

**SOCIAL SECURITY REFORM  
WITH UNINSURABLE INCOME RISK  
AND ENDOGENOUS BORROWING  
CONSTRAINTS**

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# **SOCIAL SECURITY REFORM WITH UNINSURABLE INCOME RISK AND ENDOGENOUS BORROWING CONSTRAINTS (\*)**

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## **Abstract**

We study the aggregate effects of a social security reform in a large overlapping generations model where markets are incomplete and households face uninsurable idiosyncratic income shocks. We depart from the previous literature by assuming that, because of lack of commitment in the credit market, the borrowing constraint in the unique asset is endogenously determined by the agents' incentives to default on previous debts. We find that a model with fixed borrowing constraints overestimates the positive effect of reforming social security on the capital stock and the saving rate, compared to our model with endogenous borrowing limit. The reason is that, in the latter, the size of precautionary savings is smaller because after the reform the incentives to default on previous debts are lower and consequently households face more relaxed borrowing limits. Adding retirement accounts to the basic model does not change these conclusions, although the quantitative importance of endogenizing borrowing constraints is reduced.

# 1 Introduction

The reform of social security is at the center of the political debate in most countries, at least for two reasons: First, the aging of the population is rising concern about the sustainability of public social security systems over the next decades. Second, in some countries the gross private saving rate has shown a downward trend over the last decades. For example, in the US economy the private saving rate as a percent of GDP decreased from 20.9 in 1980 to 12.7 in 2000. This trend, and its possible negative consequences for economic growth, has exacerbated the debate about the desirability of reducing the generosity of public pension systems as a tool to promote savings. In this paper, we focus on the second issue, abstracting completely from the first one. The question we address is whether the lack of commitment in the credit market is important to understand the effects of reforming social security on aggregate savings. Our answer is that when borrowing constraints are endogenous and idiosyncratic income risk is important, the magnitude of the increase in the capital to output ratio and the saving rate due to a social security reform is reduced.

Recent theoretical studies have found that reforming social security, eliminating the pay-as-you-go (PAYG) public pension system, is an important policy tool to foster capital accumulation and savings. The seminal example of this tradition is the deterministic model by Auerbach and Kotlikoff (1987). More recently, there are some papers that have addressed the aggregate effects of social security in model economies with idiosyncratic income risk. The work of Imrohoroglu et al. (1995), Conesa and Krueger (1999) and Storesletten et al. (1999) are the typical examples. Perhaps closer to the spirit of our work is the study by Fuster (1999). She finds that introducing altruism in a large overlapping generations model substantially reduces the effect of eliminating social security on the capital stock. We depart from this literature by assuming that, because of lack of commitment, financial intermediaries are only willing to lend to a worker the maximum amount of resources that satisfies the rationality condition of no default for *all* possible values of the income shock tomorrow. Consequently, individuals face state-specific borrowing limits that depend on the social security regime<sup>1</sup> and there is no default in equilibrium. This assumption has been used by Zhang (1997), Fernandez Villaverde and Krueger (2002), and Bai and Chang (2005). Notice that in the incomplete markets literature we are somewhere in between two well-established theories. On one hand, there are papers which exogenously assume the number of assets (usually one) and the borrowing constraint for each asset (in most cases, zero borrowing). This is the framework studied by Huggett (1993) and Aiyagari (1994), in which most of the social security literature is based on. On the other hand, the seminal paper by Kehoe and Levine (1993), followed by Alvarez

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<sup>1</sup>A similar intuition is provided by the paper of Krueger and Perri (1999), although their experiment is to change the progressivity of income taxation instead of eliminating social security. In an economy with complete set of assets but endogenous debt limits, they do find important effects on the amount of risk-sharing that can be sustained in equilibrium.

and Jermann (2000), assumes a full set of contingent assets but with an endogenous borrowing limit in each, arising from the lack of commitment from the borrower's side. We do restrict the set of assets, as in the first framework, but endogenize the borrowing limit, as in the second.<sup>2</sup>

We first consider a one-asset economy calibrated to US data, solve for the stationary equilibria, and find that when the borrowing constraints are exogenous eliminating social security has important effects on the capital stock and the saving rate. In contrast, when the borrowing constraints are endogenous, the magnitude of the increase in the saving rate is reduced (although not by a huge amount) and there is a debt boom. The reason is that with the elimination of social security individuals have less incentives to default on debts. The relaxation of borrowing constraints associated to this fact implies that the agents need to save less for precautionary reasons. This effect goes in the opposite direction to the traditional increase in savings associated with the reform of public pensions.<sup>3</sup> In the second part of this paper, we extend the basic model by introducing a second asset (retirement accounts) and experiment with a more realistic social security reform. Again, the model with endogenous borrowing constraints features a smaller increase in the saving rate after the reform than the model with exogenous borrowing limits, and also a larger debt boom. The differences between the two models, however, are now very small, mostly because in our model retirement accounts are protected against creditor claims upon default, as it is in most legislations. Even if our explanation goes in the right direction, there is still a long way to go in order to understand why social security reforms do not lead to the huge increases in savings predicted by current models. In this sense, our result goes in the direction of the empirical literature, which finds that actual experiences of social security reform around the world have had a small impact on saving rates. The first privatization experience, Chile in 1981, has been used as a textbook example of a successful reform. However, the aggregate effects on the saving rate show an increase of at most 10% in twenty years, of which is hard to disentangle how much comes from corporate savings instead of households savings.<sup>4</sup> Using Chilean house-

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<sup>2</sup>The formal properties of our framework have not been fully developed. We do not claim that the resulting debt contract is optimal in any meaningful sense. Moreover, we are aware of a third alternative, which is a framework in which interest rates are type specific, maximize banks ex-ante profits, and there is default in equilibrium, as in Chatterjee et al. (2004). Adding this default option is an interesting issue for future research.

<sup>3</sup>A previous attempt to incorporate endogenous borrowing constraints in social security models is the work by Andolfatto and Gervais (2001). They use a three-period overlapping generations model with no income risk to assess the role played by endogenous borrowing constraints in shaping the aggregate effects of social security. Their findings indicate that it is not quantitatively important to model these constraints endogenously. The reason is that their model does not account for the change in the magnitude of precautionary savings associated with the relaxation of borrowing limits after the elimination of social security. In contrast, in our paper we account for this additional effect and find that is important for the question at hand.

<sup>4</sup>See Coronado (2002) for a review of the problems of backing up saving rates using macro data in Chile.

hold level data, Coronado (2002) finds that the saving rate increase by about 7% for rich families, while Butelmann and Gallego (2000) find an increase in debt for low income households. It is still early to assess the results of the reform in other Latin American countries, as Mexico and Peru, which reformed their systems in the 90s, but so far there is no evidence of increases in their saving rates while consumer debt has significantly increased. A "rich" country which has been reforming its social security system since 1986 is the UK Disney et al. (2003) find no trend in household aggregate savings rate after the reform, while Granvick and Mallick (2002) finds that savings for retirement substitute other types of household savings, with no increase in the aggregate saving rate.

The rest of the paper is organized as follows. Section 2 describes the main features of our economy with only one asset and defines a stationary equilibrium for it. Section 3 explains the calibration procedure and show some features of our benchmark quantitative model. In Section 4, we perform the experiment of a social security reform which eliminates social security benefits, comparing the effects on the saving rates with fixed (exogenous) borrowing constraints and endogenous borrowing limits. Section 5 extends the model adding a second asset, retirement accounts, and analyzes a more realistic social security reform. Finally, we conclude.

## 2 The Environment: One-Asset Economy

Our economy is in many aspects similar from the economy described in Imrohoroglu et al. (1995). We work in a large overlapping generations setup, with mortality risk and individual income risk. We also preclude for contingent markets, including markets for annuities. Individuals save and borrow through only one asset, negative amounts of which corresponds to unsecured debt. We depart from the previous literature, however, by introducing limited commitment in the credit market. Individuals can only commit to pay back their previous debt if it is optimal for them to do so, compared to the option of default. In particular, we assume as in Zhang (1997) that financial intermediaries are only willing to lend to a worker the maximum amount of resources that satisfies the rationality condition of no default for all possible values of the income shock tomorrow. Consequently, there is no default in equilibrium, and individuals face age-specific, endogenously determined, borrowing constraints.

The main features of the model are the following. The economy is populated by individuals that live for a maximum of  $I$  periods. Agents with age  $i \in \{1, \dots, I_r - 1\}$  are workers and provide  $\eta e(i)$  efficiency units of labor to the market, where  $e$  is an exogenously given efficiency profile and  $\eta$  is a stochastic shock. The transitions across states of nature follow the stationary probability matrix  $\pi$ . Individuals with age  $i \geq I_r$  are retired, collect social security benefits  $TR_{ss}$  and face a probability of surviving to the next period  $s(i)$  with  $s(I) = 0$ . Each agent which dies is replaced by a newborn

with age  $i = 1$ , the lowest realization of the productivity shock,<sup>5</sup> and no assets. Total assets of dead agents are seized by the government.

Workers and retirees decide how much to consume ( $c$ ) and save/borrow ( $a$ ) to maximize their lifetime utility. The one period utility function is of the class of CRRA, with risk-aversion coefficient  $\sigma$  and discount factor  $\beta$ . In order to determine a worker's endogenous borrowing constraint, we have to compare the continuation value of paying back a loan of a given size, or defaulting. The latter implies a complete discharge of the debt but also a punishment: defaulters are permanently excluded from the credit market and can only keep a fraction  $\phi < 1$  of their interest income. Alternatively, we might think that defaulters can only save through a storage technology which yields a fraction  $\phi$  of the market interest rate.<sup>6</sup> We assume that retirees cannot borrow.

Workers pay a social security tax proportional to their labor income ( $\tau_{ss}$ ). The proceedings are used to finance social security benefits, computed as a replacement rate times the average wage in the economy. The social security system is self-financed. The government also collects income taxes ( $\tau$ ) from labor and capital income plus unintended bequests from all agents, and spends it in unproductive government consumption ( $G$ ) keeping each period a balanced budget. Finally, there is a technology to produce the only good in the economy ( $Y$ ) using labor ( $L$ ) and capital ( $K$ ), described by a Cobb-Douglas production function.

We consider only a stationary equilibrium, in which all prices and aggregate quantities remain constant over time. This allows us to write the model in a simple recursive language.

## 2.1 Consumer's Problem

To characterize consumer's problem, we first have to describe the continuation value for agents that defaulted in their previous debts and consequently are excluded from the borrowing market and from the possibility of earning the market interest rate on accumulated liquid assets. This value is necessary to compute the endogenous borrowing limit in the problem faced by consumers in equilibrium.

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<sup>5</sup>This assumption is intended to capture the transition of young workers from unemployment to their first job. A more complicated version of the model would include different employment probabilities according to age.

<sup>6</sup>This punishment is weaker than the one in Zhang (1997) and Kehoe and Levine (1993). In these papers, defaulters revert to autarky, this is, they cannot borrow nor save in their remaining periods of life. Such a harsh punishment would certainly work in our favor, although it might not be realistic. In addition, full autarky in the scenario without social security would imply zero consumption in the retirement period. We also explored the possibility of precluding defaulters only to borrow, allowing them to earn full interest income ( $\phi = 1$ ). It turned out that this punishment was too weak to sustain a positive amount of debt in equilibrium, a result already suggested by Bulow and Rogoff (1989).

### Value of default:

Let's start with a retired individual in her last period of life ( $i = I$ ). This agent will consume all her income, given by the common social security transfer plus any remaining assets. Hence, her utility is given by:

$$v_r^*(a, I) = \frac{[TR_{ss} + (1 + \phi r (1 - \tau)) a]^{1-\sigma}}{1 - \sigma}$$

Going backwards, a retired individual of age  $i = \{I_r, \dots, I - 1\}$  faces the following problem:

$$\begin{aligned} v_r^*(a, i) &= \max_{\{c, a'\}} \left\{ \frac{c^{1-\sigma}}{1 - \sigma} + \beta s(i) v_r^*(a', i + 1) \right\} \\ \text{s.t. } c + a' &= TR_{ss} + (1 + \phi r (1 - \tau)) a \\ a' &\geq 0 \end{aligned}$$

Notice that this individual cannot borrow and keeps only a fraction  $\phi$  of interest income, as a punishment from past behavior. Now let's move to workers which defaulted in their previous debts and are in their last period of working life ( $i = I_r - 1$ ). Their problem is described by:

$$\begin{aligned} v_e^*(a, I_r - 1, \eta) &= \max_{\{c, a'\}} \left\{ \frac{c^{1-\sigma}}{1 - \sigma} + \beta v_r^*(a', I_r) \right\} \\ \text{s.t. } c + a' &= (1 - \tau) (1 - \tau_{ss}) \eta we(I_r - 1) + (1 + \phi r (1 - \tau)) a \\ a' &\geq 0 \end{aligned}$$

with an additional state variable  $\eta$  representing their current income shock. The problem is similar for workers at ages  $i = \{1, \dots, I_r - 2\}$ :

$$\begin{aligned} v_e^*(a, i, \eta) &= \max_{\{c, a'\}} \left\{ \frac{c^{1-\sigma}}{1 - \sigma} + \beta \sum_{\eta' \in E} \pi(\eta, \eta') v_e^*(a', i + 1, \eta') \right\} \\ \text{s.t. } c + a' &= (1 - \tau) (1 - \tau_{ss}) \eta we(i) + (1 + \phi r (1 - \tau)) a \\ a' &\geq 0 \end{aligned}$$

with the probabilities  $\pi(\eta, \eta')$  used to compute expectations about next period's income.

### Consumer's Problem with Endogenous Borrowing Constraints:

We are ready now to described the problem faced by consumers in equilibrium. Again, we start with a retired agent in her last period of life ( $i = I$ ):

$$v_r(a, I) = \frac{[TR_{ss} + (1 + r(1 - \tau))a]^{1-\sigma}}{1 - \sigma}$$

and at ages  $i = \{I_r, \dots, I - 1\}$ :

$$\begin{aligned} v_r(a, i) &= \max_{\{c, a'\}} \left\{ \frac{c^{1-\sigma}}{1 - \sigma} + \beta s(i) v_r(a', i + 1) \right\} \\ s.t. \quad c + a' &= TR_{ss} + (1 + r(1 - \tau))a \\ a' &\geq 0 \end{aligned}$$

Notice that the only difference with the default values is that retirees now earn full interest income for their assets, although they are not allowed to borrow because they cannot commit to payback anything with certainty as they face a positive death probability. A worker in her last period of working life ( $i = I_r - 1$ ) faces the problem

$$\begin{aligned} v_e(a, I_r - 1, \eta) &= \max_{\{c, a'\}} \left\{ \frac{c^{1-\sigma}}{1 - \sigma} + \beta v_r(a', I_r) \right\} \\ s.t. \quad c + a' &= (1 - \tau)(1 - \tau_{ss})\eta we(I_r - 1) + (1 + r(1 - \tau))a \\ a' &\geq 0 \end{aligned}$$

again similar to the default value except for the interest income. The interesting problem is the one faced by worker of age  $i = \{1, \dots, I_r - 2\}$ :

$$\begin{aligned} v_e(a, i, \eta) &= \max_{\{c, a'\}} \left\{ \frac{c^{1-\sigma}}{1 - \sigma} + \beta \sum_{\eta' \in E} \pi(\eta, \eta') v_e(a', i + 1, \eta') \right\} \\ s.t. \quad c + a' &= (1 - \tau)(1 - \tau_{ss})\eta we(i) + (1 + r(1 - \tau))a \\ a' &\geq -b(i) \end{aligned}$$

where the endogenous borrowing constraint  $-b(i)$  satisfies the individual rationality constraint:

$$\min \{b(i) \mid v_e(-b(i), i + 1, \eta') \geq v_e^*(0, i + 1, \eta')\} \quad \forall \eta' \in E$$

Workers are able to borrow only that amount of resources for which the value of paying back this debt is no less than the value of defaulting next period for all possible realizations of the income shock. This gives rise to an endogenous, age-specific, borrowing constraint. Solving each of the previous problems, we obtain optimal decision rules for consumption and next period assets for workers  $g_e^c(a, i, \eta)$ ,  $g_e^a(a, i, \eta)$  and retirees  $g_r^c(a, i)$ ,  $g_r^a(a, i)$ .

## 2.2 Firm's Problem

Firms in this economy have access to a Cobb-Douglas production function that converts capital and labor into (net) output:

$$Y - \delta K = K^\alpha L^{1-\alpha} - \delta K$$

From firm's maximization problem we obtain the marginal conditions

$$w = (1 - \alpha) K^\alpha L^{-\alpha} \quad r = \alpha K^{\alpha-1} L^{1-\alpha} - \delta$$

## 2.3 Aggregate Distribution and Law of Motion

Let  $\mu_s(a, i, \eta)$  be the mass of consumers (agents) in situation  $s \in \{e, r\}$ , where  $e$  stands for a employed worker and  $r$  for a retiree, with age  $i \in \{1, \dots, I\}$ , asset holdings  $a \in A$  and shock realization  $\eta \in E$ . Define also the marginal distributions

$$\mu_s(i) = \sum_{\eta \in E} \int_A d\mu_s(a, i, \eta)$$

and the partial sum of asset holdings

$$A_s(i) = \sum_{\eta \in E} \int_A a d\mu_s(a, i, \eta)$$

The distribution  $\mu$  represents the aggregate state variable, that we normalize as a probability measure

$$\sum_{\eta \in E} \sum_{s \in \{e, r\}} \sum_{i=1}^I \int_A d\mu_s(a, i, \eta) = 1$$

The law of motion of the aggregate state variable is given by  $\mu' = \Gamma(\mu)$ , and can be defined using the optimal policy rules. In our stationary equilibrium,  $\mu$  is a fixed point of the operator  $\Gamma$ .

## 2.4 Government Budget

The government in our model faces two separate budgets, one for the social security system and another for current expenditures. We assume that the two budgets are balanced each period.

### Social Security System:

Social security benefits are computed applying a replacement rate  $\theta$  over the average earnings per worker in the economy:

$$TR_{ss} = \theta \frac{\sum_{\eta \in E} \sum_{i=1}^{I_r-1} \int_A w\eta e(i) \mu_e(a, i, \eta)}{\sum_{i=1}^{I_r-1} \mu_e(i)}$$

This transfer is assumed to be the same for all retirees. An interesting extension is to allow for some dependence of the transfer on each individual's previous wages, as in Storesletten et al. (1999). For simplicity, we abstract from this feature.

Since the social security system is assumed to be balanced, the total amount of transfers to retirees has to be equal to the social security tax collected from all workers:

$$TR_{ss} \sum_{i=I_r}^I \mu_r(i) = \tau_{ss} w \sum_{\eta \in E} \sum_{i=1}^{I_r-1} \eta e(i) \int_A \mu_e(a, i, \eta).$$

### Government Expenditures:

The government also levies labor and capital income taxes and unintended bequests to finance an exogenous level of government consumption. This part of the budget is also assumed to be balanced, hence

$$G = \tau \left[ (1 - \tau_{ss}) w \sum_{\eta \in E} \sum_{i=1}^{I_r-1} \eta e(i) \int_A \mu_e(a, i, \eta) + r \sum_{s \in \{e, r\}} \sum_{i=1}^I A_s(i) \right] \\ + \sum_{i=I_r}^I (1 - s(i)) \int_A [g_r^a(a, i)] d\mu_r(a, i)$$

## 2.5 Definition of a Stationary Equilibrium

A Stationary Equilibrium is a set of value functions, optimal decision rules, price functions, a set of government policies, aggregate law of motion  $\Gamma$ , and invariant distribution  $\mu$  such that:

1. Given prices, taxes, transfers, and aggregate law of motion, consumers optimize
2. Price functions satisfy marginal conditions from firm's problem
3. Government budget constraints are satisfied
4. Markets clear

$$Y = K^\alpha L^{1-\alpha} = C + K' - (1 - \delta) K + G$$

where aggregate capital and labor is the sum of asset holdings and the supply of labor efficiency units of all individuals in the economy respectively

$$K = \sum_{s \in \{e, r\}} \sum_{i=1}^I A_s(i)$$

$$L = \sum_{i=1}^{I_r-1} \sum_{\eta \in E} \int_A \eta e(i) d\mu_e(a, i, \eta)$$

and aggregate consumption is

$$C = \sum_{s \in \{e, r\}} \sum_{\eta \in E} \sum_{i=1}^I \left[ \int_A g_s^c(a, i, \eta) d\mu_s(a, i, \eta) \right].$$

5. The invariant distribution satisfies  $\mu = \Gamma(\mu)$ .

### 3 A Quantitative Benchmark Economy

We calibrate the model above to reproduce some features of the US economy during the eighties. We chose that period since retirement accounts (IRA's and 401(k)'s) were still not available, and therefore the social security system was closer to the pay-as-you-go system described in the model. Moreover, it had been in such a system for a long time, so presumably the old generations had time to adjust their asset holdings. We will talk later about the role played by retirement accounts and how do they change the default incentives in our model.

#### 3.1 Demographics and Employment Process

Each model period is taken to be 5 years. Individuals enter the economy at 20 and may live until age 85 (model period 13). At each point in time individuals supply  $e(i)\eta$  units of labor. The exogenous profile of age specific efficiency units  $e(i)$  is taken from Hansen (1993), who uses CPS data from 1979 to 1987, and is adjusted to our demographic setup through interpolation. The results are presented in Table 1.

For the stochastic idiosyncratic labor shocks, we discretize the process for log earnings estimated by Storesletten et al. (1999) using Tauchen's (1986) method with five states in the range  $0 \pm 1.5 \text{ st.dev.}$ <sup>7</sup> The resulting five-year process for  $\eta$  is described by the state space:

$$\eta \in E = [0.2755, 0.5249, 1.000, 1.9052, 3.6297]$$

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<sup>7</sup>In their Table 1, Storesletten, Telmer and Yaron (1999) estimate a yearly first order autoregressive process for individual log income with large persistence ( $\rho = 0.935$ ), using data from 1968 to 1991. This is the process that we discretize for our model. Other studies have also relied on these estimates. For example, Conesa and Krueger (1999) and Fernandez Villaverde and Krueger (2002) use a two-state and three-state discretization of the same process, respectively. In Storesletten et al. (2001) the authors discuss that the true process might be close to a unit root, which would still be consistent with a stationary equilibrium in a OLG setup (as opposed to an infinitely lived agent). This issue is relevant for our analysis, although we don't think the results would change by much.

Table 1: Demographics in the Benchmark Economy

Period	Age	$e$	$s$
1	20-24	0.36	1
2	25-29	0.46	1
3	30-34	0.53	1
4	35-39	0.59	1
5	40-44	0.63	1
6	45-49	0.64	1
7	50-54	0.64	1
8	55-59	0.61	1
9	60-64	0.56	1
10	65-69	0	0.54
11	70-74	0	0.52
12	75-79	0	0.44
13	80-84	0	0

and the transition matrix:

$$\pi = \begin{bmatrix} 0.4471 & 0.4007 & 0.1332 & 0.0180 & 0.0010 \\ 0.1821 & 0.4315 & 0.3012 & 0.0771 & 0.0082 \\ 0.0465 & 0.2316 & 0.4439 & 0.2316 & 0.0465 \\ 0.0082 & 0.0771 & 0.3012 & 0.4315 & 0.1821 \\ 0.0010 & 0.0180 & 0.1332 & 0.4007 & 0.4471 \end{bmatrix}$$

Finally, we assume that individuals survive with probability one until the age of 65 (the retirement age)<sup>8</sup> and after that age individuals may die according to an age specific mortality probabilities profile taken from the US Bureau of the Census, International Data Base. These probabilities have been slightly adjusted so as to reproduce the US dependency ratio (fraction of individuals of age +65 to 20-64) of 21%, as shown in Table 1.

## 3.2 Government and Social Security taxes

The role of the government in our model economy is twofold. The first is to run a pay-as-you-go social security system collecting taxes on labor earnings and paying pensions to retirees. In the initial steady state (or the benchmark economy), we set the social security replacement rate to 44%. Later, our experiment will be to reduce

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<sup>8</sup>The empirical probabilities of dying before 65 years old are of course positive, but small. Notice however that if we were to allow them to be positive no borrowing could ever be sustained in our framework.

Table 2: Calibration of Benchmark Economy

Parameters		Calibration		
		Targets	Results	
$\alpha$	0.360	rK/Y	0.360	0.360
$\beta$	0.992	K/Y	2.500	2.503
$\delta$	0.084	I/Y	0.210	0.214
$\phi$	0.113	Debt/Y	0.028	0.028

this rate to zero. The associated social security tax rate that balances the pension budget is around 9%, a realistic number in the US once Medicare and disability insurance is taken away.

With respect to current expenditures, we set exogenously unproductive government expenditures to be 20% of GDP, as in the US data. Given this number, the income tax rate is set endogenously to balance the government budget. This procedure implies an income tax of 22%, again a reasonable approximation for the US tax system.

### 3.3 Other Parameters

For the risk aversion coefficient we follow Mehra and Prescott (1985) that cite various empirical studies which suggest that the coefficient of risk aversion is between 1 and 2, and consequently we set  $\sigma = 1.5$ . We also set the capital share in output  $\alpha = 0.36$ , as suggested by NIPA data. The remaining parameters are simultaneously solved to match a set of targets for the U.S. economy. In particular, the value of the discount parameter  $\beta$ , the depreciation rate  $\delta$ , and the fraction of interest income kept by defaulters  $\phi$  are simultaneously calibrated to match a capital share in income of 0.36, an annual capital output ratio of 2.5, an investment rate of 21% and a debt-to-output ratio of 2.8% which corresponds to the rate of revolving (unsecured) debt to GDP between 1980-1989 in the US (Federal Reserve Statistical Release)<sup>9</sup>. The results of the calibration procedure (at a yearly frequency) are presented in Table 2.

Notice that we obtain a rather small value of  $\phi$  in the calibration exercise. This is, defaulters can keep only a small fraction (around 11%) of their interest income. While this might seem unrealistic, it is worth pointing out again that such a harsh punishment is required in our model to deliver the observed amount of debt in the U.S. economy.

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<sup>9</sup>This ratio increased significantly in the data between the 80s and the 90s. This is why our number is much smaller than the 7% used by Chetterjee et al. (2004), who calibrate their economy to the US in the 90s.

### 3.4 Assets, Debt, and Borrowing Limits in the Benchmark Economy

The model economy has been calibrated to match certain key ratios of the US economy. Hence it reproduces by construction  $G/Y$ ,  $I/Y$  and a realistic debt to output ratio. The average age profile of asset holdings of the initial steady state is also consistent with the empirical evidence. As seen in Figure 1, on average young individuals start accumulating wealth until they reach the age of 60-64 and after they exhaust those assets until they die. Notice also that young agents have on average negative assets, so that the aggregate debt-to-output ratio is non-zero. We do obtain some borrowing in equilibrium.

In our model, borrowing limits depends on the incentives to default on debts. Notice from Figure 2 that young individuals face more relaxed borrowing limits, since for these agents the cost of doing default is higher as they lose access to (compounded) interest income in all their savings and have a higher discount factor as compared to an old worker. The intuition is the following. Take a worker who starts retirement with some debt. This worker has the incentive to declare default. Indeed, the borrowing limit is zero at age 8, the period before retirement. Since there is no probability of death at age 9 (the period of retirement) death is not the reason why the limit is zero for age 8. However, a person starting retirement faces a very low discount factor and no uncertainty. Then this person has little incentive to save at the equilibrium interest rate, so the punishment is not severe and the person would be better off defaulting. Rolling this back to age 7, a similar thing is at work: the limit is low because an agent who is borrowing at this late stage in life has very little incentive to save (his discount factor will fall significantly two periods in the future). So, again, the punishment has little bite. Only when one is young does this effect get attenuated and the limit expands.

As in most models with incomplete markets, in our economy workers accumulate assets for two reasons: life cycle considerations (including retirement) and precautionary reasons, due to the positive probability of a long sequence of bad shocks that would make individuals hit the borrowing constraint and start to reduce current consumption. As we will see, in a world with endogenous borrowing constraints, the effects on precautionary savings are key to understand the aggregate effects of changes in policy, as a social security reform.

## 4 Effects of Eliminating Social Security

We now study the effects of a social security reform changing the replacement rate from 44% to 0%. We will perform this experiment in two cases. In the first one, we keep fixed the (endogenous) borrowing constraint of the benchmark economy, consequently the change in the social security regime does not change the age specific borrowing limits. We want to think of this case as the one analyzed in the previous

literature of social security (Imrohoroglu et al. (1995), Conesa and Krueger (1999), Fuster (1999), etc.). In contrast, in the second case (labelled Endogenous Constraints) borrowing constraints are allowed to adjust to the variation of default incentives induced by the elimination of social security. The difference between the results in the two cases will give us an idea of the quantitative importance of endogenous borrowing constraints in analyzing social security reform.

## 4.1 Fixed Borrowing Constraints

The results of this experiment can be seen in the top panel of Table 3. Notice that, as in previous quantitative studies, the elimination of the social security system increases the capital-output ratio and the saving rate. The magnitude of this change, about 37%, is in line with other related studies. For example, Imrohoroglu et al. (1995) report that changing the US social security replacement rate from 40% to zero increases the capital-output ratio by 42% in the model economy with zero population growth and certain lifetimes, which is the closest environment to our paper.<sup>10</sup> The increase in the capital stock is due to several factors. First, individuals save more to finance consumption during the retirement period and to insure against income risk since the social security benefits have been removed. And second, a PAYG pension system partially substitutes for missing annuity markets. Consequently, without these public pension benefits individuals have to save more in order to insure themselves against the risk of living more than expected. Hence, the aggregate saving rate and the capital-output ratio increases and the interest rate falls, increasing debt moderately.

## 4.2 Endogenous Borrowing Constraints

In the second case we perform the same experiment as before, i.e. eliminating the PAYG pension system. In contrast to the previous case, borrowing limits adjust to the change in individual incentives to default on previous debts. The results can be compared in Table 3. As before, the removal of the pension gives incentives to individuals to save more in order to finance consumption when retired. This mechanism increases the saving rate in the economy.

The key point, however, is that in this case the removal of social security benefits also relaxes the borrowing limits faced by agents, as seen in Figure 3. The intuition is that without social security individuals have to save on their own for retirement. Then losing interest income on their savings upon default is more costly and incentives to default are lower. The lower incentives to default translates into more relaxed

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<sup>10</sup>Unfortunately, Imrohoroglu et al. (1995) do not report the experiment with zero population growth and uncertain lifetimes (see their Table 2). Moreover, their results are not fully comparable to ours since they have productivity growth in the model, a different income process (including an unemployment state), and a value of  $\sigma = 2$ .

Table 3: Aggregate Effects of Eliminating Social Security

		<b>Fixed Borrowing Constraints</b>	
	Initial S.State	Final S.State	Change (%)
$\tau_{ss}$	0.09	0.00	–
$\tau$	0.22	0.18	–
K/Y	2.50	3.44	37.29
I/Y	0.21	0.29	37.29
Debt/Y	0.03	0.03	–11.51
		<b>Endogenous Borrowing Constraints</b>	
	Initial S.State	Final S.State	Change (%)
$\tau_{ss}$	0.09	0.00	–
$\tau$	0.22	0.18	–
K/Y	2.50	3.30	31.72
I/Y	0.21	0.28	31.72
Debt/Y	0.03	0.12	338.37

borrowing limits, in particular for young agents which still have to build most of their savings for retirement.

The top panel in Figure 4 shows the average savings rate for different age groups, before and after the elimination of social security. As expected, young agents benefit from the relaxation of borrowing limits by increasing their debt, while older agents save more for retirement in the absence of social security. The bottom panel of Figure 4 shows the savings rate of an individual in the third age category (30-34 years old), with the average asset holdings for that age group, and different realizations of the current productivity shock. As we can see, the relaxation of borrowing limits after the elimination of social security allows young agents to borrow more in bad states. More importantly, young agents also save less in good states, since they can enter more easily into debt in future bad states.

More relaxed borrowing constraints translate into less precautionary savings. This effect goes in the opposite direction to the conventional increase in savings due to the need of self-financing for retirement. Therefore, in contrast to an economy with exogenous borrowing constraints, the aggregate saving rate and the capital-output ratio increases less with the removal of social security. In particular, in our economy the capital-output ratio and the saving rate increases by 31% compared to the 37% increase with fixed borrowing limits. Consequently, *the introduction of endogenous borrowing constraints significantly reduces the increase in the saving rate due to the elimination of social security.* Moreover, the social security reform is followed by a

Table 4: Effects of Eliminating Social Security: No-Income Risk

		<b>Fixed Borrowing Constraints</b>	
	Initial S.State	Final S.State	Change (%)
K/Y	2.44	3.08	26.00
I/Y	0.21	0.27	26.00
Debt/Y	0.00	0.00	—
		<b>Endogenous Borrowing Constraints</b>	
	Initial S.State	Final S.State	Change (%)
K/Y	2.44	3.08	26.00
I/Y	0.21	0.27	26.00
Debt/Y	0.00	0.00	—

debt boom, since young agents benefit from more relaxed borrowing limits to smooth consumption during life cycle.

### 4.3 The Role of Idiosyncratic Income Risk

To further understand the importance of idiosyncratic income uncertainty when analyzing the effects social security on the incentives to default on debts, we performed the same set of experiments in a model without income risk. For this, we set the value of the stochastic shock to be always equal to its expected value. The rest of the parameters for the benchmark remain the same. This experiment is important to compare our previous results with the ones obtained by Andolfatto and Gervais (2001), namely that in an OLG models without income risk there are no quantitative differences between modelling borrowing constraints exogenously or endogenously to analyze the effects of social security.

With the elimination of income risk, individuals do not have to self-insure against bad shocks. Consequently, the initial steady state displays a lower capital-output ratio, as observed in Table 4. With a lower capital stock the interest rate and the cost of borrowing are higher, yielding a virtually zero debt-to-output ratio. After the reform, the increase in the capital stock is now smaller because the elimination of social security does not increase precautionary savings by much. This reflects the fact that, without income risk, the PAYG social security system plays no insurance role against lifetime earnings differences. In addition, the differences between the fixed vs. endogenous constraints are almost zero: in our calibrated model, the elimination of social security increases the saving rate by 26% in both cases.

The role of endogenous borrowing constraints in our model depends crucially on

Table 5: Effects of Eliminating Social Security: No-Life Cycle

		<b>Fixed Borrowing Constraints</b>	
	Initial S.State	Final S.State	Change (%)
K/Y	2.51	3.44	36.83
I/Y	0.21	0.29	36.83
Debt/Y	0.02	0.02	27.52
		<b>Endogenous Borrowing Constraints</b>	
	Initial S.State	Final S.State	Change (%)
K/Y	2.51	3.35	33.42
I/Y	0.21	0.29	33.42
Debt/Y	0.02	0.07	244.75

the fact that, with income risk, more relaxed borrowing constraints give individuals less incentives to save for precautionary reasons. Abstracting from income risk shuts down the main channel of our model and does not give a fair chance for endogenous borrowing limits to matter.

#### 4.4 The Role of Life Cycle

We also performed the same set of experiments in a model without deterministic life-cycle profile, this is, in a model in which workers of all ages have the same expected labor income until retirement. The rest of the parameters for the benchmark economy remain the same. The results are presented in Table 5. Contrarily to the elimination of income risk, without life cycle the differences between the models with fixed and endogenous borrowing limits remain, although they are less pronounced. The reason is that in the absence of a steep earnings profile, agents do not need to borrow so heavily when young in order to smooth consumption over the life-cycle. Consequently, after the elimination of social security, the debt boom in the model economy with endogeneous borrowing constraints is attenuated and the increase in the saving rate is more in line with the results of the standard case with fixed borrowing limits.

We conclude from the last two exercises that, *even though consumption smoothing over the life-cycle plays an important amplification role, it is precautionary savings triggered by uninsurable income risk the main source of differences in the predictions of models with fixed and endogenous borrowing limits.*

Table 6: Calibration of Alternative Economies

Exogenous Borrowing Constraint				
		Targets		Results
$\beta$	0.992	K/Y	2.500	2.496
$\delta$	0.085	I/Y	0.210	0.213
$b$	0.008	Debt/Y	0.028	0.028
Natural Borrowing Limit				
		Targets		Results
$\beta$	0.992	K/Y	2.500	2.505
$\delta$	0.085	I/Y	0.210	0.214
$\psi$	0.043	Debt/Y	0.028	0.028

## 4.5 Alternative Borrowing Constraints

A different approach to put our results in perspective with respect to the existing literature is to compare the effects of eliminating social security in our model of endogenous borrowing constraints and in two alternative models, calibrated as to match the same set of statistics as in the benchmark economy, described in Table 2.

The first alternative model just assumes an *exogenous borrowing constraint*  $a' \geq -b$ , equal for all agents. With  $b = 0$ , we are back in the original setup of Imrohoroglu et al. (1995). By calibrating  $b$  (and the other parameters) to the observed debt to output ratio, we get a model that allows for debt, but in which the borrowing limits are independent on changes in policy.

The second, and more interesting, alternative is a model based on the *natural borrowing limit*. Aiyagari (1994) argues that the present value of all future earnings and transfers in the *worst* possible scenario, which in our case corresponds to

$$W(i) \equiv \sum_{j=i+1}^{I_r-1} \left( \frac{1}{1 + (1 - \tau)r} \right)^{j-i} (1 - \tau)(1 - \tau_{ss}) we(j) \eta_{\min} \\ + \left( \frac{1}{1 + (1 - \tau)r} \right)^{I_r-i} TR_{ss}$$

for a worker of age  $i$ , defines a natural borrowing limit, in the sense that any level of debt beyond this point cannot be paid back if things go bad enough without violating the consumption non-negativity constraint. We assume that workers can only borrow up to a fraction  $\psi$  of this natural limit:  $a' \geq -\psi W(i)$ . This parameter  $\psi$  will help us to obtain in equilibrium the observed debt to output ratio.

Table 7: Eliminating Social Security in Alternative Economies

		<b>Exogenous Borrowing Constraint</b>	
	Initial S.State	Final S.State	Change (%)
K/Y	2.50	3.43	37.37
I/Y	0.21	0.29	37.37
Debt/Y	0.03	0.02	-17.35
		<b>Natural Borrowing Limit</b>	
	Initial S.State	Final S.State	Change (%)
K/Y	2.50	3.42	36.44
I/Y	0.21	0.29	36.44
Debt/Y	0.03	0.04	45.39
		<b>Endogenous Borrowing Constraint</b>	
	Initial S.State	Final S.State	Change (%)
K/Y	2.50	3.30	31.72
I/Y	0.21	0.28	31.72
Debt/Y	0.03	0.12	338.37

Keeping constant the risk-aversion coefficient  $\sigma = 1.5$ , the two alternative model economies are calibrated to match the same set of statistics for the benchmark economy. The results are presented in Table 6. As expected, the tightness of the borrowing constraint (parametrized by  $b$  in the first case, and  $\psi$  in the second) is key to match the observed debt to output ratio. The two calibration exercises deliver also different values for the discount factor  $\beta$ , but the differences are too small to be perceived at an annual frequency.

Table 7 summarizes the results obtained by eliminating social security (reducing the replacement rate to zero) in the two alternative economies, and compares them to the results of the same experiment in our benchmark model with endogenous borrowing constraints.

The first thing to notice is that the results of the model with exogenous borrowing limits are quite similar to the ones obtained by keeping fixed the endogenous borrowing constraint in the benchmark economy after the reform (see Table 3). With exogenous borrowing constraints, the steady state capital to output ratio increases by 37% after the reform, compared to 31% in the benchmark model in which the borrowing limit adjusts endogenously. A somehow obvious conclusion is that the differences between our results and the current literature do not arise from the existence of debt *per se*, but from the response of borrowing limits to changes in the environment.

Table 8: Welfare Effects of Eliminating Social Security

	Initial Utility	Final Utility	E.V. (%)
Exogenous Borr. Constraint	−55.11	−51.12	16.25
Natural Borr. Limit	−55.50	−51.29	17.12
Endogenous Borr. Constraint	−55.52	−50.82	19.34

The most important comparison is between the model based on the natural borrowing limit and our benchmark economy. Both models provide borrowing limits which differ by age (in the two cases, becoming tighter as workers grow old). Moreover, in the two models a social security reform does change these limits, as seen in Figure 5. In the model based on the natural borrowing limit, general equilibrium effects on wages, taxes and transfers are responsible for these changes. However, the results of the experiment are significantly different. The steady state capital to output ratio increases by 36% in the alternative model (closer to the result obtained with exogenous borrowing constraints), compared to 31% in the benchmark economy.

We conclude from this exercise that the *differences between our results and the current literature do not arise from the existence nor the endogeneity of debt per se, but from a particular response of borrowing limits to changes in the environment induced by the commitment problem.*

## 4.6 Welfare Effects

In order to quantify the welfare effects of alternative social security regimes we follow the standard practice which consists of calculating a consumption equivalent variation measure. This is, we ask by how much (in percent) the consumption of a newborn in the initial steady state with social security has to be increased (decreased) in all future periods and contingencies so as to attain the same level of expected utility as a newborn in the final steady state, without social security:

$$E.V. = \left( \frac{v_e^{final}(0, 1, 1)}{v_e^{initial}(0, 1, 1)} \right)^{\frac{1}{1-\sigma}} - 1$$

We are aware that this measure does not represent the total welfare gains (or cost) of the social security reform, since we do not take into account the transition from one steady state to the other. Still, it does provide an estimate of the relative value of the level of insurance provided by social security, compared to the additional disposable income that can be attained in an economy without such insurance.

Table 8 presents the results of this calculation for the three alternative economies analyzed in the previous sub-section. As expected, in the three cases eliminating social security improve the ex-ante welfare of newborns. Moreover, the gains are large,

equivalent to an increase in lifetime consumption of about 16-19%. Notice that the increase in welfare is larger in the economy with endogenous borrowing constraints. The reason is that, in this economy, the elimination of social security reduces the need for precautionary savings which is a costly mechanism of self-insurance.

## 5 Introducing Retirement Accounts

The social security reform analyzed in the previous section allows us to compare our results with most of the current literature. However, this type of reform is a theoretical extreme which does not correspond to the observed attempts to reform social security in some Latin American and European countries. In all these cases, the generosity of the government managed PAYG system is significantly reduced, but some form of retirement accounts are created instead to promote private savings for retirement. There are three reasons why we should consider retirement accounts as a different asset in our analysis: First, because they are less liquid, since early withdrawal is either prohibited or subject to high penalties. Second, because they receive a special tax treatment. Finally, and more importantly for our purposes, because retirement accounts cannot be confiscated by creditors upon default.

We extend the model to add retirement accounts, and perform the following experiment. Starting from the same benchmark economy as before (with 44% social security replacement rate and no retirement accounts), we now compare this steady state to one without social security (zero replacement rate) but with the possibility to save using retirement accounts. We believe this is a more realistic description of a feasible, politically implementable, social security reform.

### 5.1 A New Environment with Two Assets

The final steady state of the experiment is described by a model with two assets. Individual savings can now take the form of liquid assets ( $a$ ) or retirement accounts ( $d$ ). We model retirement accounts following the general rules that characterize the functioning of the most popular retirement accounts (401(k) and IRAs) in the U.S., which are summarized in Appendix A. Other countries (Chile, Mexico, UK, etc.) have introduced similar financial instruments, differing in the limits to contributions, tax treatment, and penalties for early withdrawal.<sup>11</sup>

In our second version of the model, only workers accumulate retirement accounts, choosing a percent of their labor income as their deposit in each period. We impose

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<sup>11</sup>One of the issues we abstract from in our analysis is the possibility of using retirement accounts as collateral for loans. This is possible in the U.S. legislation for 401(k)'s, where workers can borrow from their employers (but not from third parties) using these accounts as collateral. Notice that IRA's cannot be used as collateral for loans, and neither can retirement accounts implemented in other countries as Chile. Adding loans backed up by retirement accounts would significantly complicate our analysis.

minimum ( $\Delta_{\min}$ ) and maximum ( $\Delta_{\max}$ ) contributions, as percent of individuals labor income. This deposit is deducted from the current income tax. Retirement accounts do not pay capital income taxes. Workers can withdraw from retirement accounts, but paying a penalty ( $\tau_{pen}$ ) proportional to the amount withdrew plus the deferred income tax. Retired agents can withdraw from the retirement account without paying the penalty, only the deferred income tax. There is a minimum amount required to withdraw depending on age  $[\varpi(i)]$ . Finally, and this is a key point, retirement accounts are protected from creditors claims upon a bankruptcy declaration. This means that an individual can maintain the full property of funds invested in retirement accounts upon default.<sup>12</sup>

The new model features an interesting portfolio choice. Agents have to decide how much to save in each type of asset. The liquid asset is more suitable for precautionary reasons, since it can be used at no cost in the case of bad shocks. On the other hand, retirement accounts are better instruments to save for retirement, because of the tax incentives, but are less suitable to smooth consumption during worker's life, since early withdrawals are heavily penalized. This differentiated role for the two assets allows us to pin down the optimal portfolio choice.

Notice also that borrowing constraints are going to depend now not only on age, but on the stock of retirement accounts. Everything else equal, we should expect agents with more retirement accounts to face tighter borrowing limits for the liquid asset. The reason is that, since retirement accounts cannot be confiscated upon default, these agents' savings for retirement are more protected and therefore the punishment for default is less costly for them.

## 5.2 Effects of Social Security Reform

Suppose that an economy starts in an initial steady state corresponding to our Benchmark economy, with a social security replacement rate of 44% and no retirement accounts. The following reform is introduced: (i) the replacement rate is reduced to zero, and (ii) a system of retirement accounts is created. We set the minimum and maximum contributions to retirement accounts to 2% and 8% of worker's labor income, respectively. We also choose a penalty for early withdrawal of 50%, and follow the same rules for minimum withdrawals after retirement as in the US legislation.<sup>13</sup>

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<sup>12</sup>The formalization of an equilibrium for this new environment is presented in Appendix B. The resulting model is close to Imrohoroglu et al (1998), except that we abstract from the unemployment state (in which early withdrawals from retirement accounts are allowed) and, of course, we use endogenous borrowing constraints instead of a zero-borrowing restriction.

<sup>13</sup>The experiment does not intend to capture a particular experience of social security reform, neither the current U.S. system. The parameters are chosen just as an illustrative example. For example, neither the U.S. nor the U.K. have minimum contributions to retirement accounts, but in Chile this is 10% of worker's wages and in Mexico, around 6%. The maximum amount of tax deductible contributions is a difficult number to obtain, since legislations set absolute instead of

Table 9: Eliminating Social Security with Retirement Accounts

		<b>Fixed Borrowing Constraints</b>	
	Initial S.State	Final S.State	Change (%)
$\tau_{ss}$	0.09	0.00	–
$\tau$	0.22	0.19	–
K/Y	2.50	3.57	42.79
I/Y	0.21	0.31	42.79
Debt/Y	0.03	0.03	0.84
RA/K	0.00	0.36	–
		<b>Endogenous Borrowing Constraints</b>	
	Initial S.State	Final S.State	Change (%)
$\tau_{ss}$	0.09	0.00	–
$\tau$	0.22	0.18	–
K/Y	2.50	3.50	40.01
I/Y	0.21	0.30	40.01
Debt/Y	0.03	0.08	197.02
RA/K	0.00	0.35	–

In Table 9, we analyze the steady state after the reform to the initial steady state. As before, we perform one experiment with fixed borrowing constraints, and another with endogenous borrowing limits.

The main results of this experiment in the model economy with retirement accounts are qualitatively similar to the ones obtained in the previous economy with one asset. That is, when borrowing constraints are allowed to change as a function of the different incentives to default, eliminating social security translates into a less pronounced increase in the saving rate and a debt boom. However, in this case, the differences between the model with exogenous and endogenous borrowing are less important. Endogenizing borrowing constraints, the capital-output ratio and the savings rate increases by 40% compared to the 43% increase with fixed borrowing limits.

We expected to obtain this result because retirement accounts are protected from creditors claims upon default, so replacing the PAYG system with private savings through this instrument is not going to have an important impact in the borrowing limits. Still, since retirement accounts and liquid assets are imperfect substitutes

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relative caps. Finally, in Chile and Mexico early withdrawals are prohibited (except for unemployment or disability), while in the U.S. they are allowed with a 10% penalty. See Piñera (1996) for a description of the Chilean system, Soliz (2003) for Mexico, and Disney et al. (2003) for the U.K.

borrowing constraints are less tight after the reform. Agents which default on their debts can build savings for retirement without any punishment through retirement accounts, but still lose partially interest income on their savings through liquid assets, which are more suitable to protect them from bad income shocks in the future when borrowing is precluded. More relaxed borrowing constraints translate again into more debt and less precautionary savings, but not to the same extent as in the model with only one asset.

This effect can be seen in Figure 6, in which we plot the borrowing limits by age for two different levels of retirement account holdings.<sup>14</sup> In the top panel, we observe that conditional on having low retirement accounts the borrowing constraint is relaxed for all ages after the reform, as explained in the previous paragraph. However, comparing the two panels, the borrowing limits after the reform are tighter for individuals with higher retirement accounts holdings. Savings in retirement accounts protect workers in the case of default, making financial intermediaries less willing to lend them in equilibrium and offsetting the initial effect of eliminating social security.

Notice from Table 9 that the optimal portfolio of households between liquid assets and retirement accounts is similar (slightly more than one third in retirement accounts) in the two setups (endogenous and fixed borrowing constraints). With endogenous borrowing constraints one would expect individuals, facing more relaxed constraints so they do not need to save much for precautionary reasons via the liquid asset, to tilt their portfolio towards retirement accounts. However, if anything we observe the opposite. The reason, as shown in Figure 6, is that accumulating retirement accounts actually tightens worker's borrowing constraints, for a given social security system.

Finally, a natural question is whether the minimum and maximum contribution limits bind. For the case of endogenous borrowing limits, the top panel of Figure 8 shows that as agents become older (therefore richer and closer to retirement) they save more on retirement accounts. For these agents the maximum contribution limit binds. The bottom panel of Figure 8 shows the contribution to retirement accounts, as a percent of earnings, of an individual in the third age category (30-34 years old), with the average asset holdings for that age group, and different realizations of the current productivity shock. Contrarily to the savings rate in liquid assets, the contribution rate to retirement accounts is larger for agents in bad states, for which the maximum limit again binds. The reason is that agents partially smooth their (absolute) savings for retirement across states by adjusting their liquid asset holdings.

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<sup>14</sup>Following the notation in the Appendix, we plot the endogenous borrowing constraint  $-b(d', i)$  for all ages and two different levels  $d'_{low} < d'_{high}$ . These are *not* equilibrium retirement account holdings in any sense.

Table 10: Eliminating Social Security with Retirement Accounts: Low Penalty for Early Withdrawal

		<b>Fixed Borrowing Constraints</b>	
	Initial S.State	Final S.State	Change (%)
K/Y	2.50	3.59	43.32
I/Y	0.21	0.31	43.32
Debt/Y	0.03	0.03	3.49
RA/K	0.00	0.40	—
		<b>Endogenous Borrowing Constraints</b>	
	Initial S.State	Final S.State	Change (%)
K/Y	2.50	3.54	41.78
I/Y	0.21	0.30	41.78
Debt/Y	0.03	0.09	201.02
RA/K	0.00	0.39	—

### 5.3 The Role of Penalties and Limits to Contributions

We analyze the effects of two additional experiments. The first (see Table 10 ) consists of making retirement accounts more liquid by considering a lower penalty for early withdrawal,  $\tau_{pen} = 0.10$ . And the second (see Table 11) is an increase in the maximum contribution limit in these accounts by setting  $\Delta_{max} = 0.15$ . In both cases, individuals invest a higher share of their wealth in retirement accounts as compared to the baseline experiment with two assets. The fact that in this case individuals are more protected in the event of default means that they face tighter borrowing limits. Consequently, the reduction of precautionary savings associated with the relaxation of the (endogenous) borrowing constraints after the social security reform is lower, and the difference between the predictions of the model economy with and without endogenous borrowing constraints is less important.

### 5.4 Welfare Effects

Finally, we also compute the consumption equivalent variation of a newborn in the initial steady state with social security so as to attain the same level of expected utility as a newborn in the final steady state, without social security and with retirement accounts. The results are presented in Table 12.

Perhaps surprisingly, the welfare gains of eliminating social security are larger if the government introduces retirement accounts (see Table 8 for comparison purposes). Even though retirement accounts have a component of mandatory savings, they do

Table 11: Eliminating Social Security with Retirement Accounts: High Maximum Contribution Limit

		<b>Fixed Borrowing Constraints</b>	
	Initial S.State	Final S.State	Change (%)
K/Y	2.50	3.69	47.55
I/Y	0.21	0.32	47.55
Debt/Y	0.03	0.03	5.48
RA/K	0.00	0.57	—
		<b>Endogenous Borrowing Constraints</b>	
	Initial S.State	Final S.State	Change (%)
K/Y	2.50	3.67	46.44
I/Y	0.21	0.31	46.44
Debt/Y	0.03	0.05	81.98
RA/K	0.00	0.58	—

Table 12: Welfare Effects of Eliminating Social Security with Retirement Accounts

	Initial Utility	Final Utility	E.V.
Baseline Experiment	−5.99	−5.45	21.00
Low Penalty for Early Withdrawal	−5.99	−5.44	21.37
High Maximum Contribution Limit	−5.99	−5.45	20.83

provide a cheaper mechanism of insurance than individual's precautionary savings. The gains are larger if the penalty for early withdrawal is lower, and if the maximum contribution limit is higher. The reason is that, the significant tax deductions obtained while building retirement accounts and the fact that any interest income earned are accumulated tax free allow individuals to attain higher consumption streams over the life-cycle and higher welfare.

## 6 Conclusions

We have shown that when borrowing constraints are endogenous and idiosyncratic income risk is important, the magnitude of the increase in the capital to output ratio and the saving rate due to a social security reform is reduced. The reason is that with the elimination of social security individuals have less incentives to default on debts. The relaxation of borrowing constraints associated to this fact implies that the agents need to save less for precautionary reasons, and this effect goes in the opposite direction to the traditional increase in savings associated with the reform of public pensions.

From a quantitative perspective, the effects are significant but not large, especially if we allow for retirement accounts protected from creditors upon default. Still, our mechanism goes in the direction of the empirical literature, which finds that current models overestimate the impact of social security reforms on the saving rate.

There are two important directions for future research that we plan to pursue. One is to move to a credit contracting framework in which interest rates are type specific and there is default in equilibrium, as in Chatterjee et al. (2004). The effect of a social security reform on default rates is an interesting unexplored issue. Second, it seems relevant to add a third asset to the model (as durables or housing) which could be used as collateral for loans, in the direction of Fernandez Villaverde and Krueger (2002). Then changes in the social security system might have an additional impact on borrowing limits through the price of such an asset.

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## A The Basics of Retirement Accounts: The 401(k) and IRAs

The first appendix describes briefly the current legislation on the two most important types of retirement accounts in the U.S: 401(k) and IRAs. We focus on the features of both plans that are relevant for our model, as the limits to contributions, tax treatment, and penalties for early withdrawal. The features of retirement accounts in the U.S. (401k and IRAs) are similar to the functioning of these assets in other countries like the Tax Exempt Special Savings Accounts (TESSA) and the Individual Savings Account (ISA) in the United Kingdom.

- A 401(k) plan is a retirement plan set up by an employer, while an Individual Retirement Account (IRA) is a personal retirement savings plan opened with a bank trust or custodial company. Both are simple ways to build up retirement savings and get significant tax benefits while an individual is working. When a worker joins a 401(k), he agrees to contribute part of his salary to the 401(k) account. The money contributed is deducted from the paycheck before income taxes are taken out, although social security taxes are levied over the gross wage before deducting any contribution to a retirement account. Consequently, a worker does not pay income taxes on contributions and any interest it earns until the money is withdrawn from the account.
- Some plans require a minimum contribution to the 401k but this feature depends on the rules of the particular plan. For instance, some require participants to contribute at least 1-2 percent of their salary in order to offset administration costs.
- Regarding maximum contributions, each company decides the contribution limits for its own plan, within the IRS guidelines of a maximum individual contribution limit of 20% (in 2001) of annual earnings.
- Workers who just changed jobs or get unemployed can rollover their previous retirement plans [e. g. 401(k)] to IRAs to continue to benefit from tax-deferred growth. Moreover, there is no penalty on the rollover amount from the previous retirement plan to an IRA. This also means that a unemployed individual cannot benefit from an employer-sponsored retirement account [401(k)] but can continue to invest in an individual retirement account which is also a tax-deferred investment vehicle.
- Withdrawals before 59.5 years old are in general subject to an income tax and an early withdrawal penalty unless some specific conditions apply (e.g. disability). After that age, individuals may withdraw balances without paying the penalty but to make sure that most of the retirement benefits are paid to retired individuals rather than to their beneficiaries after death, the payments from retirement accounts must begin no later than the required beginning date which is the retirement age or 70 and 1/2 if an

individual is not retired, and there is a minimum distribution amount which depends on the expected remaining life span.

- Because both programs (401k and IRA) are personal investment programs for retirement, they are protected by pension (ERISA) laws, which means that the benefits may not be used as security for loans outside the program including the additional protection of the funds from garnishment by creditors.
- Perhaps, one of the most important differences between 401(k) and IRAs concerns the possibility to borrow against these accounts. Some 401(k)s allow participants to borrow up to 50% of the vested amount in the account, while this is not the case with IRAs. In this sense, an individual may wish to roll old 401(k) into new employer's 401(k) plan to preserve the ability to borrow. If an individual changes or loses the job, and does not roll over into another 401(k) plan, then it has to repay immediately the loan, otherwise it is considered an early withdrawal and is subject to income taxation plus penalties. The same happens if an individual defaults on the loan attached to a 401(k) account.

## B The Model with Two-Assets

This appendix formalizes the description of the Two-Assets economy. For compactness, we only present those equations and problems which differ to the corresponding expressions in the One-Asset economy. We keep referring to  $a$  as the liquid asset, and introduce the notation  $d$  for retirement accounts. We start with the consumer's value functions (default values and endogenous borrowing constraints) and then state the definition of equilibrium for this economy.

### Value of default:

a) Last period of life ( $i = I$ ):

$$v_r^*(a, d, I) = \frac{[TR_{ss} + (1 + \phi r (1 - \tau)) a + (1 - \tau) (1 + r) d]^{1-\sigma}}{1 - \sigma}$$

b) At age  $i = \{I_r, \dots, I - 1\}$ :

$$v_r^*(a, d, i) = \max_{\{c, a', d'\}} \left\{ \frac{c^{1-\sigma}}{1 - \sigma} + \beta s(i) v_r^*(a', d', i + 1) \right\}$$

$$\begin{aligned} s.t. \quad c + a' + d' &= TR_{ss} + (1 + \phi r (1 - \tau)) a + (1 + r) d - \tau \Delta d \\ \Delta d &= (1 + r) d - d' \\ a' &\geq 0 \\ \Delta d &\in [\varpi(i) (1 + r) d, (1 + r) d] \end{aligned}$$

c) Last period of working life ( $i = I_r - 1$ ):

$$v_e^*(a, d, I_r - 1, \eta) = \max_{\{c, a', d'\}} \left\{ \frac{c^{1-\sigma}}{1 - \sigma} + \beta v_r^*(a', d', I_r) \right\}$$

$$\begin{aligned} s.t. \quad c + a' + d' &= (1 - \tau) (1 - \tau_{ss}) \eta we(I_r - 1) + (1 + \phi r (1 - \tau)) a \\ &\quad + (1 + r) d + \tau \Delta d - \tau_{pen}(I_r - 1) \max\{-\Delta d, 0\} \\ \Delta d &= d' - (1 + r) d \\ a' &\geq 0 \\ \Delta d &\in [-(1 + r) d, 0] \quad \text{or} \quad \frac{\Delta d}{\eta we(I_r - 1)} \in [\Delta_{\min}, \Delta_{\max}] \end{aligned}$$

d) At ages  $i = \{1, \dots, I_r - 2\}$ :

$$v_e^*(a, d, i, \eta) = \max_{\{c, a', d'\}} \left\{ u(c) + \beta \sum_{\eta' \in E} \pi(\eta, \eta') v_e^*(a', d', i+1, \eta') \right\}$$

$$s.t. \quad c + a' + d' = (1 - \tau)(1 - \tau_{ss}) \eta we(i) + (1 + \phi r(1 - \tau)) a + (1 + r)d + \tau \Delta d - \tau_{pen}(i) \max\{-\Delta d, 0\}$$

$$\Delta d = d' - (1 + r)d$$

$$a' \geq 0$$

$$\Delta d \in [-(1 + r)d, 0] \quad \text{or} \quad \frac{\Delta d}{\eta we(i)} \in [\Delta_{\min}, \Delta_{\max}]$$

### Consumer's Problem with Endogenous Borrowing Constraints:

a) Last period of life ( $i = I$ ):

$$v_r(a, d, I) = \frac{[TR_{ss} + (1 + r(1 - \tau))a + (1 - \tau)(1 + r)d]^{1-\sigma}}{1 - \sigma}$$

b) At ages  $i = \{I_r, \dots, I - 1\}$ :

$$v_r(a, d, i) = \max_{\{c, a', d'\}} \left\{ \frac{c^{1-\sigma}}{1 - \sigma} + \beta s(i) v_r(a', d', i+1) \right\}$$

$$s.t. \quad c + a' + d' = TR_{ss} + (1 + r(1 - \tau))a + (1 + r)d - \tau \Delta d$$

$$\Delta d = (1 + r)d - d'$$

$$a' \geq 0$$

$$\Delta d \in [\varpi(i)(1 + r)d, (1 + r)d]$$

c) Last period of working life ( $i = I_r - 1$ ):

$$v_e(a, d, I_r - 1, \eta) = \max_{\{c, a', d'\}} \left\{ \frac{c^{1-\sigma}}{1 - \sigma} + \beta v_r(a', d', I_r) \right\}$$

$$s.t. \quad c + a' + d' = (1 - \tau)(1 - \tau_{ss}) \eta we(I_r - 1) + (1 + r(1 - \tau))a + (1 + r)d + \tau \Delta d - \tau_{pen}(I_r - 1) \max\{-\Delta d, 0\}$$

$$\Delta d = d' - (1 + r)d$$

$$a' \geq 0$$

$$\Delta d \in [-(1 + r)d, 0] \quad \text{or} \quad \frac{\Delta d}{\eta we(I_r - 1)} \in [\Delta_{\min}, \Delta_{\max}]$$

d) At ages  $i = \{1, \dots, I_r - 2\}$ :

$$\begin{aligned}
v_e(a, d, i, \eta) &= \max_{\{c, a', d'\}} \left\{ \frac{c^{1-\sigma}}{1-\sigma} + \beta \sum_{\eta' \in E} \pi(\eta, \eta') v_e(a', d', i+1, \eta') \right\} \\
s.t. \quad c + a' + d' &= (1-\tau)(1-\tau_{ss})\eta we(i) + (1+r(1-\tau))a + (1+r)d \\
&\quad + \tau \Delta d - \tau_{pen}(i) \max\{-\Delta d, 0\} \\
\Delta d &= d' - (1+r)d \\
a' &\geq -b(d', i) \\
\Delta d &\in [-(1+r)d, 0] \quad \text{or} \quad \frac{\Delta d}{\eta we(i)} \in [\Delta_{\min}, \Delta_{\max}]
\end{aligned}$$

where the endogenous borrowing constraint  $-b(d', i)$  satisfies

$$v_e(-b(d', i), d', i+1, \eta') \geq v_e^*(0, d', i+1, \eta') \quad \forall \eta' \in E$$

### Definition of a Stationary Equilibrium:

A Stationary Equilibrium is a set of value functions, optimal decision rules, price functions, a set of government policies, aggregate law of motion  $\Gamma$ , invariant distribution  $\mu$ , marginal distributions

$$\mu_s(i) = \sum_{\eta \in E} \int_{A \times D} d\mu_s(a, d, i, \eta)$$

and partial sums

$$A_s(i) = \sum_{\eta \in E} \int_{A \times D} a d\mu_s(a, d, i, \eta)$$

$$D_s(i) = \sum_{\eta \in E} \int_{A \times D} d d\mu_s(a, d, i, \eta)$$

such that:

1. Given prices, taxes, transfers, and aggregate law of motion, consumers optimize
2. Price functions satisfy marginal conditions from firm's problem
3. Government budget constraints are satisfied

$$TR_{ss} \sum_{i=I_r}^I \mu_r(i) = \tau_{ss} w \sum_{\eta \in E} \sum_{i=1}^{I_r-1} \eta e(i) \int_{A \times D} \mu_e(a, d, i, \eta).$$

and

$$\begin{aligned}
G = & \tau \left[ (1 - \tau_{ss}) w \sum_{\eta \in E} \sum_{i=1}^{I_r-1} \eta e(i) \int_{A \times D} \mu_e(a, d, i, \eta) + r \sum_{s \in \{e, r\}} \sum_{i=2}^I A_s(i) \right] \\
& + \tau \sum_{s \in \{e, r\}} \sum_{i=1}^I \left[ (1 + r) D_s(i) - \sum_{\eta \in E} \int_{A \times D} g_s^d(a, d, i, \eta) d\mu_s(a, d, i, \eta) \right] \\
& + \sum_{i=I_r}^I (1 - s(i)) \int_{A \times D} [g_r^a(a, d, i) + g_r^d(a, d, i)] d\mu_r(a, d, i) \\
& + \sum_{i=1}^{I_r-1} \tau_{pen}(i) \int_{A \times D} \max[(1 + r) d - g_e^d(a, d, i, \eta), 0] d\mu_e(a, d, i, \eta)
\end{aligned}$$

4. Markets clear

$$Y = K^\alpha L^{1-\alpha} - \delta K = C + K' - K + G$$

with:

$$K = \sum_{s \in \{e, r\}} \sum_{i=1}^I [A_s(i) + D_s(i)]$$

5. The invariant distribution satisfies  $\mu = \Gamma(\mu)$ .

Figure 1: Age Profile of Assets and Savings

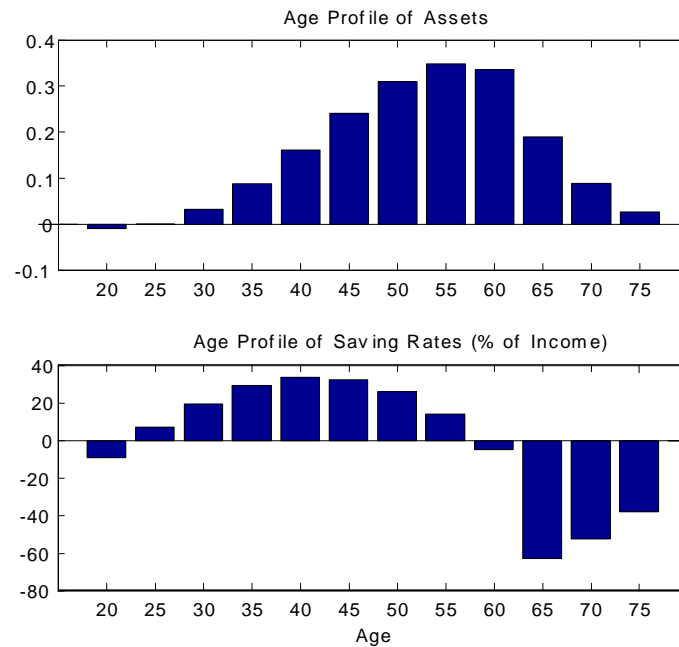


Figure 2: Age Profile of Debt and Endogenous Borrowing Constraints

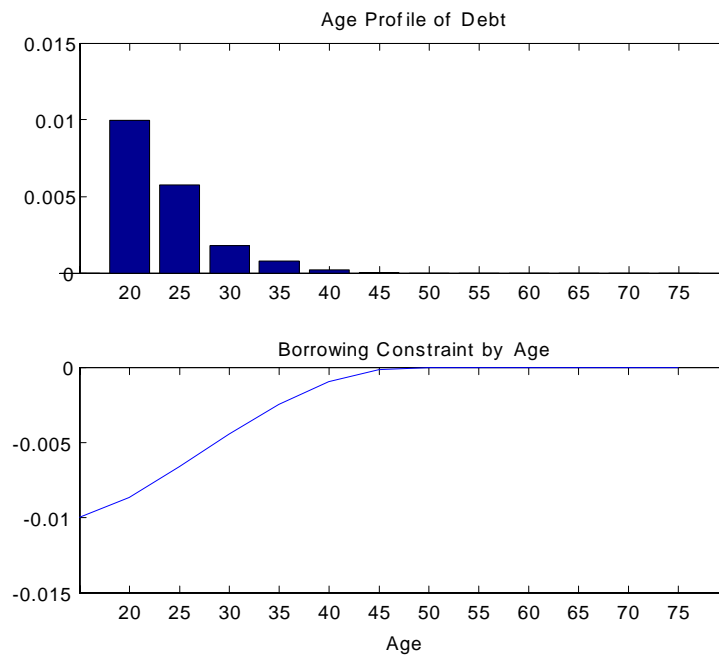


Figure 3: Changes in Borrowing Constraints by Age

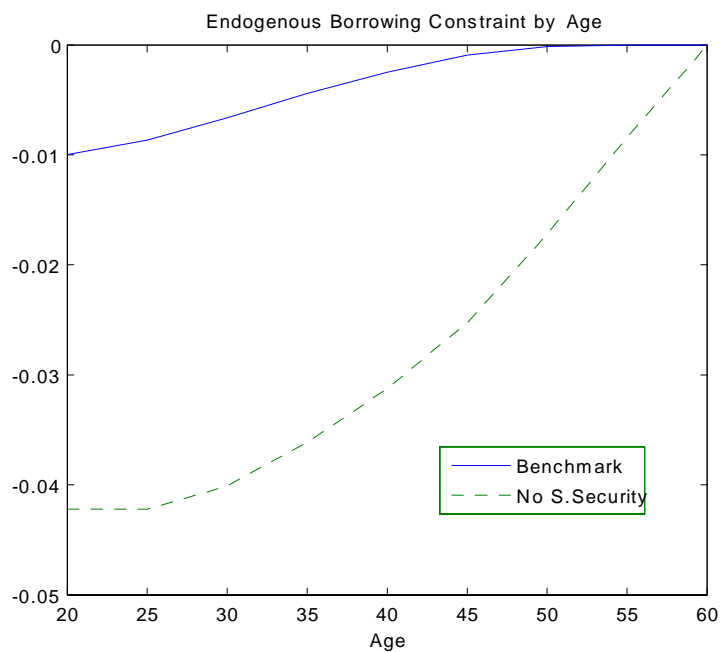


Figure 4: Changes in Savings Rates with Endogenous Borrowing Constraints

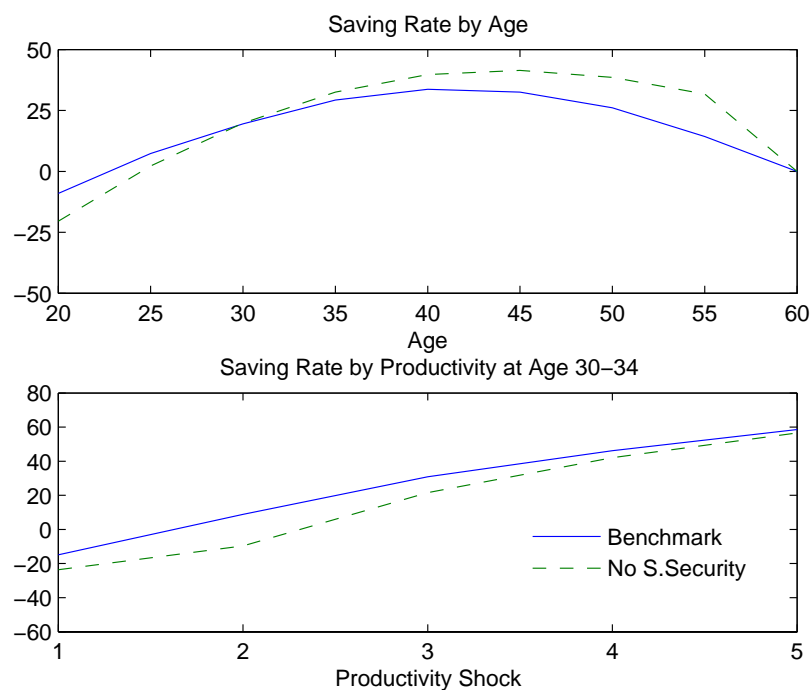


Figure 5: Comparing Endogenous Borrowing Constraints and Natural Limits

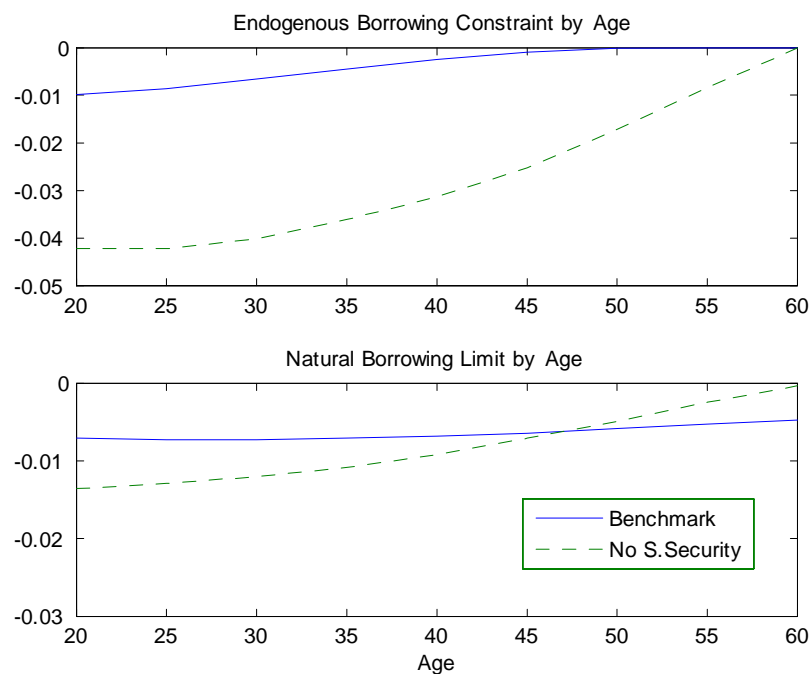


Figure 6: Changes in Borrowing Constraints after Reform

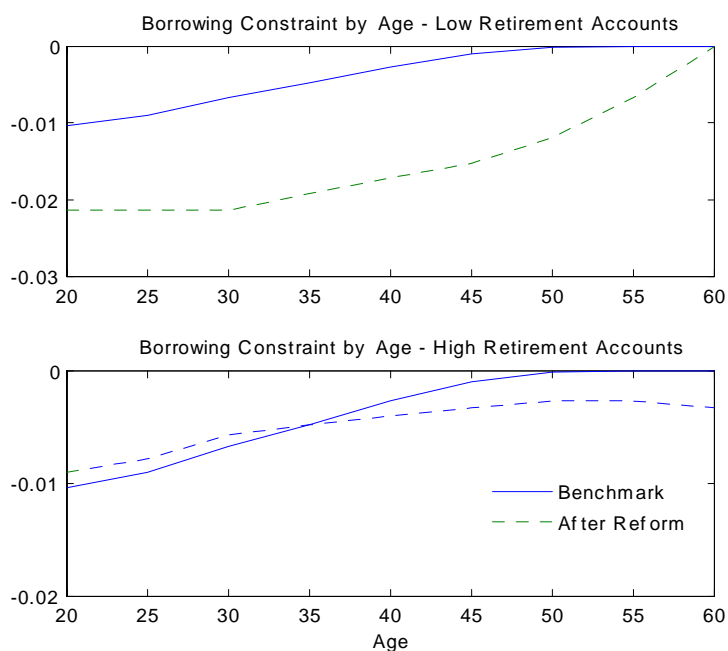


Figure 7: Age Profiles of Assets and Retirement Accounts after Reform

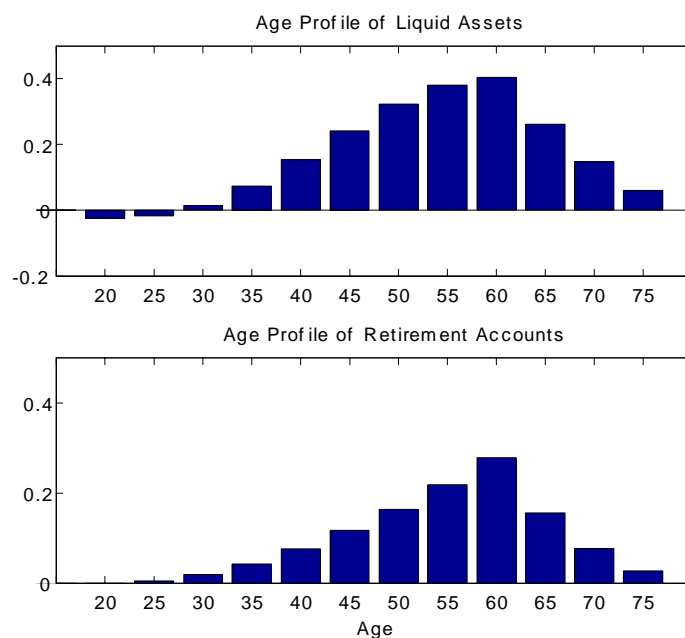
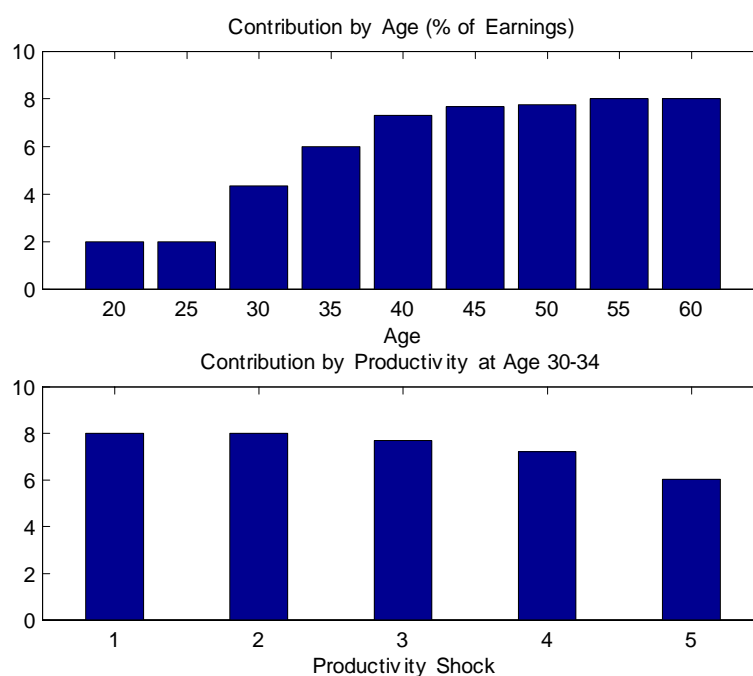


Figure 8: Contribution to Retirement Accounts as a Percent of Earnings



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