant distribution of bequests ψ^* which is a solution to the equation (14). If negative bequests were allowed in this environment, the distribution would be degenerated and an ever decreasing proportion of people would hold an ever increasing proportion of wealth (see Kotlikoff (1989, pp.

115-116)). The existence and uniqueness of the invariant distribution of bequests arises because at a stationary equilibrium the non-negativity constraint on voluntary bequest binds eventually and, then, the process of accumulation of wealth of a dynasty reaches a minimum.

The non-negativity constraint on voluntary bequests binds if $R \leq n/\beta$. A stricter restriction on the interest factor has been also key for the proof of existence of solution of the individuals' problem. The next proposition shows that at a stationary equilibrium the interest rate is lower than the correspondent to the modified golden rule.

Proposition 6 *Let $\widehat{R}$ be the interest factor at a stationary equilibrium, then $\widehat{R} < n/\beta$.*

Proof. See the appendix.

4 Equilibrium with an Egalitarian Distribution of Wealth

Since $\widehat{R} < n/\beta$, there is overaccumulation of capital at a stationary equilibrium with respect to the modified golden rule. The non-negativity constraint on bequests as well as the absence of perfect annuity markets are sources of inefficiency. Perfect annuity markets would reestablish the efficiency of the equilibrium if and only if the bequest motive were operative. If the non-negativity constraint on voluntary bequest is binding, the stationary equilibrium is inefficient since there is an excessive accumulation of capital. In this section, it will be shown that there exists a centrally provided social security system which not only plays the role of an insurance, but also prevents capital overaccumulation at equilibrium.

I consider that the planner of this economy discounts future generations' utility at the same rate that individuals do. The welfare function is taken from Samuelson (1967 and 1968) and it values the utility of the old generation alive in order to avoid a time inconsistency problem. The planner's decision problem at the initial period is

$$
\begin{aligned}
&\underset{\{c_j^1,c_j^2,k_{j+1}\}}{Max} (1-\beta)\sum_{i=-1}^{\infty}\beta^i\left\{u(c_i^1)+(1-p)\rho u(c_{i+1}^2)\right\}\\
&s.t.\\
&f(k_j)+k_j(1-\delta)=c_j^1+\frac{1-p}{n}c_j^2+nk_{j+1},\\
&for\ j=0,1,\dots,\text{ given } k_0 \text{ and } c_{-1}^1.
\end{aligned}
$$

The planner chooses the first and second period consumptions and the capital per capita that maximize its objective function subject to each period feasibility constraint. The first order conditions for the optimal consumption and capital evaluated at stationary paths are the following:

$$
\begin{aligned}
\rho u'(c^2)&=\frac{\beta}{n}u'(c^1),\\
1+f'(\tilde{k})-\delta&=\frac{n}{\beta}.
\end{aligned}
$$

The first of them gives the optimal intratemporal allocation of consumption across young and old individuals. The second gives the optimal intertemporal allocation of capital per capita and implies that the marginal productivity of capital satisfies the modified golden rule. These two conditions jointly with the feasibility constraint define the planner's optimal stationary allocation of consumption and capital. Because the planner knows the distribution of the shock on lifetime of each individual, the planner can offer a perfect insurance to individuals and, then, the optimal distribution of consumption is egalitarian across individuals of the same age.

A social security system is defined by a tax T paid by the young and a transfer T' received by the old such that

$$nT=(1-p)T',$$

which means that the system is self-financing.

Definition 2 *An optimal social security system is characterized by a transfer T' that* *satisfies the following condition:*

$$\rho u'(T') = \frac{\beta}{n} u'(\omega(\widetilde{k}) + R(\widetilde{k})\widetilde{k} - \frac{1-p}{n} T' - n\widetilde{k}), \tag{15}$$

where $\widetilde{k}$ is the capital per capita that satisfies the modified golden rule.

Note that equation (15) means that the optimal transfer induces the young to save up to the optimal capital per capita and the old to consume the transfer and leave a bequest equal to the return of their savings. Therefore, the optimal social security decentralizes the planner's allocation as a competitive equilibrium and induces an egalitarian distribution of wealth across young individuals. The next proposition shows the existence of such an optimal social security system.

Proposition 7 *There exists a unique optimal social security system that decentralizes the planner's optimal stationary allocation path as a competitive equilibrium.*

Proof. See the appendix.

5 Concluding Remarks

This paper studies the dynamics of the distribution of wealth in a general equilibrium framework. The model, by introducing accidental bequests in a model with dynasties, considers two motives for bequests which generates interesting dynamics in the distribution of wealth. This paper shows that at a stationary equilibrium there exists a unique invariant distribution of wealth. The key of the proof is that the non-negativity constraint on bequests binds in a dynasty after a finite number of good shocks on the lifetime of its members. This paper also shows that a social security system plays the role of perfect insurance and prevents capital overaccumulation with respect to the modified golden rule. This optimal social security system decentralizes the allocation of a planner as a competitive equilibrium and induces an egalitarian distribution of wealth.

In the same framework, Fuster (1994) studies mean preserving redistributive policies that improve the economy long-run welfare. As in Loury (1981), redistributive tax policies that preserve the mean of the distribution of wealth and reduces the dispersion of the distribution, imply a higher welfare in the long run. In this line of research, it would also be interesting to take into account the problems of asymmetric information that possibly cause the incompleteness of the insurance markets.

A Appendix

Proof of Proposition 1

1) It is shown that c^2 is strictly increasing with respect to b^A . Let $b_1^A < b_2^A$, and suppose that $c^2(b_1^A) > c^2(b_2^A)$. If bequest motive is operative, equation (10) and the concavity of the utility function imply that

$$\begin{aligned}\frac{\beta}{n}v^{*\prime}\left(b_2^A - \frac{1}{n}c^2(b_2^A)\right) &= \rho u'\left(c^2(b_2^A)\right) > \\ &> \rho u'\left(c^2(b_1^A)\right) = \frac{\beta}{n}v^{*\prime}\left(b_1^A - \frac{1}{n}c^2(b_1^A)\right).\end{aligned}$$

Therefore, by the concavity of the value function, $b_2^A - \frac{1}{n}c^2(b_2^A) < b_1^A - \frac{1}{n}c^2(b_1^A)$, which contradicts the initial assumption. Now, if I consider $b_2^V > 0$ and $b_1^V = 0$, I get a similar contradiction. In the other possible cases the proof is obvious.

2) The altruistic bequest is non-decreasing with respect to b^A. Let's consider that the non-negative constraint on the voluntary bequest is not binding. Let $b_1^A < b_2^A$ and suppose that $b_2^A - \frac{1}{n}c^2(b_2^A) < b_1^A - \frac{1}{n}c^2(b_1^A)$. Thus, equation (10) and the concavity of the indirect utility function imply that

$$\frac{\beta}{n}v^{*\prime}\left(b_2^A - \frac{1}{n}c^2(b_2^A)\right) = \rho u'\left(c^2(b_2^A)\right) >$$

$$> \rho u'\left(c^2(b_1^A)\right) = \frac{\beta}{n} v^{*\prime}\left(b_1^A - \frac{1}{n} c^2(b_1^A)\right),$$

and, therefore, $c^2(b_1^A) > c^2(b_2^A)$, which is a contradiction. Now, let's consider that the non-negativity constraint on voluntary bequest is binding, that is, $b_2^A - \frac{1}{n} c^2(b_2^A) = 0$, and

$$\begin{aligned}
\rho u'\left(c^2(b_2^A)\right) &\geq \frac{\beta}{n} v^{*\prime}\left(b_2^A - \frac{1}{n} c^2(b_2^A)\right) > \\
&> \frac{\beta}{n} v^{*\prime}\left(b_1^A - \frac{1}{n} c^2(b_1^A)\right) = \rho u'\left(c^2(b_1^A)\right).
\end{aligned}$$

Therefore, $c^2(b_1^A) > c^2(b_2^A)$, which is a contradiction. The proof is trivial for the other cases.

3) The accidental bequest is strictly increasing with respect to b. Let $b_1 > b_2$, and suppose that $\phi_A(b_1) < \phi_A(b_2)$. By 2) and equation (9), it is obtained that

$$\begin{aligned}
u'\left(\omega + b_1 - \frac{n}{R}\phi_A(b_1)\right) &= \frac{R}{n}\left\{\beta p v^{*\prime}(\phi_A(b_1)) + \rho(1-p) u'\left(c^2(\phi_A(b_1))\right)\right\} > \\
&> \frac{R}{n}\left\{\beta p v^{*\prime}(\phi_A(b_2)) + \rho(1-p) u'\left(c^2(\phi_A(b_2))\right)\right\} = \\
&= u'\left(\omega + b_2 - \frac{n}{R}\phi_A(b_2)\right).
\end{aligned}$$

Therefore, $b_1 - \frac{n}{R}\phi_A(b_1) < b_2 - \frac{n}{R}\phi_A(b_2)$, which contradicts the initial assumption.

4) By 3) and 2) the voluntary bequest is non-decreasing with respect to b.

5) By 3) and 1) the second period consumption is strictly increasing with respect to b.

6) The consumption of the young is strictly increasing with respect to b. Let $b_1 > b_2$ and suppose that $c^1(b_1) < c^1(b_2)$. By 3) and 4) and equation (9),

$$\begin{aligned}
&\frac{R\beta}{n}\left\{p v^{*\prime}(\phi_A(b_1)) + (1-p) v^{*\prime}\left(\phi_A(b_1) - \frac{1}{n} C^2(\phi_A(b_1))\right)\right\} < \\
&< \frac{R\beta}{n}\left\{p v^{*\prime}(\phi_A(b_2)) + (1-p) v^{*\prime}\left(\phi_A(b_2) - \frac{1}{n} C^2(\phi_A(b_2))\right)\right\}.
\end{aligned}$$

Therefore, $u'(c^1(\phi_A(b_1))) < u'(c^1(\phi_A(b_2)))$, which contradicts the initial assumption. ■

Proof of Proposition 2

i) Let $R \leq n/\beta$ and consider a b such that the non-negativity constraint on the voluntary bequest is not binding. Using equations (9), (10), and (11), it is obtained that

$$nu'\left(c^1(b)\right) = R\beta\left\{pu'\left(c^1(\phi_A(b))\right) + (1-p)u'\left(c^1(\phi_V(b))\right)\right\}.$$

Given that $\phi_A(b) > \phi_V(b)$ for all b and given that the first period consumption is strictly increasing, the concavity of the utility function implies that

$$u'\left(c^1(\phi_V(b))\right) > \left\{pu'\left(c^1(\phi_A(b))\right) + (1-p)u'\left(c^1(\phi_V(b))\right)\right\}.$$

Using $R \leq n/\beta$, the above inequalities give

$$u'\left(c^1(\phi_V(b))\right) > u'\left(c^1(b)\right).$$

Therefore, $c^1(\phi_V(b)) < c^1(b)$, which implies that $\phi_V(b) < b$ because $c^1(\cdot)$ is strictly increasing with respect to the bequest received. The proof is trivial if $\phi_V(b) = 0$ for $b > 0$.

ii) Let's assume that the first order condition (10) is satisfied with equality at $b = 0$, that is,

$$npu'\left(n\phi_A(0)\right) = \beta v^{*\prime}(0).$$

Using the above equation, the first order condition (9), and the envelope theorem I obtain the following relation:

$$\frac{n}{R}u'(\omega - \frac{n}{R}\phi_A(0)) = \beta\left\{pu'(\omega - \frac{n}{R}\phi_A(0)) + (1-p)u'(\omega + \phi_A(0) - \frac{n}{R}\phi_A\left(\phi_A(0)\right))\right\}.$$

Given that $\phi_A(0) > 0$ and c^1 is strictly increasing, from the above equation I obtain that

$$\frac{n}{R}u'\left(\omega - \frac{n}{R}\phi_A(0)\right) < \beta u'\left(\omega - \frac{n}{R}\phi_A(0)\right).$$

Finally, given that $R \leq n/\beta$, from the above inequality I get

$$u'\left(\omega - \frac{n}{R}\phi_A(0)\right) < u'\left(\omega - \frac{n}{R}\phi_A(0)\right),$$

which is a contradiction. Therefore,

$$n\rho u'\left(n\phi_A(0)\right) > \beta v^{*\prime}(0).$$

By the concavity of the utility function, I can conclude that there exists a $\underline{b} > 0$ such that

$$n\rho u'\left(n\phi_A(\underline{b})\right) = \beta v^{*\prime}(0),$$

and, therefore, $\phi_V(b) > 0$ for all $b > \underline{b}$. ■

Proof of Lemma 2

First, consider that the voluntary bequest is positive. From the first order conditions of the maximization problem (12) we obtain the relation

$$\begin{aligned} u'\left(\omega + b - s_t(b)\right) &= \frac{R\beta}{n}\left\{pv_t^{*\prime}\left(b^A\right) + (1-p)v_t^{*\prime}\left(b^V\right)\right\} < \\ &< \frac{R\beta}{n}v_t^{*\prime}\left(b^V\right) = \frac{R\beta}{n}u'\left(\omega + b_{t+1}^V - s_{t+1}(b_{t+1}^V)\right). \end{aligned}$$

Therefore, it follows that savings have to be larger if lifetime is certain than if lifetime is uncertain, $s_t^c(b) > s_t(b)$ and, therefore, $c_t^{c1}(b) < c_t^1(b)$ for all t. By the concavity of the utility function, $u'\left(c_t^{c1}(b)\right) > u'\left(c_t^1(b)\right)$ and by the envelope theorem, $v_t^{c\prime}(b) > v_t^{*\prime}(b)$. Consider now that the voluntary bequest is zero for the uncertain-lifetime case. Let us assume that $s_t(b) > s_t^c(b)$ in order to find a contradiction. Given that the voluntary bequest is equal to zero, the second period consumption is

$$c_{t+1}^2(b) = Rs_t(b) > Rs_t^c(b) \geq Rs_t^c(b) - nb_{t+1}^{cV}(b) = c_{t+1}^{c2}(b),$$

and by the concavity of the utility function and the first order condition (10), we have that

$$\frac{n}{R}u'\left(\omega + b - s_t(b)\right) < \rho u'\left(c_{t+1}^2(b)\right) < \rho u'\left(c_{t+1}^{c2}(b)\right) = \frac{n}{R}u'\left(\omega + b - s_t^c(b)\right).$$

Given that the utility function is concave, from the above relation it is obtained that

$$b - s_t(b) > b - s_t^c(b),$$

which contradicts to the initial assumption. Therefore, $v_t^{*\prime}(b) \leq v_t^{c'}(b)$. □

Proof of Proposition 6

From the necessary conditions (9), (10), and (11) for optimallity of the policy functions, the following equation is obtained:

$$\begin{aligned} nu'(\omega + b - s) \quad &\geq \quad \widehat{R}\beta(pu'(\omega + b^A - s(b^A)) + \\ &\qquad +(1-p)u'(\omega + b^V - s(b^V))). \end{aligned}$$

Substituting recursively in the above equation, we obtain an inequality that depends on the marginal utility of the first period consumption and the expected marginal utility in period t of the first period consumption,

$$u'(\omega + b - s) \geq (\widehat{R}\beta/n)^t E\left(u'(\omega + b - s(b))\right).$$

The expected marginal utility is constant at the stationary equilibrium because the distribution of wealth is invariant. Assume that this expectation is different from zero or infinity. Then, as $t \to \infty$ the above inequality holds if and only if $\widehat{R} \leq n/\beta$. We know from the proof of Lemma 4 that if $\widehat{R} \leq n/\beta$, there exists a positive measure of people for whom the non-negativity constraint on bequest is binding. Then, the first order conditions imply,

$$u'(\omega + b - s) > (\widehat{R}\beta/n)^t E\left(u'(\omega + b - s(b))\right).$$

Because the expected marginal utility is constant, as $t \to \infty$ the above inequality holds if and only if $\widehat{R} < n/\beta$.

Now, we must rule out that the expected marginal utility is close to zero or to infinity. Assume that $\widehat{R} \leq n/\beta$. The necessary conditions imply that

$$u'(\omega + b - s) \geq (\widehat{R}\beta/n) E\left(u'(\omega + b - s(b))\right).$$

We know by the proof of Lemma 4 that there is a positive measure of people leaving a voluntary bequest equal to zero. If there is a positive measure of people leaving a positive voluntary bequest, the first order conditions imply that

$$u'(\omega + b - s) = (\widehat{R}\beta/n)E\left(u'(\omega + b - s(b))\right) \leq E\left(u'(\omega + b - s(b))\right).$$

We have to show that in these dynasties marginal utility is bounded above so that the aggregate marginal utility is finite. We know by the proof of Proposition 3 that the individual consumption has a lower bound greater than zero. Therefore, consumption can not be close to zero and, then, an individual's expected marginal utility can not be close to infinity. Therefore, the aggregate marginal utility is finite.

Assume that $\widehat{R} > n/\beta$. From the necessary conditions we obtain that

$$u'(\omega + b - s) > u'(\omega + \phi_A(b) - s(\phi_A)).$$

Then, because first period consumption is strictly increasing, $\phi_A(b) > b$ for all b. Because the accidental bequest is proportional to the individual's savings, it follows that savings increase along generations. Assume that individuals' savings tend to infinity which implies that the expected marginal utility tends to zero. If individuals savings are close to infinity, aggregate savings tend to infinity which contradicts that $\widehat{R} > n/\beta$ because of technology assumptions. ■

Proof of Proposition 7

The proof follows three steps: The first proves that there exists a unique optimal transfer T' that solves equation (15). The second proves that individuals save $n\tilde{k}$ if and only if they leave a voluntary bequest equal to the return of their savings, $R(\tilde{k})\tilde{k}$. The third proves that individuals leave a voluntary bequest equal to $R(\tilde{k})\tilde{k}$ under the optimal social security system.

The first step follows from the concavity of the utility function and the continuity of $u'(\cdot)$.

The second step is divided in two parts. The first part consists in proving that if individuals save $n\tilde{k}$, they leave a voluntary bequest equal to $R(\tilde{k})\tilde{k}$. The proof follows by contradiction. Assume that $0 \leq b^V < R(\tilde{k})\tilde{k}$. The first order conditions of the individual's maximization problem give

$$\rho u'(T' + \alpha R(\tilde{k})n\tilde{k}) \geq \frac{\beta}{n}u'(\omega(\tilde{k}) + (1-\alpha)R(\tilde{k})\tilde{k} - \frac{1-p}{n}T' - s),$$

where $b^V = (1-\alpha)R(\tilde{k})\tilde{k}$ and $0 < \alpha \leq 1$. Given that the first period consumption is increasing with respect to the bequest received,

$$\frac{\beta}{n}u'(\omega(\tilde{k}) + R(\tilde{k})\tilde{k} - \frac{1-p}{n}T' - n\tilde{k}) \leq \frac{\beta}{n}u'(\omega(\tilde{k}) + (1-\alpha)R(\tilde{k})\tilde{k} - \frac{1-p}{n}T' - s),$$

which yields

$$\rho u'(T') \leq \rho u'(T' + \alpha R(\tilde{k})n\tilde{k}),$$

which is a contradiction since we have assumed that $0 < \alpha$ and that the utility is concave. The second part consists in proving that if individuals leave a voluntary bequest equal to $R(\tilde{k})\tilde{k}$, their savings are equal to $n\tilde{k}$. Let $b^V = R(\tilde{k})\tilde{k}$, and assume that $s(b^V) < n\tilde{k}$. The accidental bequest is $R(\tilde{k})s(b^V)/n < R(\tilde{k})\tilde{k}$ and, then, $c^2 < 0$ which is a contradiction. Assume now that $s(b^V) > n\tilde{k}$, then the accidental bequest is $R(\tilde{k})s(b^V)/n > R(\tilde{k})\tilde{k}$. By the first order conditions of the individual's problem, we know that

$$\frac{\beta}{n}u'(\omega(\tilde{k}) + R(\tilde{k})\tilde{k} - \frac{1-p}{n}T' - s(b^V)) =$$

$$\frac{\beta}{n}\left(pu'\left(c^1(R(\tilde{k})s(b^V)/n)\right) + (1-p)u'\left(c^1(R(\tilde{k})\tilde{k})\right)\right).$$

By concavity of the utility function, one obtains that

$$\frac{\beta}{n}u'(\omega(\tilde{k}) + R(\tilde{k})\tilde{k} - \frac{1-p}{n}T' - s(b^V)) < \frac{\beta}{n}u'(\omega(\tilde{k}) + R(\tilde{k})\tilde{k} - \frac{1-p}{n}T' - s(b^V))$$

which is a contradiction.

The third step is to prove that the voluntary bequest is equal to $R(\tilde{k})\tilde{k}$ under the optimal social security system. The proof follows again by contradiction. Assume that

$0 \leq b^V < R(\tilde{k})\tilde{k}$ and that (without loss of generality) $c^2 = T' + \alpha R(\tilde{k})s/n$, where $0 < \alpha \leq 1$. Then, by the concavity of the utility function,

$$\rho u'(c^2) < \rho u'(T').$$

By the definition of optimal social security we have that

$$\frac{\beta}{n} u'(\omega(\tilde{k}) + b^V - \frac{1-p}{n} T' - s(b^V)) < \frac{\beta}{n} u'(\omega(\tilde{k}) + R(\tilde{k})\tilde{k} - \frac{1-p}{n} T' - s(R(\tilde{k})\tilde{k}))$$

and, by the concavity of the utility function, $c^1(b^V) > c^1(R(\tilde{k})\tilde{k})$. Because $c^1(\cdot)$ is strictly increasing with respect to the bequest received, it yields the contradiction $b^V > R(\tilde{k})\tilde{k}$. ■

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