# Social Security Reform: The case of Romania

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**Abstract**

This paper presents a general equilibrium model and simulation of the reform of the social security system in Romania. The paper provides a computational simulation of the effects of the proposed increases in the retirement age, and of the introduction of a fully funded scheme in an environment where agents can choose labor supply in each period, and face individual income and mortality risk. The paper presents the effects of the proposed changes upon consumption, labor supply, and asset holdings over the life-cycle, and also shows the changes in interest rates, wages, capital and output due to the recently enacted pension reform. Results show that there is a strong effect of policy changes upon labor supply. With a utility function in consumption and leisure, when workers have the opportunity to modify the amount of hours worked, the introduction of a funded component in the pension system does not necessary increase the amount of capital in the economy.

# 1 Introduction

This paper evaluates a proposal for reform of the Romanian Social Security[1] system. Given the political and economic transformations that have taken place in Romania in the last decade, the Romanian Parliament recently passed a law that reforms the country's pay-as-you-go (PAYG) social security system. This new law includes two major changes to the existing pension system. A third proposal, to introduce a fully funded pension scheme is currently debated in Parliament.

1. The first enacted change is to increase the retirement age both for males and for females and to extend coverage for all people in the labor force. The objective of this reform is to increase the dependency ratio[2].

2. The second proposed change is to create a better link between contributions paid in social security taxes and benefits received.

3. A third major change, to diminish the replacement rate of the pay-as-you-go (PAYG) portion of the pension and introduce a fully funded supplementary pension system to compensate the decrease in the PAYG portion, will be enacted by future legislation.

In this paper, we follow Auerbach and Kotlikoff (1987) and employ a general equilibrium model of overlapping generations of long-lived agents that face mortality risk and individual income risk to study the aggregate effects of the proposed changes. The model assumes that agents that come into the system at age 20, which for simplicity we will denote as age 0, live 60 years, and retire after 40 years of active life, at age 40. Our strategy is to calibrate the model to mimic the pre-reform situation in Romania, and then to study the impact of the changes discussed above. The model consists of three sectors: a household sector, a production sector, and a government sector. We

[1] In this paper, we use the term Social Security to denote the old age pension.

[2] The dependency ratio is defined as the ratio of people contributing to the system to the number of beneficiaries.

solve a system of nonlinear equations to obtain the equilibrium path.

Once we build the mathematical model that simulates the behavior of the economy in steady state, we will analyze three system-based changes. Two of the changes to the system are: an increase in the retirement age and a change in the way benefits are calculated. As a separate post-reform change we are analyzing the effect of the introduction of a fully funded system. In order to be able to separate and identify aggregate effects of each proposed change, we will analyze each change one at a time.

We use data and estimates from the Romanian National Commission for Statistics (1998) to match the Romanian conditions, associated with the initial steady state in 1998. We compute the initial steady state using the rules in place before any change occurred. We simulate a general equilibrium model and the model endogenously determines the wage and the interest rate as given by the marginal products of labor and capital respectively.

We compute the initial steady state values of the output, aggregate per capita physical capital, and per capita consumption and investment. More importantly, we solve for the age profile of consumption, assets and labor supply in the initial steady state, as well as in the final steady state. The model is solved for different values of income taxes and different values of replacement rates for the social security benefit.

According to the proposed changes there are three transition processes:

1. Increasing the participation to the system, which is expected to be completed over a period of 40 years. The new law closes a loophole existent in the old legislation. Given that the pension system was initially designed before 1989, when there was no private sector, there was no provision for employees in the private sector to contribute to the system. Therefore, since 1990, employers and employees from the newly established private sector have chosen not to contribute to the social security system. The new legislation mandates that all employees

and employers, regardless if they are in the private or state-owned sector, should contribute into the system. However, there are no economic incentives to join the system and there is a widespread expectation that the high rate of evasion (currently legal) will continue to stay high.

2. The change in the retirement age will take only 24 years as the transition toward a new retirement age starts in 2001, and ends in 2024 (2014 for males.) The retirement age increases in monthly increments, adding one month to the retirement age at each 6 months (persons entitled to old age retirement will retire at age 57 in January, and a younger entitled person will retire at age 57 and a month in July, another person will retire at 57 and 2 months next January and so on, until the transition ends.)

3. The transition towards a fully funded system will take place starting in the second quarter of 2001 with people under 40 years contributing to the new system, and therefore the first payment is expected around 2020 for females and in 2025 for males.

We will consider the longest transition period, therefore we set the end of our simulation period in $2040 + T$, where $T$ is the maximum length of an individual lifetime, since it takes a full lifetime for the transition to make its way through the system.

To compute the post-reform (final) steady state, we follow Auerbach and Kotlikoff (1987), and Huang, Imrohoroglu and Sargent (1996) and assume that we are making only a minor approximation error by forcing convergence to a final stationary equilibrium after a long but finite transition period.

In separate exercises we look at the impact of the enacted and proposed changes of the social security system upon consumption, asset holdings and labor supply profile between the initial and the final steady states. The first exercise simulates only the changes already enacted in law, i.e., changes in retirement age and in the way benefits are computed. The second one adds the fully funded component that will be introduced in the future.

The fiscal soundness of the Social Security system is one of our main concerns. Therefore, for each separate case studied we will compute the social security tax that will keep the system solvent, and we will study what is the effect on pension benefits of individual changes in the tax rate on labor income, in the tax rate on assets, and the tax rate on consumption.

In order to compare different social security arrangements we are using the ex-ante utility at birth. Also, to enable comparisons between different arrangements, we build and present a measure of a consumption-based utility gain (loss) associated with policy reforms.

The paper is structured in the following way: Section 2 discusses the current literature on computational models of social security. Section 3 describes the current pension system in Romania and the proposed changes. Section 4 presents the model economy. Section 5 describes the algorithm that is used to solve the model and a description of the parameters used. Section 6 provides the results of multiple simulations, and Section 7 concludes.

## 2 A summary of current literature

The issues linked to social security privatization and the influence upon the solvency of the system of an aging population have been analyzed in many studies, most of them collected in NBER volumes[3]. We will look only at the literature devoted to computational aspects of privatizing social security and to the studies that employ overlapping generations models to simulate the macroeconomic and welfare effects of changes to the system. All studies mentioned in this brief survey deal only with the United States retirement system.

Auerbach and Kotlikoff (1987) employ a 55-period life cycle simulation model. Chapter 10 of

[3]For example, *Social Security and Retirement around the World*, edited by Jonathan Gruber and David A. Wise, or *Topics in the Economics of Aging*, David Wise (ed.)

their book on dynamic fiscal policies looks at the problems of the social security system. It considers the impact of social security on savings and the potential distortionary impact on labor supply, by allowing agents to choose consumption and labor supply each period. The principal findings of this study are: an unfunded social security system with a 60 percent benefit to earnings replacement rate reduces the simulated long run level of physical capital by 24 % compared to the standard case of no social security. Another finding refers to the labor supply distortions introduced by the missing link between marginal social security taxes and marginal social security benefits. The authors report the efficiency gains from switching from an unlinked social security benefit formula to two alternative benefit-tax linked formulae.

In a follow up to this study, Kotlikoff (1996) studies the macroeconomic effects of privatizing social security. His study looks at the effects of eliminating the payroll tax, in an environment with no liquidity constraints and where saving for any other purposes than retirement is ignored (i.e., no bequests.) His simulations indicate that privatizing social security can generate long run increases in the capital stock and output, can generate substantial efficiency gains, and improves the well being of the lifetime poor compared to the lifetime rich.

Imrohoroglu, Imrohoroglu, and Joines (1998a) use a model in which agents face uncertain lifetime and endowments. Huang, Imrohoroglu, and Sargent (1996) extend the framework of previous papers by introducing the risk-sensitive linear-quadratic model of Hansen and Sargent (1998) This feature allows the authors to study the transition between steady states, and the effects of the transition within cohorts and across cohorts. De Nardi, Imrohoroglu and Sargent (1998) accommodate time-varying survival probabilities and demographic patterns. They also use a linear quadratic model in which agents choose each period's consumption and labor supply. To calibrate the model to realistic capital/output ratios, the authors introduce a life-long bequest motive.

Imrohoroglu, Imrohoroglu, and Joines (1998c) describe the computational particularities of two large scale, general equilibrium, overlapping generations models and how equilibria of these models can be computationally obtained. They present a standard algorithm to compute steady state equilibria in an environment where agents face mortality risk and individual income uncertainty, but supply inellastically one unit of labor when employed. They also present computational aspects of a linear quadratic Gaussian preference setup.

Cooley and Soares (1998) use the same framework as the one described above for Huang, Imrohoroglu and Sargent (1996) but add labor supply choice to the model. The authors study the political sustainability of the existing pay-as-you-go system and analyze different scenarios of privatizing the social security system. They employ a model with a large number of agents that live 4 periods, a simplification that makes the problem of finding an equilibrium path during transition computationally feasible.

Our paper differs form the previous mentioned literature by using a model with consumption and labor supply choice, and agents that live 60 periods. We let agents choose labor supply each period they are of working age and employed. Individuals face both mortality and unemployment risks. Previous studies considered the labor supply fixed and analyzed only the effect of consumption choice upon the behavior of social security system. Also, our study tries to depart form the standard US model, and uses existent Romanian data to perform the simulations.

In addition to the metodological differences, this paper also differs from the existing literature in that it analyzes the effect of introducing a fully funded component of the social security system upon the labor supply, consumption and asset holding profiles.

## 3 Description of the Romanian pension system

Romania, as many other countries in Central and Eastern Europe, faces the interesting situation that they look more like underdeveloped countries with respect to their economic performance, but very similar to developed countries with respect to the demographics and pension systems. As it has a pay-as-you-go pension system, and it faces a multitude of problems due to the aging of population but also to a decrease in participation into the system, Romania has decided to reform its current pension system. Current legislation will introduce changes with respect to participation to the system, and to the linkage between contribution and benefits. Separate proposals introduced in the Romanian Parliament, and supported by the World Bank and the European Union, will introduce a fully funded component of the pension benefit.

The main factors that contributed to the decision to reform the pension system are:

1. *A rapid aging of the population.* A current estimate shows that the population of an age over 60 will be 30 % of the population in 2040 compared to 15.6 % in 1990. This implies that the dependency ratio will decrease dramatically and that the number of people receving benefits will double.

2. *A continuous decrease in the number of participants to the system combined with a substantial increase in the number of beneficiaries.* In 1990, there were 10.5 million people contributing to the system out of a 11.2 million in the labor force, while in 1996 the contributors were only 6 million people from a labor force of 10.9 millions. The number of people benefiting from the system increased from 3.138 millions at the end of 1989 to 5.34 millions at the end of 1996. The above changes reduced the dependency ratio (number of people contributing to the system to the number of beneficiaries) from 3.6/1 at the end of 1989 to 1.1/1 at the end of 1996. The major reasons for this rapid decrease in the participation to the system

are: an increase in unemployment (unemployed persons are not required to contribute to the system), generous early retirement programs designed to alleviate to impact of closing large state enterprises, and a loophole in the old legislation that does not make it mandatory for employees or employers in the private sector to contribute to the social security system.

3. *An increase in the rate of the contribution to the system.* To keep the system solvent the social security tax increased from 14 % in 1990, to 25.5 % in 1992, and to 32.5 % in February 1999.

4. *A decrease in the real level of pensions.*

5. *Changes in the distribution of benefits,* by disproportionately increasing the pensions with a level below the average pension.

6. *Inefficiencies associated to the formula to compute pension benefits.* The current formula to compute the pension benefits is based on the 5 highest income years out of the last 10 years in which a contribution to the pension system was paid. Due to this way of computing the benefits, collusion between employees in the last years before retirement and employers made possible for the employees to have a higher level of pension benefits. As an example, an employee might agree to a lower wage for the first years of his last decade in the workforce, in exchange for a substantial increase in wages in the last five years of employment. Or, to better avoid risks, employer and employee, might report a much higher salary, pay taxes for it but not receiving it, in exchange for the high pension benefit that will result from this behavior.

7. *An increase in the rate of evasion.*

The proposed changes can be summarized as follows:

1. *Increasing the retirement age and the participation rate.* The retirement age will increase from 60 to 65 years for males in 14 years and from 55 to 62 years in 28 years. The number of people contributing to the system will be increased by mandatory extending the coverage of the law to everyone in the labor force and by reducing the evasion rate [4]

2. *Creating a stronger link between contribution paid and benefits received.* The proposal includes a change in the structure of contribution (2/3 paid by the employer and 1/3 by the employee in the future, compared to currently all contribution being paid by employer) in order to make the employee aware of his contributions and future benefits. A new formula to compute the benefits will be introduced. The new formula is based on points. Every year a worker receives a number of points calculated as the ratio between his gross wage and the average gross wage in the economy. All points obtained in a lifetime career are summed up and give the total number of points for an employee. For retirees, the value of a point is announced every year and is given by the ratio between half the forecasted net average wage for the coming year and the full length of a career for that year (generally, 30 years for women and 35 years for men.) The pension benefit received by the retiree for the given year is his total number of points times the announced value of a pension point. In this way, the benefits keep up with the average wages in the economy.

3. *Introducing a complementary fully funded system.* A portion of the contribution will be diverted towards the creation of a fully funded component. Every worker aged 40 or less in 2000 will contribute a portion of his social security tax towards a fully funded component. It is expected that from a contribution of 28.5 %, 10 % will go towards a private fully funded scheme.

[4] It is unclear how this mandatory reduction in the evasion rate will increase the participation into the system. So far, the new law does not provide for any mechanism that will reduce the evasion rate.

# 4 The model economy

## 4.1 Preliminaries and Notation

The model economy [5] consists of overlapping generations of individuals who live no longer than $T$ years - they die at the beginning of period $T+1$ - , and an infinitely lived government. During the first $t_R$ periods of life, a consumer receives labor income which she divides between consumption, taxes, and accumulation of assets. During the final $T - t_R$ periods of life, the individual receives social security benefits. The government taxes income from labor and capital, issues and services debt, purchases goods, and pays retirement benefits. When we introduce the mandated changes the government separately administers a fully funded pension system.

Workers contribute a portion of their social security tax into the fund. When they reach retirement age they receive an annuity based on the total individual contribution into the system. Individuals and the government face a time-varying, but deterministic rate of interest.

For any variable, we use a subscript $t$ to denote age, and an argument $s$ to denote calendar time. Thus, the number of people of age $t$ at time $s$ is $N_t(s)$; $a_t(s-1)$ denotes the assets (we do not make any distinction between physical capital and bonds, and any agent can split her portfolio anyway she wants)held by an age $t$ person at the end of period $s-1$; $K(s-1) = \sum_{t=0}^{T} a_t(s-1)N_t(s-1)$ is aggregate capital held by residents at the end of period $s-1$; $\delta$ is the physical rate of depreciation of capital, and $R(s-1) = 1 + r(s-1) - \delta$ is the rate of return on asset holding; $r(s-1)$ is the gross-of-depreciation rate of return on physical capital from time $s-1$ to time $s$; $g(s)$ is per-capita government spending on goods at time $s$; $\epsilon_t$ is an exogenous age-efficiency profile; $w(s)$ is a base wage rate at time $s$; $c_t(s)$ and $h_t(s)$ are consumption and labor supply at time $s$ for an individual of age $t$; $\Upsilon_t(s)$ denotes total tax payments, $S_t(s)$ are the social security payments (the pension

[5] This part draws heavily from Huang, Imrohoroglu, and Sargent (1996) and Imrohoroglu, Imrohoroglu and Joines(1998b0

benefit from the public system), $FB_t(s)$ are the benefits from the fully funded source and $f_t(s)$ are the cumulative contributions into the pension fund for a representative agent of age $t$ at time $s$; $a_{t-1}(s-1)$ are the consumer's asset holdings at the beginning of age $t$ at time $s$. To simplify the presentation, Table 1 has a summary of the basic notation.

**Table 1: Notation**

| Demography | | Government | |
|---|---|---|---|
| $N_t(s)$ | population, age $t$ time $s$ | $g(s)$ | government spending |
| $\nu_t(s)$ | survival rate | $\tau_i$ | income tax |
| $T$ | maximum age | $\tau_{pb}$ | PAYG system tax |
| $t_R$ | retirement age | $\tau_{ff}$ | funded system tax |
| **Household (age $t$, at time $s$)** | | **Production** | |
| $c_t(s)$ | consumption at age t | $w(s)$ | individual wage |
| $h_t(s)$ | labor supply at age t | $\epsilon_t$ | efficiency coefficient |
| $a_t(s)$ | asset holdings | $r(s)$ | interest rate |
| $k_t(s)$ | physical capital | $K(s)$ | aggregate capital |
| $h_t(s)$ | labor supply at age t | $L(s)$ | aggregate labor supply |
| $S_t(s)$ | benefits from PAYG system | $VF$ | individual accumulated fund |
| $FB_t(s)$ | benefits from funded system | $PF$ | value of the pension fund |
| $\Upsilon_t(s)$ | total tax payments | $T(s)$ | accidental bequests |

## 4.2 Demographics

At date $s$, a cohort of measure $N_0(s)$ of consumers is born who live in periods $s, s+1, ..., s+T$. Most of cohort will die before $T+1$, only the luckiest will live during all periods. As the cohort ages, mortality is described by $\nu_t(s)$, the conditional probability of surviving form age $t$ to age $t+1$ at time $s$. Let $N_t(s)$ be the number of age $t$ people alive at time $s$. We denote the rate of growth of $N_t(s)$ by $n(s)-1$, and we take $n(s)$ and $\nu_t(s)$ as exogenous. Total population alive at time $s$ is

$$N(s) = \sum_{t=0}^{T} N_t(s) \tag{1}$$

For simplicity we will normalize $N_0(s)$ to one.

### 4.3 The Resource Constraint

The national income identity for this economy at time $s$ is

$$\begin{aligned} g(s)N(s) + \textstyle\sum_{t=0}^{T} c_t(s)N_t(s) + K(s) &= R(s-1)K(s-1) + w(s)\textstyle\sum_{t=0}^{t_R} \epsilon_t h_t(s) N_t(s) \\ g(s)N(s) + \textstyle\sum_{t=0}^{T} c_t(s)N_t(s) + K(s) - (1-\delta)K(s-1) &= AK(s-1)^{\alpha} L(s-1)^{1-\alpha} \end{aligned} \tag{2}$$

### 4.4 Factor Prices

As assumed above, we perform the numerical simulations under the assumption that factor prices are determined by the marginal productivity conditions from a constant returns to scale Cobb-Douglas aggregate production function. Price taking behavior implies that factor prices are:

$$\begin{aligned} r(s-1) &= r\left(\tfrac{K(s-1)}{L(s)}\right) = \alpha A \left(\tfrac{K(s-1)}{L(s)}\right)^{\alpha-1} \\ w(s) &= w\left(\tfrac{K(s-1)}{L(s)}\right) = (1-\alpha) A \left(\tfrac{K(s-1)}{L(s)}\right)^{\alpha} \end{aligned} \tag{3}$$

where $L(s) = \sum_{t=0}^{t_R} \epsilon_t h_t N_t(s)$ ($h_t$ is zero when unemployed and retired)is the aggregate labor input in efficiency units, $K(s-1)$ is the total physical capital in the economy at the beginning of period $s$, $\alpha \in (0,1)$ is the income share of capital and $A$ is total factor productivity. The wage of an age-$t$ worker at time $s$ is $\epsilon_t w(s)$, where $\epsilon_t$ is a time invariant (it depends only on the age of the worker) and exogenous (to the factors that we are interested in studying) age-earnings index.

Each period, individuals face a stochastic employment opportunity. We assume that the employment follows a first order Markov process over two states: employed or unemployed. The resulting $2 \times 2$ transition matrix is parametrized in such a way that the invariant probability of being employed is 0.92. This estimate is obtained from the Romanian National Commission for

Statistics (1998) data on the length of unemployment (see Appendix 1.)

To simplify, we initially study the special case of an *iid* distribution. The employment state $\{e, u\}$ where $e$ =employed and $u$ =unemployed follows an iid process. Individuals face the same probability of being employed or unemployed in the next period, no matter what their current status is. In other words, there is no less opportunity to find a job next period if the individual is unemployed this period. To study the impact of unemployment rates upon labor supply and consumption choices, we have chosen two unemployment rates for our simulations. We start with an unemployment rate of 8 % but we also study the impact upon aggregate variables of a reduction in the unemployment rate to 6 %. The value of unemployment rate of 8 % is identical to the invariant probability to be unemployed in the more general Markov case.

Each period, when she is employed, each agent chooses how much labor she will supply in that period, as a number of hours per period, where the total number of hours in the period (equal to one year) is normalized to one.

### 4.5 Households

We will assume a one-period utility function in consumption and leisure for an age $t$ person

$$\begin{aligned} u(c_t, l_t) &= \frac{(c_t^{\sigma} l_t^{1-\sigma})^{1-\rho}}{1-\rho} \\ l_t &= 1 - h_t \end{aligned} \tag{4}$$

where $l_t$ is the amount of leisure during period $t$, $\sigma$ is the coefficient of consumption in the Cobb-Douglas utility function, and $\rho$ is the inverse of the intertemporal elasticity of substitution. Conditional on being alive, households discount future utilities by a constant $\beta$. For $t = 0, ..., T$, let $V_t[y(s), l(s)]$, where $y(s)$ are asset holdings and $l(s)$ employment status, denote the state of an age $t$ person at the beginning of period $s$, be the optimal value function of an age $t$ person. For simplicity, we have chosen the value of the objective function if the agent dies to be identically zero. The household's Bellman equations are:

$$V_t[y(s), l(s)] = \max_{c_t(s), l_t(s), y'(s)} \{u(c_t(s), l_t(s)) + \beta \nu_t(s) E_t V_{t+1}[y'(s), l'(s)] \tag{5}$$

where the maximization is subject to the following constraints:

**1. Under initial rules**

$$\begin{aligned} c_t(s) + a_t(s) = &\quad R(s-1)a_{t-1}(s-1) + w(s)\epsilon_t h_t(s) + T(s) + S_t(s) - \Upsilon_t(s) \\ T(s) = &\quad \frac{R(s-1)\sum_{t=0}^{T}(1-\nu_t)a_t(s-1)N_t(s)}{N(s)} \end{aligned} \tag{6}$$

$$\Upsilon_t(s) = [\tau_i(s) + \tau_{pb}(s)]w(s)\epsilon_t h_t(s) + \tau_a(s)[R(s-1) - 1]a_{t-1}(s-1) \tag{7}$$

The right hand side of 6 is the household's after-tax income, the sum of wages, earnings on assets, and retirement benefits from public source ($S_t(s)$) minus the tax payments. Equation 7 decomposes the total tax payments into taxes on labor income and assets. The tax on labor income is decomposed in two components, an income tax $\tau_i$, and a social security tax (the contribution to the public system) $\tau_{pb}$.

$T(s)$ are the transfers received by individuals alive from the individuals who have died in the previous period. To keep this simple, we have opted for a formula in which all individuals alive receive an equal share of the bequests left by agents that accidentally died, as the ones that die after the last period of life (age 80) have no incentive to leave bequests.

To keep the computations simple, we will calculate the social security benefit ($S_t(s)$) as a percentage (replacement rate) of the labor income in the last five years of active life, and we assume that it is constant across years of retirement, i.e. there is no discounting.

$$S_t(s) = \begin{cases} 0 & t < t_R + 1 \\ \frac{\theta \sum_{i=t_R-5}^{t_R} w(s-t+i)\epsilon_i h_{s-t+i}}{t_R} & t \geq t_R + 1 \end{cases} \tag{8}$$

Note that as $h_t$ is zero when unemployed, the way we compute the social security benefits does take into account the employment history. There are no private annuity or insurance markets in our model.

**2. Under modified legislation**

The enacted changes will change the retirement age and the way the benefits are calculated. Therefore the maximization problem changes slightly. The social security benefit is calculated as a percentage of the average of the whole duration of working life wages.

$$S_t(s) = \begin{cases} 0 & t < t_R + 1 \\ \frac{\theta \sum_{i=1}^{t_R} w(s-t+i)\epsilon_i h_{s-t+i}}{t_R} & t \geq t_R + 1 \end{cases} \tag{9}$$

The social security payments (the public system part of the pension benefit) per individual follow the formula described above that tells how benefits are related to past earnings. Under this new rule, there is no incentive to underreport or to not report at all wage income during the entire working career.

The government budget constraint under initial rules and under modified legislation is shown in equations 14 and 16 below.

**3. Introducing a fully funded component.**

Under this proposed change, the individual will pay a smaller amount in contribution to the public system, but the remaining portion of her taxes will be capitalized. The labor income tax is now divided in three components, an income tax $\tau_i$, a social security tax (the contribution to the public system) $\tau_{pb}$, and a contribution to the fully funded system $\tau_{ff}$. When employed, the individual contributes to an individual pension fund, that will have the accumulated value

$$f_t(s) = R(s-1)f_{t-1}(s-1) + \tau_{ff} w(s)\epsilon_t h_t(s) \text{ for } t \leq t_R + 1 \tag{10}$$

where $f_0(s) = 0$. The amount that was contributed to the fully funded system by the generation aged $t$ at time $s$ is given by

$$VF_t(s) = f_t(s)N_t(s) \tag{11}$$

Denote the accumulated amount by an agent that retires at time $s$

$$VF_i = f_{t_R+1}(s) \tag{12}$$

The pension benefit from the fully funded source received by each household is calculated as an annuity

$$FB_t(s) = \begin{cases} 0 & t < t_R + 1 \\ \frac{VF}{1+\sum_{i=1}^{T-t_R} \prod_{j=1}^{i} R^{-1}(s+j-1)\alpha_{t_R+j}} & t \geq t_R + 1 \end{cases} \tag{13}$$

An individual agent will now collect pension benefits from two sources: a public source, which will give a benefit $S_t(s)$ determined by equation 9, and a private benefit whose value is given by equation 13.

Aggregate quantities of interest such as aggregate per capita consumption and aggregate per capita physical capital can be easily computed by weighting averages across individuals alive at a point in time. The aggregates are deterministic functions of time.

### 4.6 The government

Private asset holdings $a_t(s)$ of an age-$t$ individual at time $s$ are divided between government bonds and private physical capital: $a_t(s) = b_t(s) + k_t(s)$ where $b_t(s)$ is the time $s$ holding of government debt by an age-$t$ individual. Consumers are indifferent between holding capital of bonds, since the two assets have a common return and tax treatment. Therefore, the distribution of wealth between physical capital and bonds at individual level is indeterminate. The government faces three separate budget constraints. One is the balanced budget constraint for the non-social security part of government activity, the second one shows the equilibrium of the public pension system, and the third implies that the government is just the administrator of the fully funded pension system.

$$\begin{aligned} & g(s)N(s) + R(s-1)\textstyle\sum_{t=0}^{T} b_{t-1}(s-1)N_t(s) = \sum_{t=0}^{T} N_t(s)\{\tau_i(s)w(s)\epsilon_t h_t(s) \\ & +\tau_a(s)[R(s-1)-1]a_{t-1}(s-1)\} + \textstyle\sum_{t=1}^{T} b_t(s-1)N_t(s) \end{aligned} \tag{14}$$

$$\sum_{t=0}^{T} a_t(s) = K(s) + B(s) \tag{15}$$

$$\sum_{t=t_R+1}^{T} S_t(s)N_t(s) = \sum_{t=0}^{t_R} \tau_{pb}[w(s)\epsilon_t h_t(s)N_t(s)] \tag{16}$$

$$PF(s) = R(s-1)PF(s-1) + \sum_{t=0}^{t_R} \tau_{ff} w(s)\epsilon_t h_t(s)N_t(s) - \sum_{t=t_R+1}^{T} FB_t(s)N_t(s) \tag{17}$$

where $B(s)$ is the total amount of government bonds and $PF(s)$ is the total amount accumulated in the pension fund up the year $s$.

For simplicity, we assume that the assets collected at the end of period $t$ from individuals that died that period are divided equally amongst all agents alive at the beginning of period $t+1$. As we mentioned earlier, there are no intentional bequests in this economy.

# 5 Computation algorithm

## 5.1 Creating an invariant distribution

To compute the decision rules we are starting from the last period of life. Since death is certain at age $T+1$, the value function at this age is identically zero. Therefore, the solution to the value function at age $T$ is a function of consumption, leisure, and the assets accumulated in the next to last period of life only, since any individual, in the absence of any motive for leaving bequests, will run down all the assets in his last period of life.

To find the solution to the optimum problem, we take each possible combination of assets in the next to last period and the labor supply (we employ a 1025-point grid for assets and a 46-point grid for labor supply) and compute the value of the optimal function for each combination. The value function so computed is passed on to the next step, i.e. computing the next to last period optimal value function. Note that the employment choice does not kick in until we arrive at the first period before retirement age, as there is no unemployment uncertainty in retirement. The optimal value function for the age $T-1$ is a vector of size $m \times 1$ which gives the optimal value function for each beginning of period possible asset holdings. We match this vector with a vector of decision rules, of size $m \times 1$ that gives the grid index of assets.

We continue with this algorithm until we reach the age prior to retirement. There we separate the problem in two cases, corresponding to each employment status. For each case we compute the optimal value function and a matrix of decision rules. When employed, the decision rule matrix will have a $m \times 2$ size, and includes in the first column the grid index of assets as well as in the second column the grid index of labor supply.

At the end of this backward induction we have the results for all possible trajectories at all ages. The indices give us the labor supply decision and the next period (or end of period) asset holding decision at any asset grid position.

To obtain the distribution of agents of age $t$, $\lambda_t(y,s)$, over beginning of period asset holding levels, we need to start from a given initial wealth distribution. Therefore, it is necessary to decide on a starting point for newborns. The choice of initial assets for newborns affects the equilibrium of the model and the distribution of individuals. In line with Imrohoroglu, Imrohoroglu and Joines (1998b), we choose zero assets holdings for newborns. This implies a distribution of agents across assets and employment status at the end of first period given by

$$\lambda_2(y',s') = \sum_s \sum_y \Pi(s',s)\lambda_1(y,s) \tag{18}$$

where $\lambda_1$ is a $m \times 2$ matrix that has zero entries everywhere except the first line which is equal to (0.92, 0.08). Since we have already computed all possible values for asset holdings, depending on employment status, individuals will make decisons and go to different positions in the state-space matrix. We employ recursively this formula an find the age-dependent distribution of individuals.

The age-dependent distributions are computed from the following recursion

$$\lambda_t(y',s') = \sum_s \sum_y \Pi(s',s)\lambda_{t-1}(y,s) \tag{19}$$

For all $t > t_R$, i.e. when agents are retired, there is no employment uncertainty, and the $\lambda_t$ is a $m \times 1$ matrix.

## 5.2 Computing the equilibrium

We use an algorithm similar to that used by Imrohoroglu, Imrohoroglu and Joines (1998b). However, since in our case the labor suppply is elastic the algorithm must be modified. Below we present a summary of the necessary steps to perform the computations.

The problem is to find the solution to a three dimesional fixed-point problem, with physical capital, labor supply and end of life assets (unintentional bequests) as variables. We will solve the problem, in steady state, under the three assumptions mentioned in Section 4.5 above (initial conditions, the state of the economy using only the enacted changes, and a prediction of the effects using the current plus the proposed changes.)

First we compute the initial steady state, using the old rules in place before the reforms are instituted. We use a backward recursion to compute each agent's value function, taken as given the government policy and prices. The steps are the following:

1. We guess initial values for aggregate physical capital, $K$, for aggregate labor supply, $L$, and bequests, $T$, and then use the first order condition from the firm's profit maximization problem to compute prices, i.e. the rate of return of physical capital and wages.

2. Compute the decision rules for each beginning of period possible asset holdings, age, and employment status (if not retired.)

3. For each age, compute the distribution of individuals across assets and employment status.

4. Compute the new aggregate capital stock, labor supply and bequests, by summing across types, cohorts, and states. For the ages beyond retirement, we sum only across types and cohorts.

5. Check to see if the new values of capital, labor supply and bequests are close enough to the initial values (we have specified a convergence criterion at the beginning of the computation). If yes, stop. If not, choose a new starting value for capital stock, labor supply and bequests as a point between the initial and the final values of the respective variables. Continue until the convergence criterion is satisfied. [6]

[6] On a DEC-Alpha machine each iteration takes 15-30 minutes, and typically there are 6-8 iterations until we reach

6. Compute the aggregate consumption, investment, and output using decision rules and the distribution of agents across types and ages, and check if the market clears. The results will also show the social security tax rate that is needed to keep the system in equilibrium.

We repeat the above algorithm in the initial steady state for different values of the replacement rate, and then compute the final steady state equilibrium using the new rules.

### 5.3 Calibration

The parameters used by us are similar to the ones used in most of the literature described in Section 2, and are summarized in Table 2. We use mortality tables from Romania in 1998, and we have tried to adapt the parameters as to fit as much as possible the Romanian conditions. However, this is at most an educated guess, since there are no studies or even data to base our assumptions. In order to be able to better show the differences between current literature and the Romanian conditions, we are using two sets of parameters. For an initial run of the model we choose values for the parameters that are consistent with the existing literature on the US economy cited in Section 2. A second run of the model is using parameters estimated by Borc (2001), parameters that consider the current Romanian conditions.

We calibrate our model under the assumption that the model period is one year. Individuals are born at real age 21 and they live for a maximum of 60 years, to the real age of 80, when death is certain. They retire at real age of 60. The conditional survival probabilities are taken from the Romanian Commission for Statistics (1998). The efficiency index $\{\epsilon_t\}$ is taken form Imrohoroglu, Imrohoroglu and Joines (1998b), which in turn take it from Hansen (1993) (and interpolate it to in-between years, and normalize it to average one.) The index is meant to provide a cross-sectional age distribution of earnings at a point in time. Appendix 2 shows the data that we have used in

convergence

our model.

We set the coefficient of risk aversion $\rho$ at 2 as in Cooley and Soares (1998), Auerbach and Kotlikoff (1987) and Imrohoroglu et al (1998b). The intratemporal rate of substitution between consumption and leisure is set at 0.4, which will have as result that on average one quarter of the available time will be spent on labor market related activities. The subjective discount rate is set at 0.978. To match the consumption to output ratio we choose a multiplicative constant in the production function of 1.1 and growth rate of the aggregate output of 0.01 (which matches the economy's growth rate from 1980 to 1998.)

| $\beta$ | $\rho$ | $\sigma$ | $\alpha$ | $\delta$ | $A$ | $g$ | $n$ |
|---|---|---|---|---|---|---|---|
| 0.978 | 2 | 0.4 | 0.36 | 0.08 | 1.1 | 0.01 | 0.0 |

**Table 2: Benchmark Calibration**

For the initial steady state, we set the population growth at zero to match the Romanian average population growth rate in the period 1970-2000. In line with current predictions of the Romanian Commission for Statistics we keep the population growth rate at zero for the entire duration of the transition between steady states.

To move one step closer to the Romanian economy's conditions, we will also simulate the model using parameters estimated in Borc (2001). Borc uses a household survey to estimate the coefficient of risk aversion, the intratemporal rate of substitution between consumption and leisure, and the subjective time discount factor. The particular values for the parameters are shown in Table 3.

| $\beta$ | $\rho$ | $\sigma$ | $\alpha$ | $\delta$ | $A$ | $g$ | $n$ |
|---|---|---|---|---|---|---|---|
| 0.9745 | 1.6 | 0.32 | 0.36 | 0.08 | 1.1 | 0.01 | 0.0 |

**Table 3: Calibration using Borc's estimates**

# 6 Results

## 6.1 Initial Steady State

We begin by computing the initial steady state. In all our computations we use a constant labor income tax of 0.18, which corresponds to a labor income tax of 25 % applied on the after social security tax income. The value that we have chosen is similar to the average labor income tax currently in place in Romania.

In the initial steady state, the replacement rate $\theta$ is the major social security policy instrument. We will search over values of $\theta$ between 0.0 and 0.4 to compare the existing pension arrangement with other possible schemes based on different replacement rates.

The existing pension system has a replacement rate of $\theta = 0.4$. The replacement rate represents the ratio between social security benefit and the pre-tax labor income that we use as a base for our computation. In this case, for the initial steady state, the labor income that we use as a base is the average labor income in the last five years of employment. If, instead of pre-tax labor income, we report the replacement rate to the after-tax labor income, the replacement rate is 0.68.

In all our simulations we report aggregate values (values that refer to an individual agent representing the independent distribution of types computed above in Section 5.1.)

For the case of the initial steady state, we obtain an aggregate labor supply of 0.2522 (where 1 is the total available time during a year), which means that one quarter of the available time is supplied to the market.

The aggregate physical capital is 1.1351, the wage rate 1.2104 and the interest rate in the economy is 7.11 %.

For the initial steady state we are also looking at four more replacement rates for $\theta$, 0.0, 0.1, 0.2 and respectively 0.3. In these exercises as the replacement rate is changed, the tax rate is adjusted to ensure the solvency of the Social Security system. All results are reported in Table 4. In order to compare alternative regimes we will use a measure of utility. For each case, we will calculate the ex-ante utility at birth, and report it to facilitate comparisons.

**Table 4: Initial Steady State**

| $\theta$ | Tax Rate | Cons | Output | Int. Rate | Wage | Capital | Labor | Utility | Utility Loss(%) |
|---|---|---|---|---|---|---|---|---|---|
| 0.0 | 0.00 | 0.3682 | 0.5835 | 0.0439 | 1.3531 | 1.7101 | 0.2760 | -57.91 | 28.14 |
| 0.1 | 0.078 | 0.3435 | 0.5469 | 0.0529 | 1.3005 | 1.4924 | 0.2691 | -60.10 | 21.15 |
| 0.2 | 0.144 | 0.3225 | 0.5199 | 0.0602 | 1.2621 | 1.3281 | 0.2636 | -62.25 | 13.90 |
| 0.3 | 0.199 | 0.3060 | 0.4973 | 0.0658 | 1.2346 | 1.2233 | 0.2578 | -64.21 | 7.97 |
| 0.4 | 0.245 | 0.2917 | 0.4771 | 0.0711 | 1.2104 | 1.1351 | 0.2522 | -66.09 | - |

The first column gives alternative values for the replacement rate of the public social security system, the second column presents the tax rate that should be in place for the pay-as-you-go pension system to be in equilibrium. The following columns present the equilibrium values of aggregate variables.

As the replacement rate goes up, the aggregate consumption goes down and the steady state output goes down. The aggregate capital stock is reduced by an increase in $\theta$. With the reduction in capital stock, the equilibrium interest rate (the net real return to capital) goes up, and the wage goes down.

The social security has a lower return than the physical capital, since the rate of growth of population is 0.0 % and the rate of growth of technology is set at 1.0 %, and in the absence of a social security arrangement the real return on physical capital is 4.39 %.

The capital stock is very sensitive to changes in the replacement rate, and there are larger changes in the capital stock than in the labor supply for the same change in the replacement rate.

While the labor supply decreases by 8.63 %, when $\theta$ increases from 0 to 0.4, the capital stock decreases by 33.63 %. For the same change in $\theta$ output per capita decreases by 18.2 %. Thus at the aggregate level, a change in the replacement rate has large effects. In this case, decreases in $\theta$ result in more demand for assets in old age and this, in return, induces increases in output.

We have chosen to compare different social security arrangements using the ex-ante utility at birth, presented in the last column of the above table. Utility decreases as $\theta$ increases, and for a change in $\theta$ from 0.0 to 0.4, utility decreses by 14.64 %. The decrease in utility is slightly smaller as $\theta$ increases (i.e. the difference between the utility when $\theta$ is 0.0 and the utility when $\theta$ is 0.1 is 2.19 compared to a value of 1.88 for a change in $\theta$ from 0.3 to 0.4. In terms of utility, the representative consumer is better off without a social security arrangement.

The last column of table 4 presents a measure of a consumption-based utility gain (or loss) associated with a policy reform. We suppose that the "base case" for the initial steady state is when $\theta = 0.4$. We want to find out what are the gains from moving to $\theta = 0.3$. One potential measure is the decrease in consumption that people "living" in the $\theta = 0.3$ regime would be willing to suffer - holding their labor supply constant - in order not to change to $\theta = 0.4$. formally, this the value of $v$ such that:

$$U(0.3, v) = U(0.4, 1)$$

where

$$U(\theta, v) = E\{\sum_{t=1}^{T+1} u(vc_t, l_t)\}$$

The expectation is taken with respect to the respective regime, and in all the calculations presented in the paper, $v$ is set equal to one. Given the form of the utility function $U(\theta, v) = v^{\sigma(1-\rho)}U(\theta, 1)$.

$U(\theta, 1)$ is the utility reported in Table 4. It is then easy to compute the value of $v$. With this given value, we then calculate how much of lifetime consumption individuals are willing to pay not to switch from one regime to another.

The results show that an individual is willing to pay 7.9% of lifetime consumption in order not to switch from 0.3 to 0.4. In order not to move from 0.2 to 0.4, the respective loss in consumption is 13.9 %.

Figure 3 shows the consumption profile over the lifetime for a representative individual for different values of $\theta$. The decrease in consumption at retirement is due to the jump in leisure, as individuals who retire will allocate all their available time to leisure during retirement.

In the case when the replacement rate is 0, the agents choose consumption in such a way in which they can enjoy almost constant consumption over the retirement years. As the replacement rate increases, consumption during retirement increases. The existing system "forces" and upward sloping profile.

The aggregate labor supply goes down as the replacement rate increases. Figure 4 presents the labor supply profile for each individual replacement rate. As $\theta$ increases there is a shift in the labor supply from old ages to young ages, in the sense that individuals choose to supply less labor when they are old if they are promised a large pension benefit. There is a large variation with the replacement rate of the labor supply in the last years previous to retirement. While for a retirement rate equal to 0 labor supply stays almost constant from age 20 to age 40 (labor income varies due to the efficiency index), for a retirement rate equal to 40 % the labor supply decreases to one fourth of the available time in the year prior to retirement.

Figure 5 presents the asset accumulation over the lifetime, and shows a reduction in the accumulation of assets as the replacement rate increases. Due to the influence of missing bequests in this economy, agents adjust their asset holdings in order to have zero assets when they die with certainty. For the highest value of $\theta$ in our model we can observe a slight reduction of assets during the last years of the working career, since the high interest rates and the reduction in labor supply allow the individual to keep a high level of consumption by dissaving.

### 6.2 Sensitivity Analysis. Lower Unemployment Rate.

We examine the sensitivity of the impact of changing the replacement rate to alternative assumptions about the long run unemployment rate. The results in Table 5 below are obtained using an unemployment rate of 6 %, and keeping the probability of being employed and the probability of being unemployed distributed *iid*. This change corresponds to a case in which there is less "income uncertainty" while an individual is of working age.

**Table 5: Initial Steady State. Unemployment rate 6%**

| $\theta$ | Tax Rate | Cons | Output | Int. Rate | Wage | Capital | Labor | Utility | Utility Loss(%) |
|---|---|---|---|---|---|---|---|---|---|
| 0.0 | 0.00 | 0.3743 | 0.5944 | 0.0440 | 1.3523 | 1.7261 | 0.2812 | -57.69 | 27.70 |
| 0.1 | 0.076 | 0.3502 | 0.5571 | 0.0531 | 1.3001 | 1.5196 | 0.2743 | -59.83 | 20.81 |
| 0.2 | 0.141 | 0.3300 | 0.5306 | 0.0600 | 1.2634 | 1.3651 | 0.2688 | -61.87 | 15.88 |
| 0.3 | 0.196 | 0.3133 | 0.5072 | 0.0661 | 1.2334 | 1.2548 | 0.2632 | -63.87 | 6.75 |
| 0.4 | 0.242 | 0.2986 | 0.4875 | 0.0708 | 1.2114 | 1.1561 | 0.2575 | -65.68 | - |

The consumption, labor supply and asset holdings life-long profiles in the initial steady state are shown in Figures 6 to 8. As we have done for the case when the unemployment rate was 8 %, we have presented profiles for different values of $\theta$ in the same figure so it will be easy to see the differences due to changes in the replacement rate.

Similar to our first simulation, the aggregate capital stock is very sensitive to changes in replacement rate. When $\theta$ increases from 0.0 to 0.4, aggregate capital decreases by 33.02% (almost unchanged from the precedent case). Labor supply is less elastic and decreases by only 8.42%, which is a smaller change than in the previous case from Table 4.

Note that the capital stock and the aggregate labor supply increase in comparison with the values when unemployement was 8 %, as they are very sensitive to small changes in interest rates and wages. At each value of the replacement rate lower unemployment induces higher labor supply, and a higher level of aggregate capital stock. Lower unemployment rates also affect aggregate consumption which increases by 2.3 % for a replacement rate of 0.4. The effect on equilibrium wage and interest rate is mixed, with wages and interest rates being very close to the values when unemployment was higher.

The efect of lower unemployement on utility is significant, with utility being higher when unemployment is lower. The variation due to changes in the replacement rate is smaller for lower unemployment, and accounts for a decrease of 11.83 % (compared to 12.37% for an unemployment rate of 8 %).

### 6.3 Sensitivity Analysis. Employment state follows a Markov process.

In order to better capture unemployment duration it is necessary to add more heterogeneity to our model. To this end, we assume that employment status is governed by a two-state Markov process. Our Markov transition matrix is defined in the following way: $Prob\{l' = e | l = e\} = 0.9577$, $Prob\{l' = e | l = u\} = 0.486$, $Prob\{l' = u | l = u\} = 0.514$, and $Prob\{l' = u | l = e\} = 0.0423$.

We choose the probability of being employed next period, conditional of being employed this period in such a way as to satisfy a stationarity condition of having a constant rate of unemployment. The transition matrix above will keep a steady unemployment at 8 %. A better description of our choice for the unemployment probabilities is found in Appendix 1.

The results of this simulation are presented in Table 6, and in Figures 9 to 11

**Table 6: Initial Steady State. Unemployment follows a Markov Process.**

| $\theta$ | Tax Rate | Cons | Output | Int. Rate | Wage | Capital | Labor | Utility | Utility Loss(%) |
|---|---|---|---|---|---|---|---|---|---|
| 0.0 | 0.00 | 0.3673 | 0.5829 | 0.0435 | 1.3555 | 1.7086 | 0.2752 | -57.94 | 28.21 |
| 0.1 | 0.078 | 0.3426 | 0.5471 | 0.0526 | 1.3024 | 1.4921 | 0.2688 | -60.13 | 21.23 |
| 0.2 | 0.144 | 0.3223 | 0.5200 | 0.0600 | 1.2634 | 1.3313 | 0.2634 | -62.27 | 14.41 |
| 0.3 | 0.199 | 0.3061 | 0.4971 | 0.0657 | 1.2352 | 1.2293 | 0.2575 | -64.21 | 7.18 |
| 0.4 | 0.246 | 0.2913 | 0.4761 | 0.0712 | 1.2096 | 1.1356 | 0.2518 | -66.15 | - |

Comparing the results in Table 6 with the results in Table 4, we observe no change in taxes due to the increase in heterogeneity and to the increase in the average duration of unemployment. In the case when the employment state follows a Markov process we observe a very slight decrease in labor input, and almost no changes in consumption and output.

Physical capital and prices change more, with interest rates going down and wages going up.

Aggregate labor supply is affected by higher uncertainty, and at each value of the replacement rate we observe a decrease in aggregate labor supply. At $\theta = 0.0$ the decrease is 0.3 %, and at a replacement rate of 0.4 the decrease is only half of that. Capital stock increases slightly as an effect of higher uncertainty, with an increase in assets in the first part of the life, when the individual is employed.

We can conclude this exercise by stating that higher heterogeneity and a longer duration of unemployment does not affect too much the equilibrium, and that the consumption, labor supply and asset holdings profiles are similar to the one simulated in the *iid* case.

From now on we consider the results obtained for a replacement rate of 40 %, under the Markov specification, as a base case for comparison with the results of the simulations of the final steady state.

### 6.4 Initial Steady State. Employment follows a Markov process. Estimated parameters for Romania.

Borc (2001) uses the Romanian Integrated Household Survey data from 36,000 households in Romania to estimate the parameters of the utility function. The results of his estimation are presented in Table 3. Compared to previous estimations, we will now use different values for the subjective discount rate, the intratemporal rate of substitution between consumption and leisure, and the coefficient of risk aversion. The results of the simulation using Borc's parameters are presented in Table 7.

**Table 7: Initial Steady State. Unemployment follows a Markov Process. Estimated parameters for Romania**

| $\theta$ | Tax Rate | Cons | Output | Int. Rate | Wage | Capital | Labor | Utility | Utility Loss(%) |
|---|---|---|---|---|---|---|---|---|---|
| 0.0 | 0.00 | 0.3023 | 0.4780 | 0.0424 | 1.3625 | 1.3942 | 0.2245 | -68.38 | 25.54 |
| 0.1 | 0.079 | 0.2815 | 0.4498 | 0.0502 | 1.3160 | 1.2331 | 0.2187 | -69.57 | 18.56 |
| 0.2 | 0.143 | 0.2648 | 0.4269 | 0.0561 | 1.2836 | 1.1212 | 0.2128 | -70.63 | 10.89 |
| 0.3 | 0.195 | 0.2512 | 0.4100 | 0.0606 | 1.2606 | 1.0417 | 0.2081 | -71.60 | 5.42 |
| 0.4 | 0.234 | 0.2412 | 0.3963 | 0.0634 | 1.2466 | 0.9920 | 0.2034 | -72.37 | - |

It is easily observable that there are large differences between values presented in the above table and the values from Table 6. Aggregate labor supply is much lower with a decrease of 18.4 % at a zero replacement rate, and a decrease of 19.2 % at a replacement rate of 0.4. Capital stock is also lower with the newly estimated value being only 81.6 % of the value from Table 6, when the replacemnt rate is zero. When $\theta$ is 0.4, the capital stock is only 87.3 % of the value using parameters from the existing literature.

Wages are higher when we estimate using Romanian parameters, and interest rates are smaller. As $\theta$ increases, the differences in interest rates are higher, with a difference of more than 10 % for a replacement rate of 0.4.

Output is with almost 20 % lower when the replacement rate is zero, and the difference stays unchanged as the replacement rate increases. As for utility, it also significantly lower when we use Borc's estimates for the utility function parameters.

Comparing the utility loss from the last column of Table 7 with the same column from table 6 we observe that the results when we use Romanian estimates are smaller than the results when we use estimates from the existing US literature. This implies that individuals in Romania are better-off with an increase in the replacement rate -which is an indirect increase in taxes - than their counterparts in the United States.

Consumption profiles, labor supply profiles and asset holdings during lifetime are presented in Figures 12, 13, and 14.

### 6.5 Post-Reform Steady State

To compute the final steady state of the economy, we use the same model as before, with the same parameters, as described in Section 5.3 and in Table 3. However, we now use a new formula to compute the social security benefits. The benefits are now calculated using the life long income and not only the last five years of employment, as in the previous cases. The formula for the calculation of the benefits is

$$S_t(se) = \begin{cases} 0 & t < t_R + 1 \\ \frac{\theta \sum_{i=1}^{t_R} w(s-t+i)\epsilon_i h_{s-t+i}}{t_R} & t \geq t_R + 1 \end{cases} \tag{20}$$

The second change that we take into account when computing the final steady state is an increase in retirement age from age 60 to age 65 (or from year 40 to year 45 in the model.)

The results of this simulation are shown in Table 8 which includes the effects of both above mentioned changes at once.

Table 8: **Final Steady State (PAYG Scheme Only)**

| $\theta$ | Tax Rate | Cons | Output | Int. Rate | Wage | Capital | Labor | Utility | Utility Loss I | Utility Loss II |
|---|---|---|---|---|---|---|---|---|---|---|
| 0.0 | 0.00 | 0.3163 | 0.4918 | 0.0487 | 1.3248 | 1.3680 | 0.2376 | -68.35 | 15.29 | 25.71 |
| 0.1 | 0.030 | 0.3065 | 0.4767 | 0.0515 | 1.3090 | 1.2960 | 0.2330 | -68.80 | 10.28 | 23.14 |
| 0.2 | 0.060 | 0.2985 | 0.4658 | 0.0539 | 1.2951 | 1.2438 | 0.2301 | -69.27 | 7.05 | 20.37 |
| 0.3 | 0.090 | 0.2901 | 0.4535 | 0.0566 | 1.2807 | 1.1863 | 0.2266 | -69.76 | 3.58 | 17.39 |
| 0.4 | 0.119 | 0.2820 | 0.4421 | 0.0588 | 1.2693 | 1.1458 | 0.2229 | -70.25 | - | 14.33 |

The consumption, labor supply and asset holding profiles are shown in figures 15, 16 and 17. For easy comparison, we have presented in the same figure a plot of the base case of consumption, labor supply and asset holdings respectively in the initial steady state with higher uncertainty for a replacement rate of 0.4.

A comparison between data in Table 8 with the respective data in Table 7 shows that there is a strong increase in consumption and output. The change is larger for higher replacement rates. While at a replacement rate of 10 % there is a very small change in prices, at a replacement rate of 40 %, the changes are substantial. The interest rate is lower in the case when we use the life long income to compute pension benefits and the wages are significantly higher. As a result of the combined action of lower interest rates and higher wages, there is a large increase in the aggregate physical capital, and the increase is larger for higher values of the replacement rate.

The labor supply is higher when benefits depend on lifetime earnings. However, the changes in labor supply are smaller than the changes in physical capital. The labor supply is lower when young, but is higher in the last years before retirement. This effect might be attributed to the shape of the efficiency profile, since $\epsilon$ is larger before retirement than when young. See Appendix 2 for more details.

It is interesting to see that at a replacement rate, $\theta = 0.1$ the interest rate in the final steady state is higher and the wage rate is smaller than the case when the unemployment is 8 % and the employment state follows a Markov process or even in the case when unemployment rate is 6 %. Due to the increase in labor supply, the amount of aggregate physical capital is higher in the final steady state.

The column Utility Loss I reperesents how much individuals are willing to lose from lifetime consumption in order not to move from the regime where they currently are to a regime with $\theta = 0.4$. The last column, Utility Loss II, shows the amount, in percentage points, that the individuals are willing to lose in lifetime consumption in order not to move from the regime they are in to the "base case" - Romanian parameters, Markov process for unemployment, $\theta = 0.4$ - . Therefore, an individual is willing to loose more than a quarter of his/her consumption in order not to move from $\theta = 0.0$ in the post reform case to the pre-reform case of $\theta = 0.4$.

Figure 15 shows the lifetime consumption profile in the final steady state. We observe that for any replacement rates below 0.4 the consumption in the last years of life is smaller than in the initial steady state. Only for a replacement rate of 0.4 the lifetime consumption profile is above the base case scenario for all values.

Figure 16 shows the labor supply profile. Individuals supply labor until they reach the real age of 65, and this will be the major departure from the initial base scenario. However, it is interesting to observe that for a replacement rate of 0, the labor supply will decrease from the age 30 (real life age of 50). In the initial steady state, for a replacement rate of 0 the labor supply was almost constant in the last years prior to retirement. An explanation might be that agents know that they can enjoy a higher level of consumption during retirement so they choose to maximize their current period utility by increasing the amount of leisure available.

Figure 17 shows asset accumulation over the lifetime. There is no change in shape compared to the similar profiles in the initial steady state, but there is a substantial increase. At the peak - age 60 -even with $\theta = 0.4$ assets in the post reform equilibrium are 26.3% higher than the pre-reform peak.

One observation is that in the final steady state all aggregate values are less sensitive to changes in the replacement rate. For example, the amount of physical capital in the economy for a replacement rate of 0.0 is lower in the final steady state than in the initial steady state. However, the value for a replacement rate of 0.4 is higher than the one in the initial steady state case.

### 6.6 Post-Reform steady State. Two Regimes

For the simulation of a pension plan with two regimes, i.e., a public pay-as-you-go scheme and a funded component, we have chosen to look at replacement rates of 0.1-0.2 for the public system and to introduce a mandated contribution to a funded component. The reason why we chose to do so is that higher values of the replacement rate for the public portion of the pension benefit will generate implausible return rates for the overall benefit.

The income tax that we specify for the contribution to the individual pension fund is half of the tax that is necessary to keep the public system in balance. The results of this simulation are presented in Table 9, and in Figures 18-20.

**Table 9: Final Steady State (PAYG and funded scheme)**

| $\theta$ | Tax Rate | Cons | Output | Int. Rate | Wage | Capital | Labor | Utility | Utility Loss I | Utility Loss II |
|---|---|---|---|---|---|---|---|---|---|---|
| 0.1 | 0.045 | 0.3079 | 0.4585 | 0.0560 | 1.2846 | 1.2038 | 0.2284 | -68.96 | 4.34 | 22.20 |
| 0.2 | 0.087 | 0.3024 | 0.4232 | 0.0623 | 1.2516 | 1.0640 | 0.2164 | -69.55 | - | 18.68 |

The tax rate reported in Table 9 above is the total income tax that is allocated to the social security system. Of this total tax, two-thirds go towards the public pay-as-you-go system and one-third is accumulated in a pension fund.

The pension fund remunerates the deposits with a constant interest rate, equal to the return on capital. However, we have chosen to keep the fund separate and not invested at all in capital, due to the constraints imposed by the draft Romanian legislation. The capital market in Romania is very small and non-diversified. The volatility is high and a stock market was established only few years ago, which makes investing in it very risky. Therefore, we kept the pension fund completely separate, and the only investment allowed is in Treasury securities. We do assume that the return on bonds is identical to the return on capital.

The figures show that even with such a small replacement rate, the individual can enjoy a higher consumption than in the base case scenario in the initial state, and of any of the cases of the PAYG scheme presented in Table 8.

It is interesting to see (Figure 20) that due to the promised annuity from the pension fund, the individual decreases his asset holdings towards the end of the working career. This behavior will induce a decrease in savings and this, in turn, induces a decrease in capital and in output. When the replacement rate increases, the individual agent chooses to decrease her assets even prior to retirement and in turn to reduce the labor supply. We consider that this effect is due to the mandatory retirement age, and the behavior under a voluntary retirement scheme will be different.

Figure 19 shows labor supply profiles. In the case of a replacement rate of 0.2 for the public portion of the pension benefit, the individuals decrease their labor supply in the period prior to retirement to less than 15 % of the available time.

### 6.7 Sensitivity Analysis. Pension Fund partially invested in Capital

To move from the very strong assumption that no part of the pension fund is invested in the capital market, we are exploring one more option, in which a quarter of the accumulated assets in the pension fund are invested into capital. The rest is still invested in treasury bonds, and is remunerated at the same rate as the physical capital. The results are presented in Table 10 and in figures 21-23.

**Table 10: Final Steady State. Pension Fund Partially Invested in Capital**

| $\theta$ | Tax Rate | Cons | Output | Int. Rate | Wage | Capital | Labor | Utility | Utility Loss I | Utility Loss II |
|---|---|---|---|---|---|---|---|---|---|---|
| 0.1 | 0.045 | 0.3064 | 0.4638 | 0.0543 | 1.2932 | 1.2308 | 0.2296 | -68.95 | 4.62 | 22.26 |
| 0.2 | 0.087 | 0.2990 | 0.4324 | 0.0605 | 1.2608 | 1.0975 | 0.2195 | -69.58 | - | 18.49 |

It is interesting to observe that individuals increase their asset holdings, and therefore our study does not confirm the common wisdom that individual saving decreases when the social security contributions are invested in Treasury securities or in capital. The interest rate decreases substantially while wages increase, and the combined effect is a small increase in the aggregate labor supply and an increase in output. However, aggregate consumption decreases since individuals increase their aggregate saving.

We have solved all the exercises that imply the accumulation of a private pension fund only for values of $\theta$ of 0.1 and 0.2, because a look at the actual payoffs for the last period of work and the first period of retirement shows that for a replacement rate of 0.2 of the gross average labor income, the ratio between social security benefits (public and private) and the net labor income in the last period of work is 4.677. Therefore, increasing the replacement rate (which, again, represents only the replacement rate of the public portion of the social security benefit) will show an implausible return, as the total replacement rate will be higher than 1.

Table 11 presents a comparison between a "total wage" and a "total benefit" for some of the exercises performed in this paper. We looked at the initial steady state - the case where the unemployment follows a Markow process, presented in Table 3 -,at the final steady state (pay-as-you-go only) and at the final steady state (pay-as-you-go and funded portion, no investment in capital). The values are units of the only consumption good available in the economy.

The definition of the "total wage" is

$$W = w_0(1+r)^{40} + w_1(1+r)^{39} + ... + w_{40} \tag{21}$$

where each wage is after-tax effective period labor income while the individual is employed. We extend the period to 45 years in the post reform calculations.

The definition of total benefit from social security is:

$$B = e_1 + (1+r)^{-1}e_2 + ... + (1+r)^{-20}e_{20} \tag{22}$$

where $e_t$ is the expected, taking into account mortality, benefit from social security. We reduce the benefit period to only 15 years in the post reform calculations. When benefits come from both public and private funds sources we have added them together and computed the total benefit. Let $rr = B/W$

**Table 11: Labor Income and Social Security Benefits**

| $\theta$ | Initial State | | | Final-PAYG | | | Final-PAYG+Funded | | |
|---|---|---|---|---|---|---|---|---|---|
| | W | B | rr | W | B | rr | W | B | rr |
| 0.1 | 24.1942 | 0.9929 | 0.0410 | 37.0626 | 0.5272 | 0.0142 | 39.4716 | 1.6603 | 0.0420 |
| 0.2 | 24.2665 | 1.6308 | 0.0672 | 37.1496 | 1.0087 | 0.0271 | 40.9365 | 2.5762 | 0.0629 |
| 0.3 | 24.0847 | 2.0729 | 0.0860 | 37.3773 | 1.4438 | 0.0386 | | | |
| 0.4 | 23.4596 | 2.3568 | 0.1004 | 37.1505 | 1.8405 | 0.0495 | | | |

The first part of the reform (increasing the retirement age and changing benefits formula) will significantly reduce the replace this "psedo-replacement" rate. This effect is mainly due to the increase in expected wages and decrease in expected benefits. However, we can see that individuals maximize their expected wage at $\theta = 0.3$. For a higher value of $\theta$ the effect of higher social security taxes reduces the lifetime expected wage.

In the post reform case when social security contributions are invested in private funds, the "pseudo-replacement" rate is higher and is similar to pre reform values even if retirement period is much shorter.

# 7 Conclusions

We have presented a simulation of a reformed social security system with two regimes, a pay-as-you-go and a funded portion. Our paper determines the changes in individual labor supply due to the changes in the social security system. One of the main findings is that labor supply changes significantly due to changes in the system. Therefore, some of the current assumptions, that a funded pension system will increase the physical capital and the individual asset holdings should be taken with caution. We have shown that individual asset holdings respond to changes in the design of the social security system, and that the asset holdings (that represent the voluntary savings) actually decrease strongly due to the introduction of a pension fund.

We have simulated an extreme case in which the asset holdings decrease after the introduction of the funded component. When we have invested a portion of the pension fund into capital, the individual savings decline even more, due to the decrease in interest rates and increase in wages. In this second case, the decrease in interest rates implies an increase in the labor supply especially in the second part of the employment, in order to maintain the same level of consumption as before.

In our simulations, social security taxes decrease sharply from the initial case to the PAYG case and are the smallest for the case of PAYG+funded benefit.

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# Appendix 1

The data on the duration of unemployment is from the National Commission of Statistics and is presented in Figure 1. The data represents the number of unemployed, irrespective of age or sex, at the end of 1996, by duration of unemployment. Therefore, the first column will show how many people are unemployed only for the last quarter, the second column will show how many people are unemployed for the last two quarters, and so on. The longest spell of unemployment in our data is 9 quarters. The second series in Figure 1 below shows the cumulative ratio of unemployed per length of unemployment, or how many people out of the total number of unemployed have found a job at the end of the respective quarter.

Our model has one period set to one year, so we want to know how many people have found a job after a year. We consider that we are in a stable environment in which the rate of unemployment does not change over time, and the number of people that register for unemployment benefits stays constant every quarter. Under these assumptions, the total number of people that are unemployed for more than a year (4 quarters) are the ones that have not yet found a job. Adding up the number of unemployed, at the end of 1996, that have a duration of unemployment longer than 4 quarters, and dividing this number by the total number of unemployed, we obtain the probability of being unemployed, conditional of being unemployed last year. Under our assumption of stationarity, this probability is the same with the probability of being unemployed next period, conditional of being unemployed this period. We have also looked at the data divided by sex, or by age of individuals, and we found no significant differences. However, the number of unemployed declines over the age of the individual, with a very low number of people claiming unemployment when they are between age 50 to 55, or over 55. The data is in agreement with the data presented in Section 3, and suggests that the number of pension beneficiaries has increased significantly, and that a large fraction of the individuals over 50 years of age that face unemployment choose early retirement.

We find from the data that 48.66 % of the unemployed have a length of unemployment of less than a year, therefore we transform our Markov transition matrix in the following way: $Prob\{l' = e|l = e\} = 0.9577$, $Prob\{l' = e|l = u\} = 0.486$, $Prob\{l' = u|l = u\} = 0.514$, and $Prob\{l' = u|l = e\} = 0.0423$.

We choose the probability of being employed next period, conditional of being employed this period in such a way as to satisfy a stationarity condition of having a constant rate of unemployment. The transition matrix above will keep a steady unemployment at 8 %.

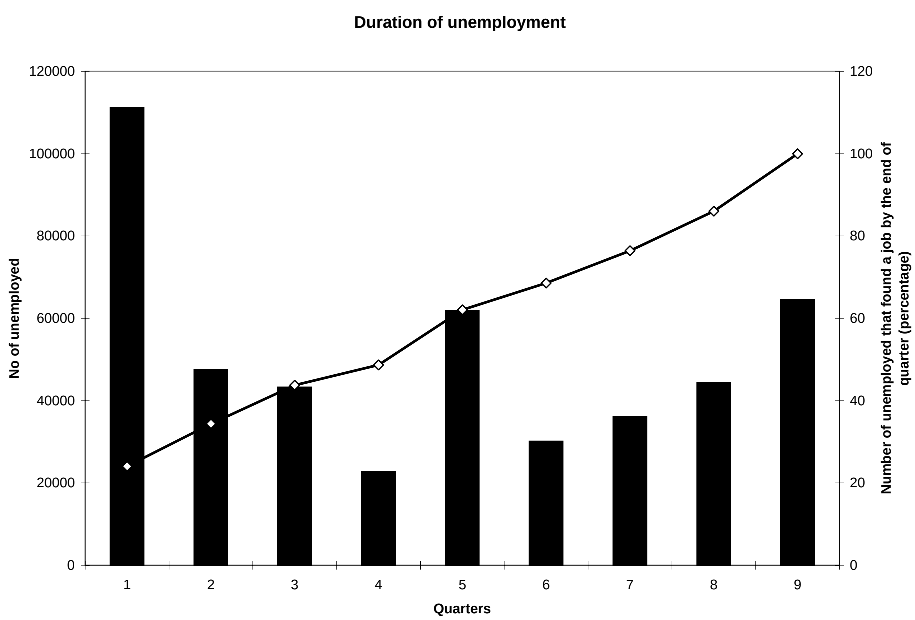


**Figure 1: Unemployment and ratio of unemployed that found work at the end of quarter**

# Appendix 2

The efficiency index $\{\epsilon_j\}$ is intended to provide a realistic cross-sectional age-distribuiton of labor related earnings at a point in time. The index is taken from Imrohoroglu, Imrohoroglu and Joines (1998b), which in turn take it from Hansen (1993).

The values of $\{\epsilon_j\}$ are plotted in Figure 2 below.

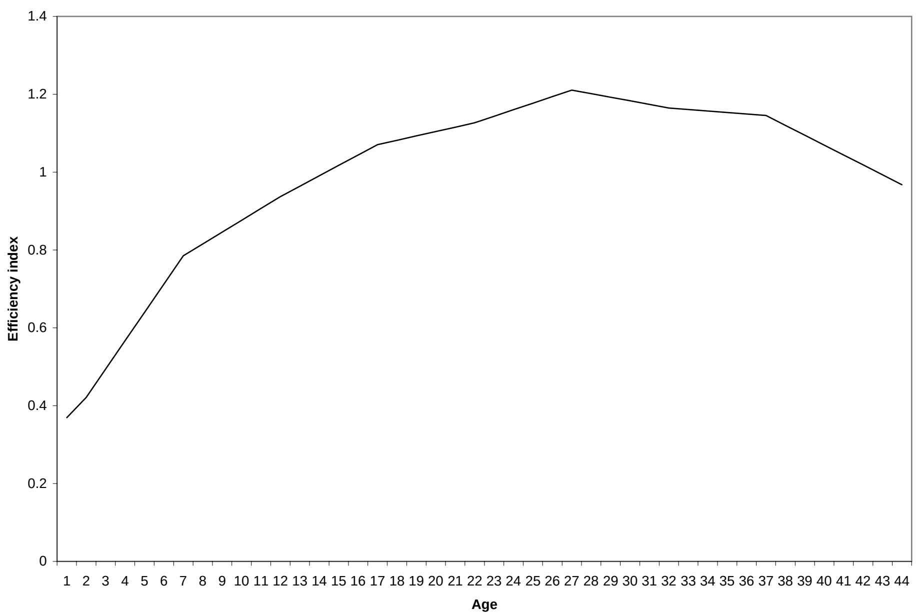


**Figure 2: Efficiency index**

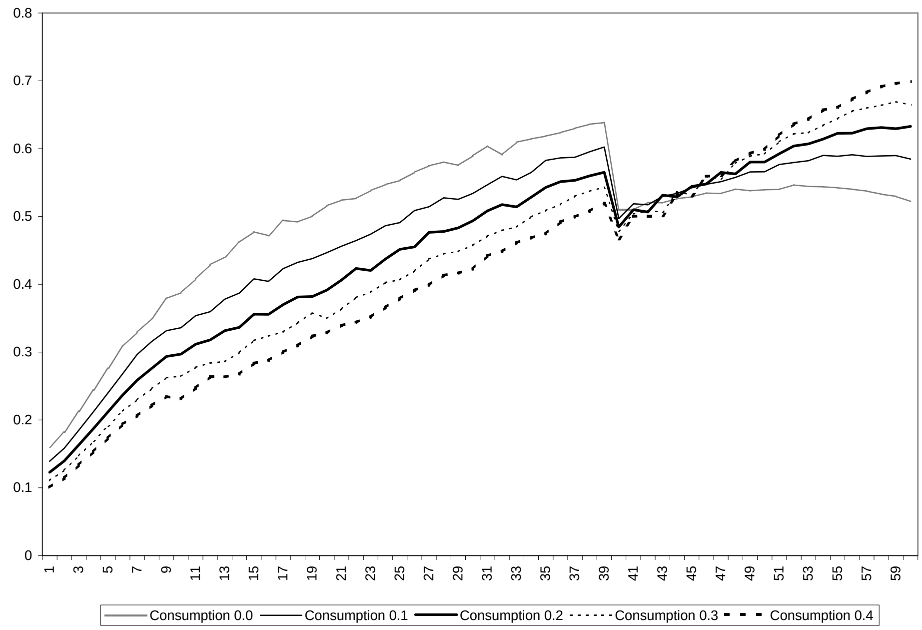


**Figure 3: Consumption Profile. Initial Steady State**

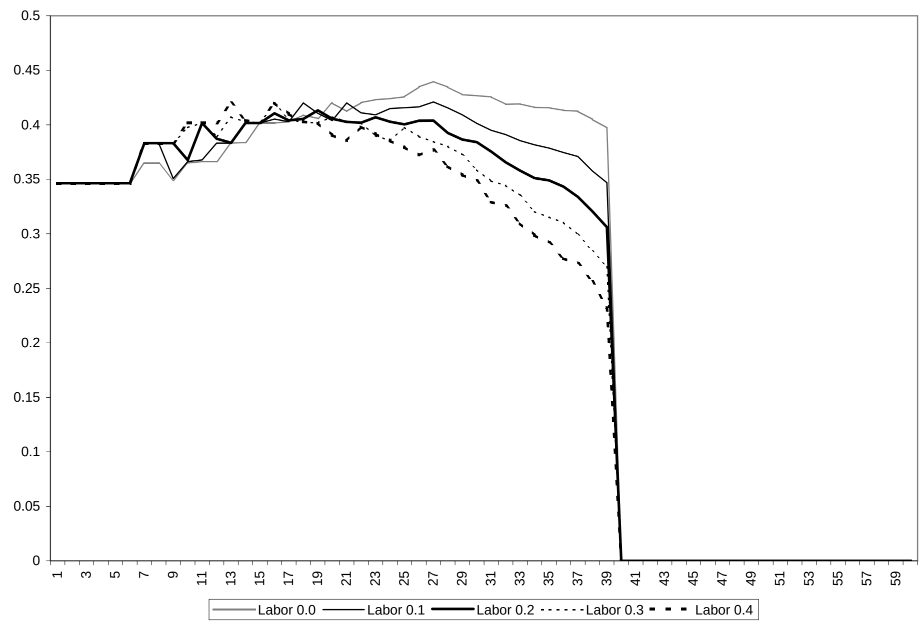


**Figure 4: Labor Supply Profile. Initial Steady State**

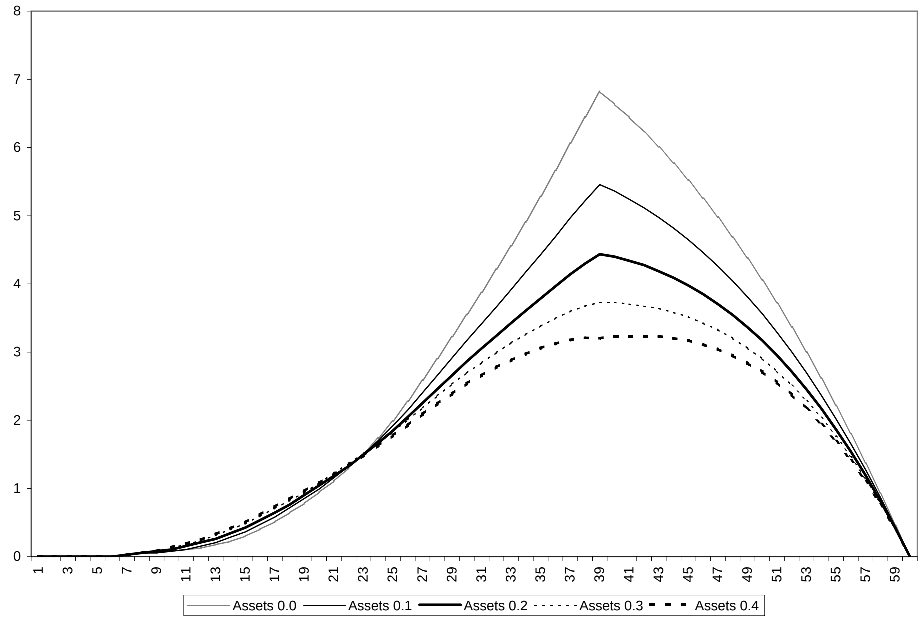


**Figure 5: Asset Holdings Profile. Initial Steady State**

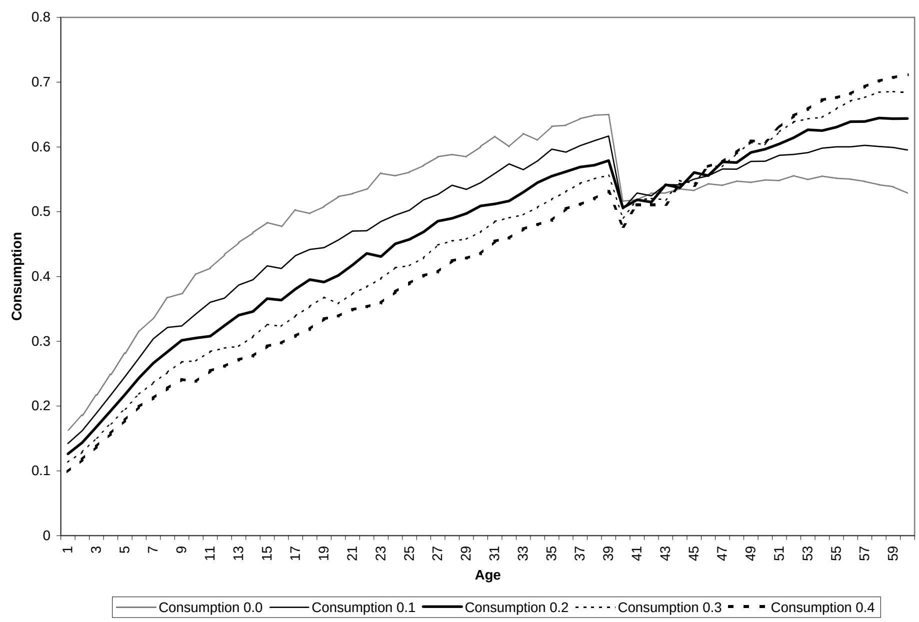


**Figure 6: Consumption Profile. Initial Steady State. Lower Unemployment**

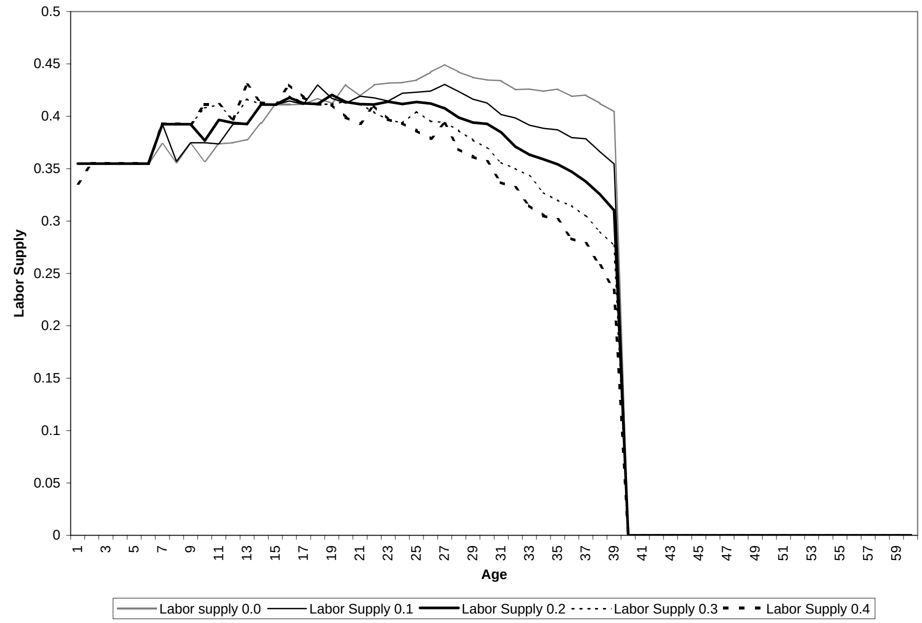


**Figure 7: Labor Supply Profile. Initial Steady State. Lower Unemployment**

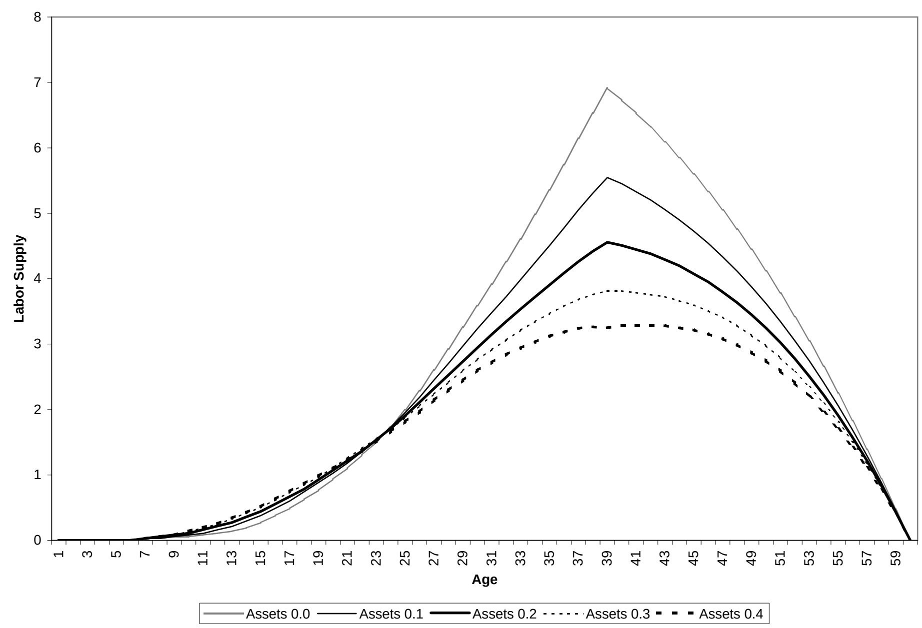


**Figure 8: Asset Holdings Profile. Initial Steady State. Lower Unemoployment**

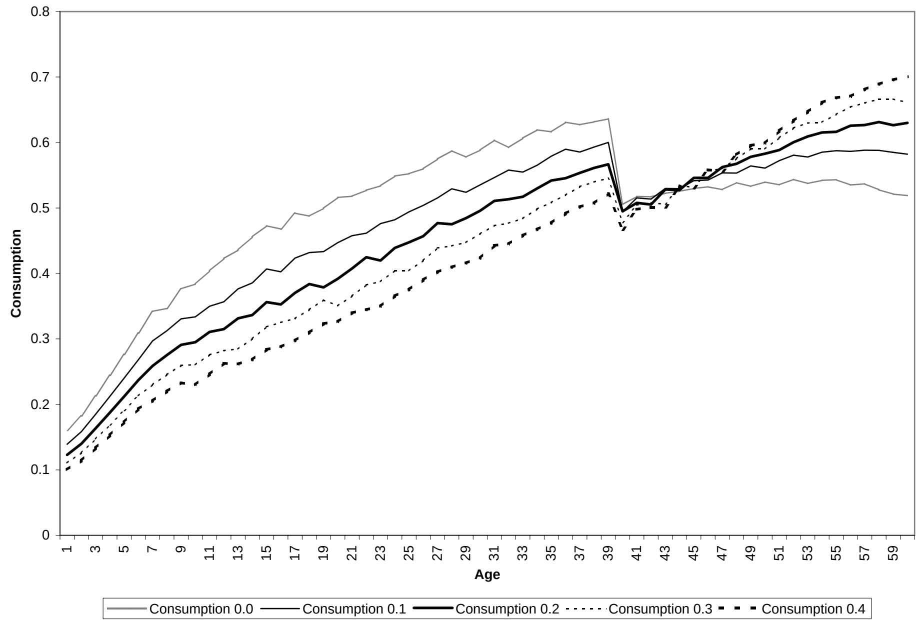


**Figure 9: Consumption Profile. Initial Steady State. Markov Process**

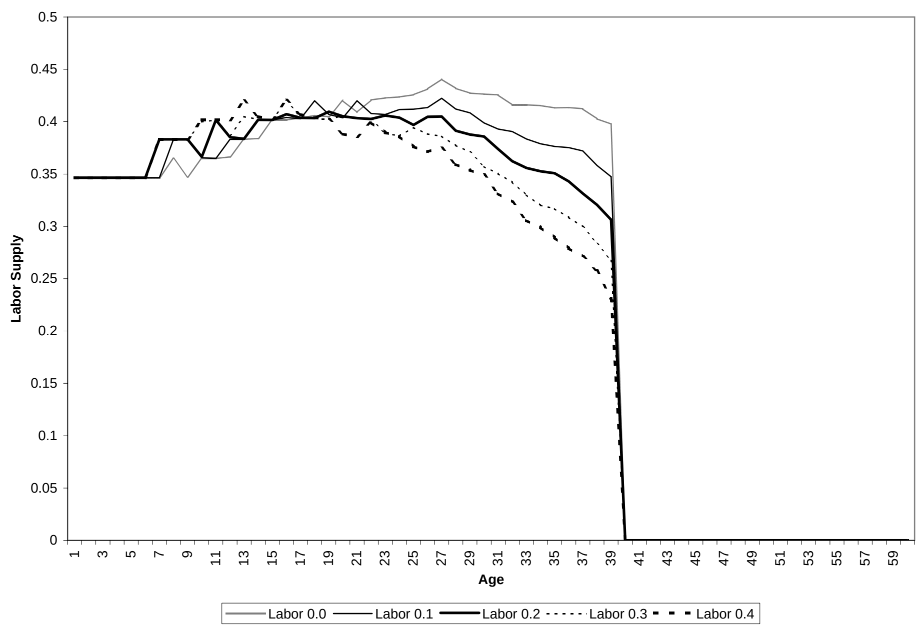


**Figure 10: Labor Supply Profile. Initial Steady State. Markov Process**

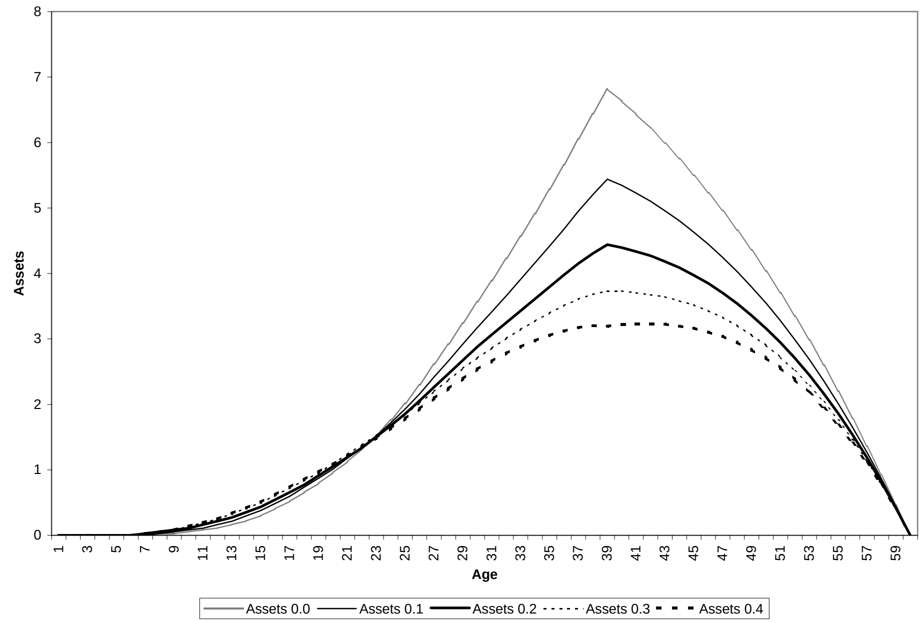


**Figure 11: Asset Holdings Profile. Initial Steady State. Markov Process**


**Figure 12: Consumption Profile. Initial Steady State. Romanian Conditions**

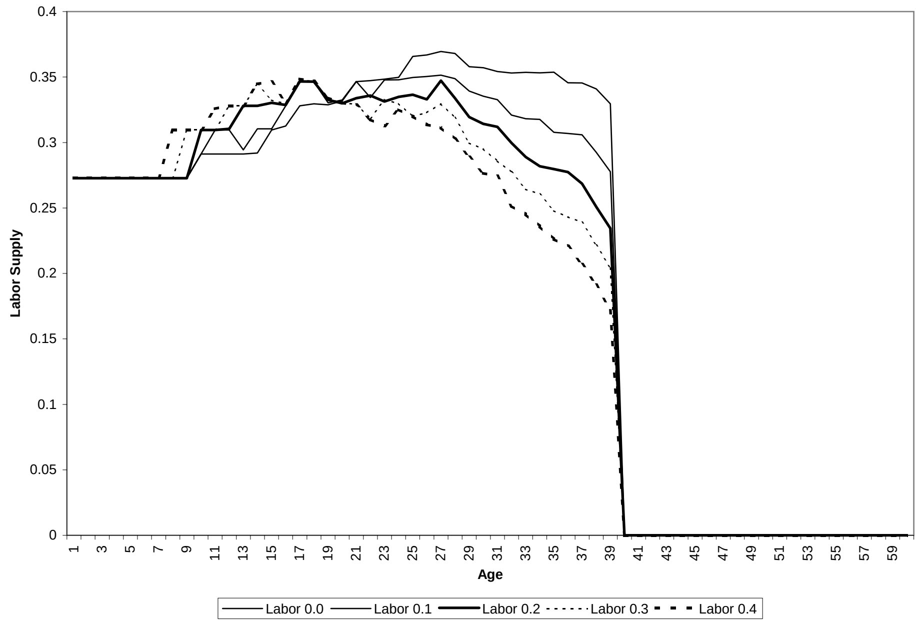


**Figure 13: Labor Supply Profile. Initial Steady State. Romanian Conditions**

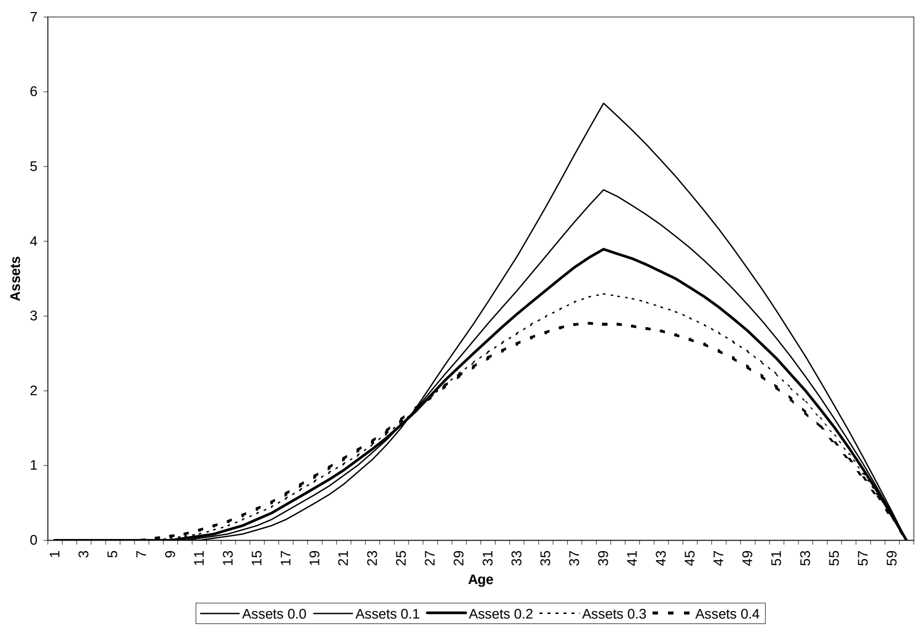


**Figure 14: Asset Holdings Profile. Initial Steady State. Romanian Conditions**

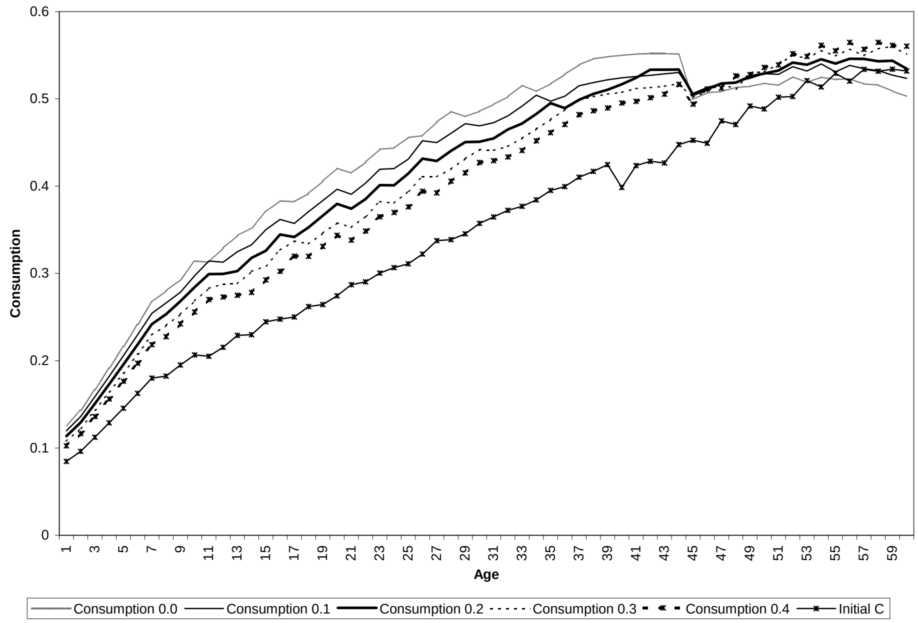


**Figure 15: Consumption Profile. Final Steady State (PAYG Only)**

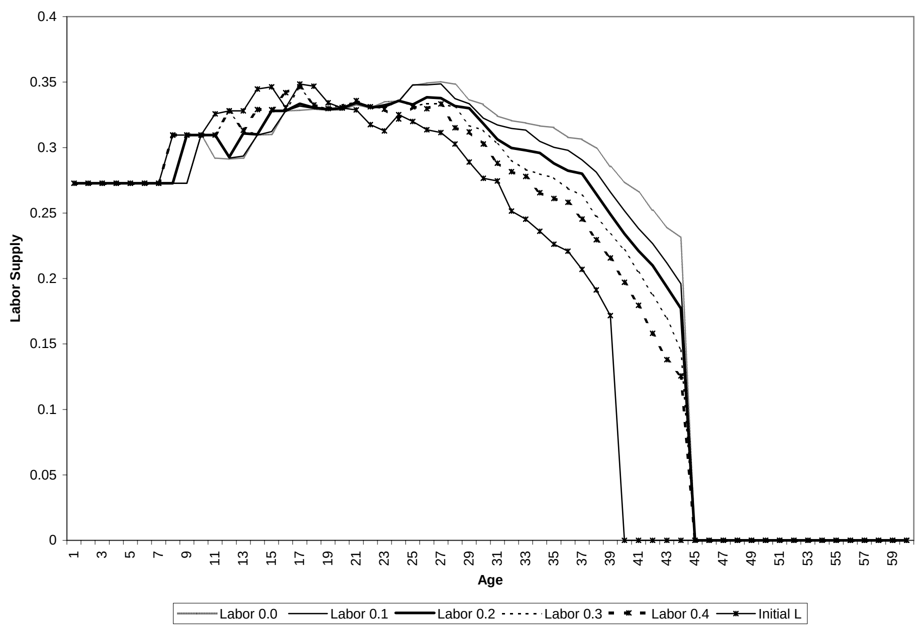


**Figure 16: Labor Supply Profile. Final Steady State (PAYG Only)**

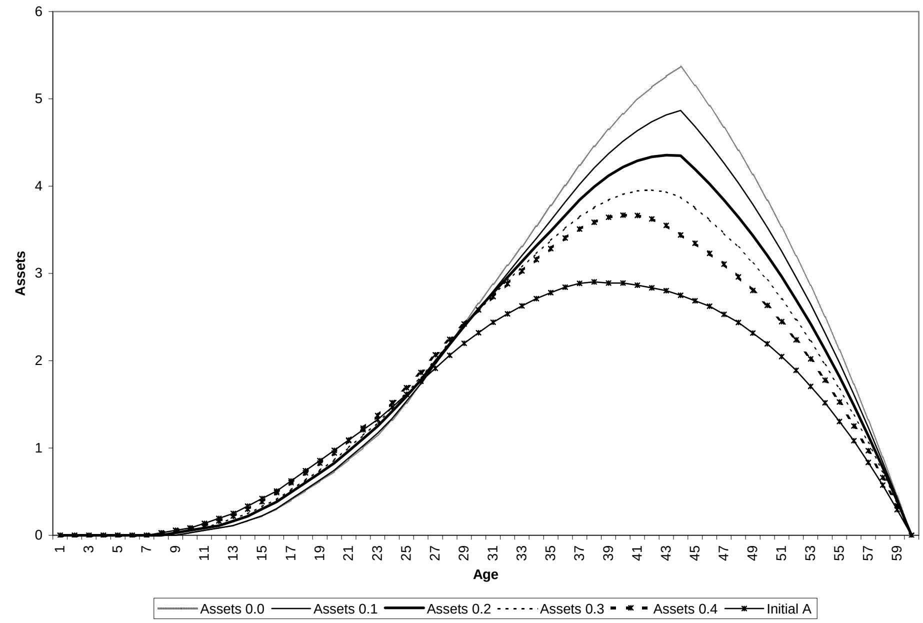


**Figure 17: Asset Holdings Profile. Final Steady State (PAYG Only)**

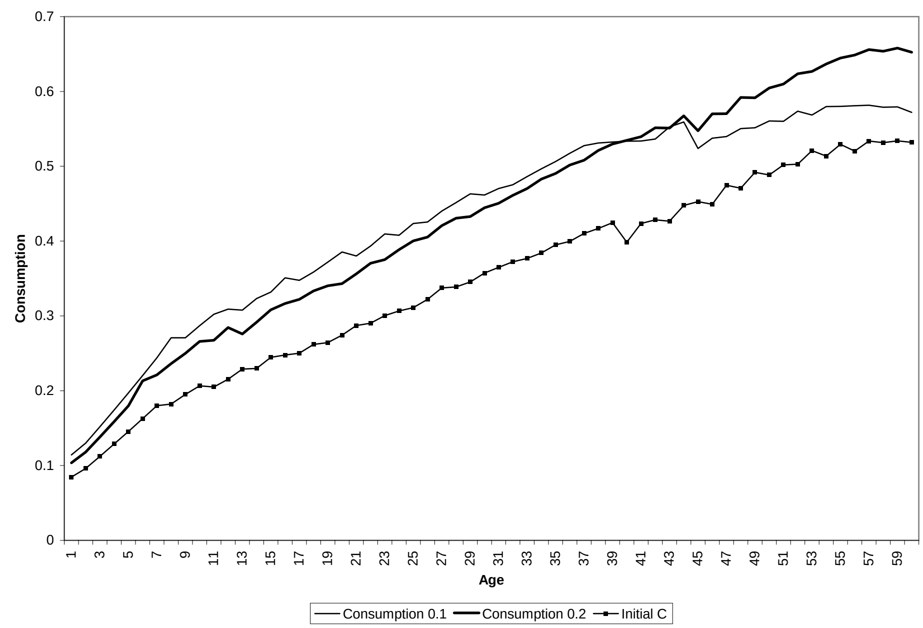


**Figure 18: Consumption Profile. Final Steady State (PAYG + Funded Scheme)**

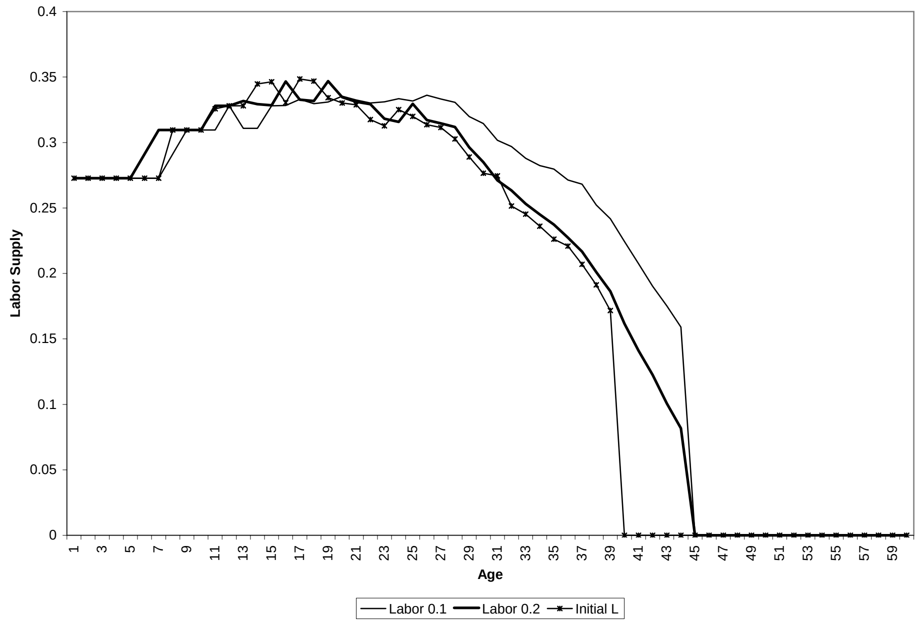


**Figure 19: Labor Supply Profile. Final Steady State (PAYG + Funded Scheme)**

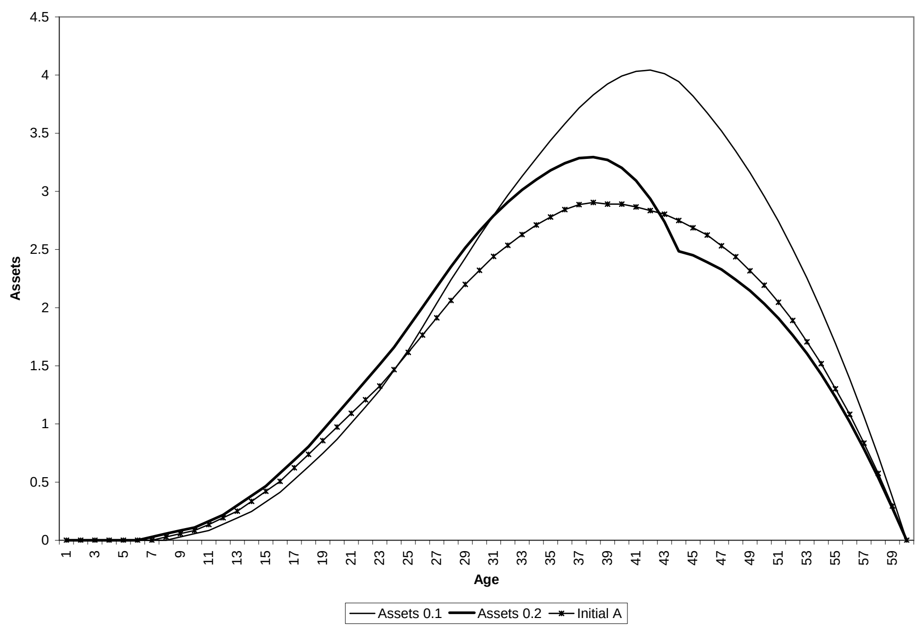


**Figure 20: Asset Holdings Profile. Final Steady State (PAYG +Funded Scheme)**

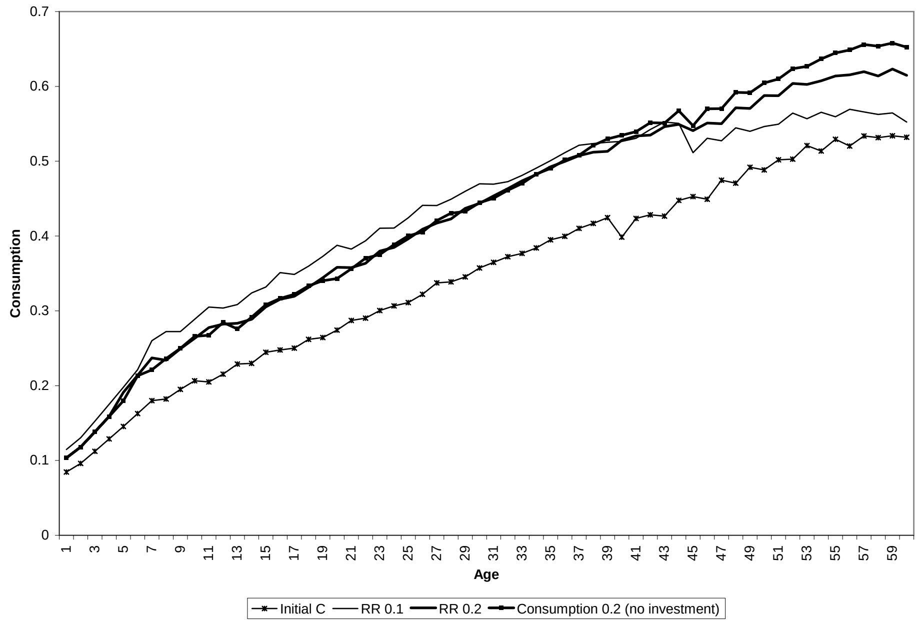


**Figure 21: Consumption Profile. Pension Fund Partially Invested in Capital**

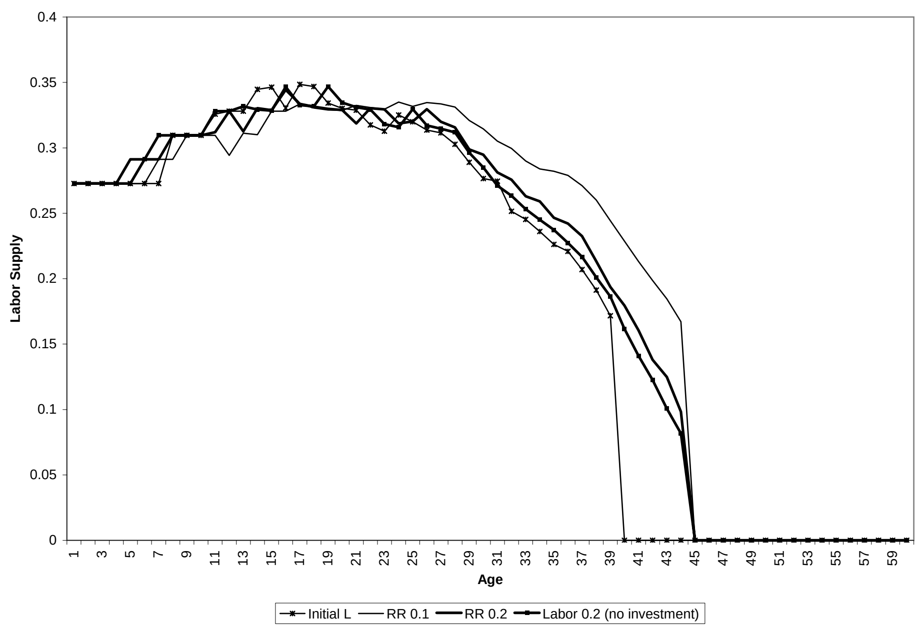


**Figure 22: Labor Supply Profile. Pension Fund Partially Invested in Capital**

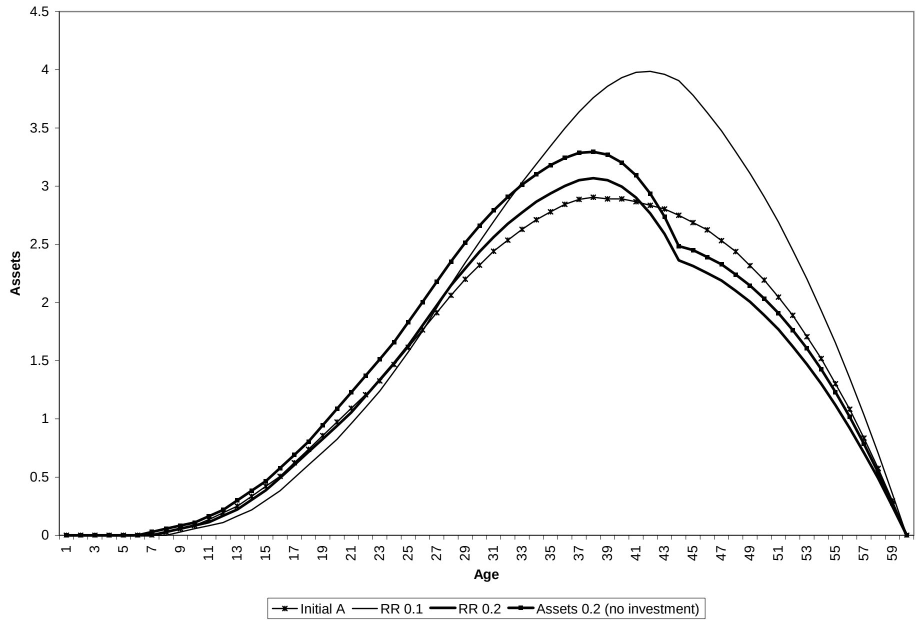


**Figure 23: Asset Holdings Profile. Pension Fund Partially Invested in Capital**