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Endogenous Retirement and Public Pension System Reform in Spain

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Keywords: Pension System Reform, Applied General Equilibrium, Retirement.

Department of Economics

Endogenous Retirement and Public Pension System Reform in Spain *

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Abstract

All around the world, population aging has spurred developed countries to reform their PAYG pension systems. In particular, delaying legal retirement ages and reducing the generosity of pension benefits have been widely implemented changes. In this paper we assess how successful those policies can be in the case of the Spanish economy, and compare with the results obtained by the already implemented reforms (1997 and 2001). This evaluation is accomplished in a heterogeneous-agents, applied general equilibrium model where individuals can adjust their retirement ages in response to changes in pension rules. We check the ability of the model to reproduce the basic stylized facts of retirement behavior (specially the pattern of early retirement induced by minimum pensions). We then use to model to explore the impact of pension reforms. We find that already implemented changes actually increase the implicit liabilities of the system, while delaying the *legal* retirement age to 68 may roughly halve the size of the current pension debt.

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1 Introduction

Population aging and the fast approaching retirement of the large cohorts of baby-boomers has cast considerable doubts about the financial viability of current Pay As You Go (PAYG) pension systems. It is widely agreed that providing future retirees with benefits of similar size to that enjoyed by current generations can only come at the expense of large increases in future payroll taxes. This would demand a very large effort from future taxpayers, putting the *intergenerational contract* in jeopardy. As a result, most industrialized countries have made attempts to reform their pension systems, targeting lower benefits and higher labor participation by their more senior workers.[1]

In this paper we explore the ability of these reforms to enhance the financial prospects of PAYG pensions systems over the next few decades. This is undertaken via simulation in an heterogeneous-agents, large-scale, neoclassical growth model with overlapping generations (OLG) and endogenous retirement ages. This model is calibrated to reproduce the demographic process, pension system details and macroeconomic aggregates of the Spanish economy. After checking its ability to reproduced observed retirement patterns, the model is used to simulate the impact of recent reforms in pension rules.

By now there is a rather large literature using applied general equilibrium models to explore pension issues. However, the specific topic of pension reform under unfavorable demographics has been the subject of only a small number of papers. Auerbach, Kotlikoff, Hagemann, and G. Nicoletti (1989) and De Nardi, İmrohoroğlu, and Sargent (1999) stand out as the closest to our target. Both papers focus on the effects of reductions in pension benefits and increases in the *mandatory* retirement age. They find a substantial positive role for the reforms, in terms of the size of the expected fiscal adjustment and of the welfare of future generations (largely obtained at the expense of damaging older cohorts). There are, however, some aspects of this previous literature that are not entirely satisfactory. In the first place, real world governments cannot directly determine the workers' retirement age. In general, they can only affect individual behavior indirectly, by changing the *incentives* implicit in the pension rules. By limiting to changes in mandatory retirement ages, the previous literature has left unanswered the question of whether governments can actually delay *effective* retirement ages by changing the pension rules. Secondly, reductions in the pension generosity can decrease the opportunity cost of working at advanced ages, and therefore foster later retirement. As early retirees are typically more expensive to the pension system than the normal ones, this side effect can reinforce the positive impact of generosity reductions on the Social Security accounts. This issue has not been addressed in the previous simulations, which assume a mandatory retirement age and pay no attention to the existence of early retirement. The endogenous response of retirement to pension reform is considered in Kenc and Perraudin (1997a) *partial* equilibrium analysis of the

[1] See Caseay et al. (2003) for updated projections on fiscal imbalances in OECD countries, and Kalisch and Aman (1998) for a detailed survey of the implemented reforms.

distortions induced by the different pieces of the pension regulations. The general equilibrium version of the paper (Kenc and Perraudin (1997b)), however, assumes exogenously fixed retirement ages.[2]

In this paper we allow individuals to decide when to stop working and collect the pension benefits, and study the effectiveness of policies aimed at delaying retirement. We also account for the indirect behavioral effects of generosity reductions, as those implemented in 1997 and 2001. We consider two possible extensions to those already implemented reforms: (i) larger generosity reductions, engineered through changes in the length of the averaging period in the pension formula; and (ii) delays in the system's *Normal* retirement age. These institutional changes are explored in a neoclassical economy featuring a detailed representation of public pension rules, intra-cohort differences in labor earnings and hours worked, realistic inflows of overseas workers and imperfect credit and annuities markets. Borrowing constraints at the end of the life cycle are implemented by extending the rigorous characterization of savings under life uncertainty in Leung (2000) to the analysis of optimal retirement in Crawford and Lilien (1981) and Fabel (1994).

Our main findings can be summarized as follows: First, it is crucial to model minimum pensions and labor income heterogeneity to successfully reproduce the basic stylized facts of retirement in Spain. Second, the reforms implemented so far have failed to improve the financial prospects of the Spanish pension system. Changes introduced in 2001 have actually made things worse by increasing the tendency to early retirement. In its current form the pension system would run into deficit from 2020 onwards, and the imbalance will peak around 2045, at a figure larger than 10% of the GDP. In contrast, the proposed additional reforms are quite effective: (i) increasing the *legal* retirement age make most workers willing to stay in the labor force until more advanced ages, while (ii) accounting for the full working history when computing the pension benefit makes the system significantly less generous. Although this makes some workers retire later, the reform significantly reduces the overall size of the liabilities of the system. The size of this implicit debt is, however, still rather large, adding up to around 70% of the GDP after either reform. Finally, the inter-generational welfare effects of the reforms are quite similar to those already found in the previous literature. We contribute some new results about the key role played by the minimum pensions on the intra-generational welfare effects of the reforms. Note that, although these specific quantitative results only apply to the Spanish case,

[2]Kenc and Perraudin (1997b) explores the effects of an alignment in pension rules across some major European countries. Kenc and Perraudin also assume a stable population structure and avoid looking into the impact of demographic changes. The Spanish case is explored in Conesa and Garriga (2003), where the abolition of public pensions is accompanied by the lifting of the obligation to retire at the age of 65. Although the authors refer to this as "endogenous retirement", individuals in their model take no participation decision. The papers also differ in the reproduction of the details of the pension rules and of the empirical patterns of retirement, and on the general scope of the reforms (in Conesa and Garriga (2003) people are allowed to work till the age of 85, while we limit ourselves to more modest extensions in working careers).

the general *qualitative* picture obtained from our simulation is probably similar for other countries with similar pension systems (like, eg. Italy, Germany or France).

The paper is organized as follows. In section 2 we review the basic empirical patterns of labor supply at advanced ages in Spain, and discuss their interactions with the public pension rules. The model is describe in section 3, calibrated to the Spanish economy in section 4 and simulated in a number of institutional settings in section 5. The paper finishes with some concluding comments and suggestions for future research in section 6.

2 Pension rules and the labor supply of older workers

In this section we review the basic labor supply patterns of older workers in Spain focusing on the interaction between pension rules and retirement behavior. This analysis provides the rationale for our modeling choices in section 3. We start with a brief review of Old Age pension rules in Spain.

2.1 Old Age pension regulations in Spain

The system is financed with contributions paid by current active workers, ie. it is run on a PAYG basis.[3] Contributions are a fixed proportion of gross labor income between an upper and a lower limit (*contribution bases*), which are annually fixed and vary according with the professional category. Fifteen years of contributions and the complete withdrawal from the labor force are needed to be entitled to receive a pension.[4]

The initial pension is worked out by multiplying a *regulatory base* and a replacement rate. The *regulatory base* is a moving average of the *contribution bases* in the 15 years immediately before retirement (8 before the 1997 reform). The replacement rate depends on the age and the number of years of contributions. An individual is granted a 100% of the *regulatory base* if he retires at the age of 65 (Normal retirement age, τ_N) having contributed for more than 35 years. It is possible to start collecting the pension at the age of 60 (Early retirement age, τ_m) under a 35% penalty on the regulatory base. This corresponds to a 7% (8% for workers with a short contribution record) annual penalty for anticipating the retirement age. There is also a penalty for insufficient contributions if the length of the working career is less than 35. In that case, a 2% reduction is applied to the *regulatory base* for every year the individual's contribution record is below that number. The real value of the initial benefit is kept constant according to the evolution

[3]We focus on the General Regime (RGSS), the cornerstone of the Spanish Social Security system. In 2006 76% of affiliated workers were contributing to this scheme, though a number of Special Schemes were still in place. Reforms starting in 1997 have targeted a rationalization of the system, including the progressive elimination of the Special Regimes, with the exception of the one for Self-employed workers.

[4]Minor changes in the entitlement conditions and the pension formula were introduced in January 2002. We abstract from them in this paper.

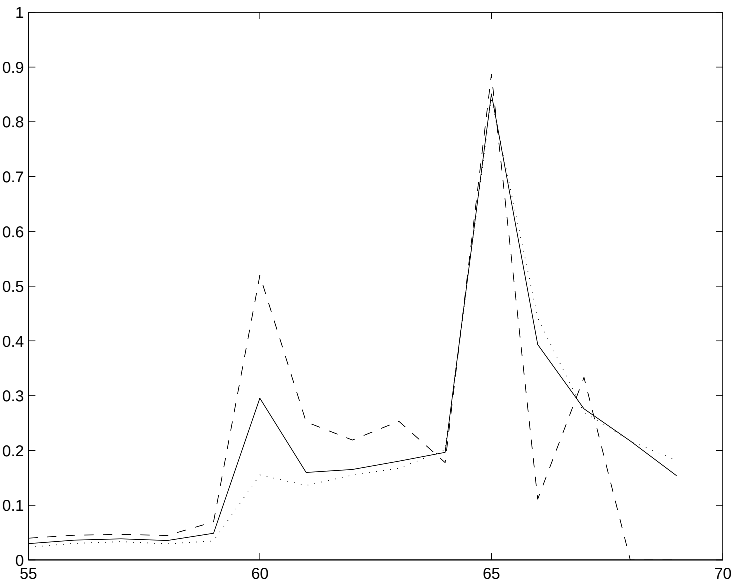

Figure 1: Conditional retirement probability by age: total population (–), workers receiving minimum pensions (- -) and workers who do not receive minimum pensions (·). Source: Historiales Laborales de Seguridad Social (HLSS), 1995

of the Retail Price Index. There are upper and lower limits on the pension benefit, which are annually fixed by the government.

2.2 Labor supply patterns of older workers and their economic interpretation

Figure 1 makes clear that most workers withdraw from the labor force either at the *early* retirement age or at the *normal* retirement age. This is a very robust empirical pattern, repeatedly observed across countries with similar PAYG, Defined Benefit (DB) pension systems.[5] To explore the composition of these flows according to labor earnings, figure 2 presents a non-parametric estimation of the retirement hazard as a function of the level of labor income at the age of 60, for some selected ages. It shows that, while the probability of leaving the labor force is unaffected by the salary level at the *normal* retirement age, it is clearly decreasing at the *early* retirement age. By splitting the sample according to

[5]Our data come from a sub-sample of administrative records from the Spanish Social Security (HLSS). This database is described in detail in Boldrin, Jiménez, and Peracchi (1999). Similar patterns are found in other databases and in cross-country comparisons of retirement hazards. Gruber and Wise (1999) or Jiménez, Labeaga, and Martínez (1999) are good examples.

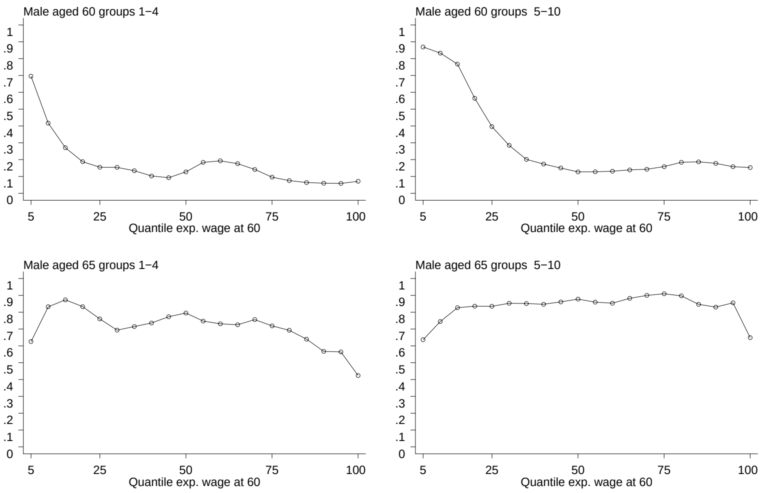

Figure 2: Retirement hazard at the age of 60 (top panels) and 65 (bottom panels) as a function of the wage *level* at the age of 60, for workers of high (left panels) and low (right panels) education. The educational level is approximated by the social security contribution group. Source: HLSS, 1995 sample.

the social security *group of contribution*, we can appreciate that the previous patterns are essentially independent of the worker educational achievement. Most early retirees are, then, low income workers who qualify for a top-up of their pensions under the minimum pension scheme. Actually, 67.7% of the people who retire at the exact age of 60 are receiving the guaranteed minimum, or are expecting to receive it at some future point of their life-cycle.

The stylized facts just described can be rationalized as a set of rational responses to the incentives provided by the pension regulations. This can be easily showed by reviewing the impact of pension rules in the marginal benefits and costs of working.[6] An individual who decide to stay in the labor force at any age τ, faces two marginal costs: a reduction in the amount of leisure, and the financial cost of the foregone pension benefit (if his age is advance enough to be entitled to it). At the same time, by staying active the worker receives a flow of labor income and changes (typically increases) the pension benefit he/she is entitled to receive in the future. In Spain, this latter effect depends on two elements. First, postponing retirement in the age range $\{\tau_m, \ldots, \tau_N\}$ reduces the early retirement penalty (and the penalty for insufficient contributions, if his working career is shorter than

[6]A formal treatment of this topic can be found in chapters 1 & 2 of Sánchez-Martín (2002).

35). Secondly, the *regulatory base* changes as current gross earnings substitutes for the value recorded 15 years back in time. Notice that while the former element always results in a higher benefit, the latter may have the opposite effect (as a result of the concavity of the life cycle profile of gross labor income).

Keeping all this in mind, it is not difficult to explain the discontinuities in retirement hazard by age. The age-65 peak is the optimal answer to (1) the lack of any further rise in the replacement rate of the *regulatory base* after the normal retirement age, (2) the drop in the *regulatory base* induced by the concavity of the income profiles and (3) the high opportunity cost represented by the penalty-free pension when compared with the relatively low wages prevailing at those ages. Notice that the combination of (1) and (2) implies that anyone postponing retirement after the age of 65 can only expect *lower* future pension benefits.

Early retirement patterns are easily rationalized as an artifact ofthe minimum guaranteed benefit. As the value of the minimum is completely independent of the individual characteristics, it entirely eliminates the incentive effects stemming from the pension formula. In particular, it increases the opportunity cost of the foregone pension and wipes out the strong incentives to work associated with the early retirement penalties. As working an additional year does not increase the minimum pension, the best strategy for the affected workers is to leave the labor force as soon as the pension is first available. All in all, our conjecture is that the basic empirical regularities may be satisfactory explained as the rational reply to the non-linearities induced by the pension rules on the individual inter-temporal budget constraint.[7].

The rationale for our main modeling choices

We conclude from the evidence presented so far that an endogenous retirement age is an important element for any model intended for analyzing the type of reforms we focus on in this paper. This is obvious in the case of reforms explicitly designed to delay retirement, but it is also important in the case of changes in the pension formula targeting generosity reductions. The bias induced by omitting the behavioral reply in this latter case is potentially important, because early retirees receiving minimum pensions are substantially more expensive than normal retirees (as confirmed later, by comparing the internal rates of return obtained when retiring at different ages). Reproducing the empirical retirement pattern also demands a detailed reproduction of the pension rules and the inclusion of intra-cohort income heterogeneity as part of the model specification.

[7]This conclusion is also supported by the results in a large body of empirical an econometric literature (see for example Diamond and Gruber (1999) Rust and Phelan (1997) for the USA and Boldrin, Jiménez, and Peracchi (1999) for the Spanish case)

3 The model

The model consists of overlapping generations of agents that live up to I periods. A period in the model stands for one year of real time, which we denote by t when referring to calendar time and by i when referring to age. The cohort the individual belongs to is denoted by u. Individuals start taking economic decisions at the age of entrance in the labor market (20 years). At that time individuals are classified according to their educational attainment in one of J possible categories (denoted by $j \in \mathcal{J} = \{1, \ldots, J\}$).[8] The description of the model demands substantial notation which, for easy reference, is collected in tables 1 (endogenous variables) and 2 (parameters). As a general rule, individual variables are written in lower case with a couple of subscripts and a superscript representing age, education and calendar year. Aggregate variables are denoted with capital letters and have just one superscript indicating calendar time.

3.1 Demographic Model

We model a one sex population were individuals are classified according to their birth place as "Natives", N^t, or "Migrants", M^t. The number of people born at t is determined by the profile of age-specific fertility rates $\{\theta_i^t\}$ (assumed to vary between the threshold ages f_0 and f_1):

$$N_1^t = \sum_{i=f0}^{f1} \theta_i^t \, (N_i^{t-1} + M_i^{t-1}) \tag{1}$$

After-birth population dynamics is given by:

$$N_i^t = hs_i^{t-i+1} \, N_{i-1}^{t-1} \qquad M_i^t = hs_i^{t-i+1} \, M_{i-1}^{t-1} + F_i^t \qquad 1 < i \leq I \tag{2}$$

where F_i^t stands for immigrants flows and $\{hs_i^u\}_{i=1}^I$ for cohort-u vector of age-conditional survival probabilities. Equations (1) and (2) can be combined to represent the entire population dynamics at any point in time as a system of linear difference equations:

$$\overline{P}^{t+1} = \Gamma^t \, \overline{P}^t + \overline{F}^t \qquad \overline{P}^t = (\, \{N_i^t\}\,, \, \{M_i^t\}\,) \; \overline{F}^t = \{F_i^t\} \tag{3}$$

This is the law of motion of the population in the interval $t \in (t_0, t_1)$, a stage of *demographic transition* in which fertility and mortality parameters are changing in time (see section 4.1). After t_1 the economy progressively converges to a stable population, and in the very long run we simply assume that the economy reaches a balanced growth path.[9] The complete time span of the simulation is represented by $\mathcal{T}$.

[8] We abstract from schooling and labor market entrance decisions. It is not difficult to let the distribution by education, ω_j^u, change with the cohort (according with empirical evidence), but we have opted to keep it constant to assess the effects of pension reform in isolation. The distribution by education within a cohort is also assumed to be constant.

[9] The long run convergence is achieved in two steps. We assume that after t^1 (set to 2050 in the simulations) fertility and mortality patterns are constant and immigration flows progressively die out.

INDIVIDUAL variables			
Retirement age	τ_j^u	Initial pension	$b_j(\tau, u)$
Accumulated assets	$a_{i\,j}^t$	Consumption	$c_{i\,j}^t$
Gross labor income	$il_{i\,j}^t$	Gross pension income	$ib_{i\,j}^t$
Life-cycle utility	$V_j(\tau, u)$		

AGGREGATE variables			
Public Policy		**Macroeconomy**	
Revenues form bequests	BI^t	Product	Y^t
Fiscal Income	FI^t	Capital stock	K^t
Lump-sum tax	φ^t	Labor Supply	L^t
Minimum pension	bm^t	Pension Expenditure	PP^t
Public Consumption	CP^t	Pension System balance	PSB^t
Technology index	A^t		
Population		**Prices**	
Total	P^t	Wage	w^t
Natives/Inmigrants	N^t, M^t	Rental capital	r^t
Distribution	$\mu_{i,j}^t$		

Table 1: List of endogenous **variables** in the model. The counters used are: $i \in \{1, \ldots, I\}$ for individual age; $t \in \mathcal{T}$ for calendar year, u for cohort (year of birth) and j for educational type.

Population		**Public policy**	
Age specific fertility rate	θ_i^t	Pay-roll tax rate	ς^t
Conditional survival probability	hs_i^u	Number of years in benefit base	D
Immigrant flows	$F_{i,j}^t$	Early entitlement age	τ_m
Population growth rate	n^t	Normal retirement age	τ_N
Leisure	l_i	Early retirement penalties	$\alpha(\tau)$
Efficiency labor units	$\varepsilon_{i\,j}$	Minimum pension (% y)	b_m
Distribution by education	ω_j	Public Consumption (% Y)	c_p
Preferences		**Technology**	
Relative risk aversion	η	Depreciation rate	δ
Time discount factor	β	Capital share (on National Income)	ζ
Relative leisure value	σ	Exogenous productivity growth rate	ρ

Table 2: List of **parameters** defining the individual preferences and the economic and demographic environments.

3.2 Economic Model

We use the standard neoclassical growth model extended with life uncertainty, borrowing constraints at the end of the life cycle and flows of workers from abroad. At the aggregate level the economy is deterministic, while at the micro level individuals are uncertain about the length of their life. There is no insurance market for this risk, as annuity markets are closed by assumption.

The Public Sector

The main role played by the Public Sector is to run a PAYG, DB social security system. After contributing a fixed proportion, ς, of their gross labor income, workers become elegible for a pension benefit during retirement. The pension can be claimed at any time after the *early retirement age*, τ_m, an following a complete withdrawal from the labor force. The *initial* pension for an individual belonging to cohort u and retired at age τ is computed according with the following expression:[10]

$$b(\tau, u) = \alpha(\tau) \left(\frac{\sum_{i=\tau-D}^{\tau-1} il_i^{u+i}}{D} \right) \tag{5}$$

where il_i^t stands for the gross labor income at age i and calendar year t. The formula combines a *regulatory base* (averaging gross labor earnings in the D years immediately before retirement) and a replacement rate $0 < \alpha(\tau) \leq 1$ that penalizes retirement before the *normal* retirement age, τ_N :

$$\alpha(\tau) = \begin{cases} \alpha_0 < 1 & \text{if } \tau < \tau_m \\ \alpha_0 + \alpha_1(\tau - \tau_m) < 1 & \text{if } \tau \in \{\tau_m, \ldots, \tau_N - 1\} \\ 1 & \text{if } \tau \geq \tau_N \end{cases} \tag{6}$$

This *initial* pension is kept constant in real terms as the individual becomes older. However, the effective pension can eventually increase as a result of the minimum pension: the unique guaranteed minimum set by the government on a year by year basis (denoted bm^t). In the past, it has been common practice to increase its real value roughly at the same pace as wages. Consequently, the effective pension income for an individual of age i in t and retired at age τ is given by:

$$ib_i^t(\tau) = max\{bm^t, \, b(\tau, t - i + 1)\} \tag{7}$$

After $t^2 = t^1 + I$ the law of motion simplifies to

$$\overline{P}^{\,t+1} = \Gamma \, \overline{P}^{\,t} \tag{4}$$

and we assume convergence to a final balance growth path at some point well after t^2 (2220 in the current calibration). We check that this final value do not affect the performance of the economy in the interval of interest (t_0, t_1).

[10]We abstract from some minor pieces of the Spanish pension regulation, in an attempt to get a sharper characterization of the effects of the most determinant ones. In particular, we omit the floor and ceilings on covered earnings, the maximum pensions and the penalties for insufficient contributions.

In addition to running the pension system, the Public Sector performs two functions: it runs a fiscal system and consumes a certain amount, CP^t, of the aggregate output. In our model, fiscal revenue comes from the confiscation of involuntary bequests and from a system of lump sum taxes.[11] The policy rule is to set the annual per-capita tax φ^t in such a way that *the entire* public budget (including the pension system) balances.

The production side of the economy

We assume a neoclassical technology, $F(K, L)$, with constant returns to scale, no adjustment costs and exogenous labor-augmenting technological progress (represented by the index A^t). The growth rate of the labor productivity, ρ, is constant. As usual, we assume that this technology is run by a large number of profit-maximizing, competitive firms.

The Households

Agents in the model maximize their expected lifetime utility by choosing an optimal savings path and a "once and for all" retirement age. Formally, individuals of type j belonging to cohort u choose a retirement age, τ_j^u, and life-cycle profiles of consumption and accumulated wealth, $\{c_{ij}^{u+i-1},\ a_{ij}^{u+i-1}\}_{i=1}^{I}$, that maximize the sum of expected, discounted utility flows stemming from a period utility function u:

$$V_j(\tau, u) = \sum_{i=20}^{\tau-1} \beta^{i-1}\, s_i^u\ u(c_i^{u+i-1}, l_i) + \sum_{i=\tau}^{I} \beta^{i-1}\, s_i^u\ u(c_i^{u+i-1}, 1).$$

where β stands for a pure discount factor while s_i^u is the unconditional probability of surviving till age i for a member of the cohort u. The fraction of the time endowment allocated to market activities,$(1 - l_{ij})$, is assumed to be fixed exogenously[12].

[11]The problem here is that using taxes to balance the public budget has the unintended effect of making the assessment of pension reform harder. Whenever the financial condition of the pension system is altered (eg after a legislative change), the tax rate should be adjusted accordingly. With a non-neutral tax system, this implies an *additional* distortion on behavior, whose effects should be separately accounted for when evaluating the impact of the pension reform. We have, in any case, checked that the qualitative outcome of the model with a proportional income tax is very similar to that under a system of lump-sum taxes. Of course, the quantitative findings are different, but the changes are small. We report the results obtained under a non-distorsionary tax system, then, only for expositional convenience.

[12]Including an endogenous working-hours decision results in a strong counterfactual prediction: hours worked late in the life cycle should jump in order to accumulate additional pension rights. This is a direct outcome of the short averaging period in the pension formula. There is, however, not a trace of such a behavior in the Spanish data. This most certainly reflects the existence of institutional constraints that prevents workers from implementing their optimal life cycle profiles of hours worked. Legal limits in the number of overtime hours and other restrictive dispositions stemming from the Collective Bargaining are most likely behind this rigidity in the Spanish labor market. Although some of the reforms we study in this paper are due to modify the optimal amount of hours worked, we have opted for keeping them constant throughout the simulations. Making them endogenous is not specially difficult (eg. Sánchez-Martín (2002)) but that will amount to assume a future weakening of the institutional constrains that have prevented pension incentives from having an observable impact on labor supply in the past.

While the individual is active in the labor market, the relevant budget constraint is:

$$c_{i\,j}^{u+i-1} + \; a_{i+1\,j}^{u+i} = (1-\varsigma)\, il_{i\,j}^{u+i-1} + (1 + r^{u+i-1})\, a_{i\,j}^{u+i-1} - \varphi^{u+i-1} \tag{8}$$

where r^t stands for the return on savings carried to year t and $il_{i\,j}^{t}$ is gross labor income at age i and calendar time t. This is the product of the number of hours worked, the productivity of time at that specific age and date ($\varepsilon_{i\,j}^{t}$), and the current market value of those efficiency labor units (w^t). After retirement, the relevant budget constraint is

$$c_{i\,j}^{u+i-1} + a_{i+1}^{u+i} = ib_{i\,j}^{u+i-1}(\tau_j^u) + (1 + r^{u+i-1})\, a_{i}^{u+i-1} - \varphi^{u+i-1} \tag{9}$$

Pension income $ib_{i\,j}^{u+i-1}(\tau_j^u)$ is computed according to expressions (5) to (7). Finally, individuals are not allowed to borrow from their future pension flows, which is equivalent to a nonnegative constraint on the value of the stock of assets at any age after retirement. This constraint always becomes binding before the maximum lifespan (Leung (2000)). Consequently, the numerical solution of the model involves finding another discrete variable (for each cohort and educational type): the optimal wealth depletion age $\bar{t}_j^u$.

3.2.1 The Equilibrium.

An *equilibrium path* over the time interval $\mathcal{T}$ is a set of time series of population (aggregates and distributions), assignments (consumption, savings and retirement), aggregate inputs, prices and public policies (taxes, minimum pensions and public consumption) with the standard properties: individuals are rational, factor markets clear, prices are competitive, the public budget balances and all assignments are feasible. Appendix A-1 provides a formal definition of the equilibrium of the model economy. As in Auerbach and Kotlikoff (1987), the equilibrium is completed with a final balance-growth steady state (to which the *equilibrium path* converges) and an initial steady state from where all the initial conditions are taken.[13] The initial and final steady states are particular cases of the *equilibrium path* above, were the population is stable and grows at a constant rate; aggregate variables grow at a fixed rate given by the sum of the population and productivity growth rates; *per capita* variables and wages grow at the productivity growth rate and the interest rate is constant.

[13]The set of initial conditions varies depending on the cohort. For very old individuals at t_0 (which are already retired when the simulation starts), it includes their initial pensions and assets. For cohorts of workers close to retirement (ie, older than $\tau^u - D$), it includes the assets and some of the salaries used in the pension formula. For all the rest, the set of predetermined variables reduces to the stock of accumulated assets. The more natural way of assigning those initial conditions is via direct measurement form empirical data. Unfortunately, it is not possible to get a reliable estimation of the distribution of wealth by age and education with the currently available Spanish databases. Therefore, we follow the standard procedure: we obtain them from an initial steady state, calibrated to reproduce the economic environment prevailing when these conditions came into existence.

4 Calibration

We calibrate our model economy to mimic the performance of the Spanish economy along the interval 1970/2000 and in accordance with standard projections for future demographic and productivity trends. Specifically, the properties that we want our model to show by construction are:

(i) Demographic & immigration patterns should be consistent with the Spanish historical experience and with standard projections for the near future.

(ii) Pension rules should be consistent with Spanish Institutions.

(iii) The pension system's financial balance should match the empirical values at the beginning of the simulation.[14]

(iv) Productivity & hours worked by educational level must be consistent with the empirical evidence.

(v) The aggregate performance of the model should reproduce some key ratios of the Spanish National Accounts.

(vi) Average retirement age should be aligned with that in the data.

4.1 Demographic patterns

A period in the model stands for one year of calendar time and we assume a maximum lifespan I of 100 years. The simulated *equilibrium path* reproduces the population distribution and the age profiles of fertility and survival probabilities observed in $t_0 = 2000$. From t_0 to $t_1 = 2050$ we simulate a changing pattern of fertility and mortality. The total fertility rate (TFR) is assumed to recover from the extremely low values observed during the nineties (1.2 children per women in 1995) to a final stationary value of 1.75 in 2050. We also reproduce the trend towards lower mortality rates by assuming that life expectancy rises from the 79.7 years observed in 2000 to 84.0 years in 2050. These projections are a bit more optimistic than the basic INE scenario (Spanish Statistics Institute "hipótesis 2" in INE (2001)). Finally, we estimate the aggregate number of immigrants and their distribution by age in 1995, and assume a future input of workers from abroad similar to that in the basic INE projection.[15] Under these circumstances the share of immigrants in the total population increases form 4.2 % in 2000 to 14.5 % in 2050.

[14]Note that we calibrate the balance of the system to the values observed on the onset of our simulation rather than to 1970/2000 averages. This is important because the Spanish pension system is still converging to a unified structure from a variety of disperse regimes. What we want to test in this paper is the capacity of the final design of the system to cope with the population aging.

[15]INE projection reproduces the very large aggregate flows observed up to 2005 and conjectures a quick convergence to more sustainable figures (slightly above one hundred thousand a year) by the end of the decade. We correct the 2005 figure to include the amnesty granted to a large number of workers without legal residence. The alternative INE scenario ("hipotesis 1") assumes implausibly large immigration flows,

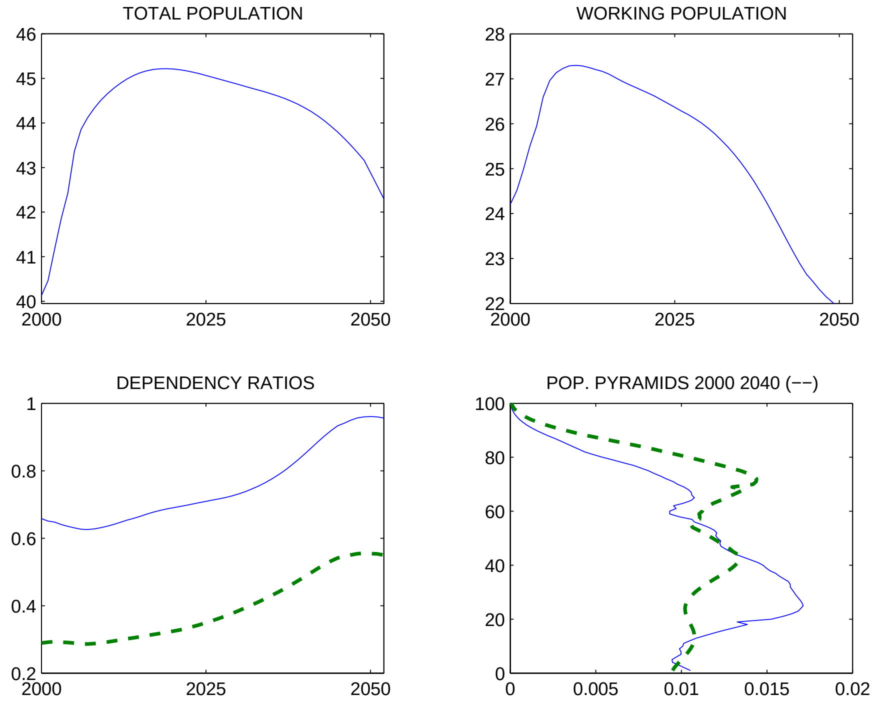

Figure 3: Population Projections: total and working population in millions (upper panels); Total (-) and old age (- -) dependency ratios and population pyramids in 2000 (-) and 2040 (- -) (lower panels).

According to this model, the aging of the Spanish population in the next decades will be quite dramatic. The main tendencies are displayed in figure 3. The projected *total* and *working* population (upper panels of figure 3) are expected to start their decline within the next two decades, although the precise timing and intensity of the reductions is very sensitive to the assumptions about immigration. In contrast, the number of senior (older than 65) citizens increases all along the simulation. Driven by these two simultaneous forces, the dependency ratios soar: the ratio of retirees to active workers almost doubles (29% to 55% from 2000 to 2050) while the total dependency ratio (including people under 20) increases from around 65% at the beginning of the simulation to 96% in 2050, a figure quite close to the feared one-dependent-person-per-worker outcome (left bottom panel of fig 3). The drastic alteration in the overall age distribution of the population is best

given the historical experience in other European countries. Finally, note that the absence of reliable empirical data makes it impossible to account for the differences between native and immigrants in terms of earnings, asset holdings, fertility or mortality.

captured by the change in the population pyramid (right bottom panel of fig 3).

4.2 Economic model

The individual period utility is a separable CES function, with unitary intertemporal elasticity of substitution (IES): $u(c_i, l_i) = log(c_i) + \sigma\, log(l_i)$. The logarithm is adopted in accordance with econometric evidence (Hurd (1989) for US or Jiménez-Martín and Sánchez-Martín (2003) for Spain) and to guarantee the invariance of the discrete decisions in the final balance growth path of the model. Individual preferences are, therefore, fully specified by choosing σ and β. The production side of the economy is standard: capital and efficient labor units are combined according to a Cobb-Douglas production function to generate aggregate output (ie, $Y = K^{\zeta} L^{1-\zeta}$). This part of the model is completely specified by choosing the capital share in aggregate income ζ, the rate of capital depreciation, δ, and the constant productivity growth rate, ρ. The government policies include (apart from the pension formula and the contribution rate) the functions determining the annual values of the minimum pension and public consumption. In both cases we choose linear functions: we make the minimum pension proportional to the average productivity ($bm^t = b\_m\, y^t$), in broad agreement with the empirical evidence, while public consumption is assumed to be a constant fraction, c_p, of the aggregate product. Finally, we use smooth quadratic curves to represent the age-profiles of productivity and working hours by educational type, and an additional set of $J-1$ parameters to fix the invariant distribution by education. We try to reproduce the calibration targets **(ii)** to **(vi)** by imposing the following specific values to the parameters above:

- **Public pension system (ii):** The parameters of the pension formula are set to reproduce the General Regime (RGSS) of Spanish social security system. Our benchmark case correspond to the structure in place before the 1997 reform. Alternative pension formulae are described and studied in section 5.2. The parameter determining the *level* of the minimum pension b_m is fixed to target the minimum-to-average pension ratio in the interval 1980/1995 (77 %).

- **Pension system's financial balance (iii):** The contribution rate is set in such a way that the model reproduces the imbalance of the pension system at the beginning of the simulation. According to Herce (2002), pension expenditure amounted to 9.28% of GDP in 2002, while contributions added up to a 10.17% of GDP. Therefore, the calibration target is a surplus of 0.89% of the GDP at the beginning of the simulation path, which is obtained by setting ς to 24.9%.[16]

[16]Although the model reproduces the magnitude of the system's imbalance, it overstates the size of both its revenues and expenditures. This is the unavoidable consequence of: (1) abstracting from some of the RGSS rules (eg. maximum pensions and contributions); (2) the heterogeneity in the pension rules of different regimes, featuring in most cases a much lower proportionality between income and pensions and

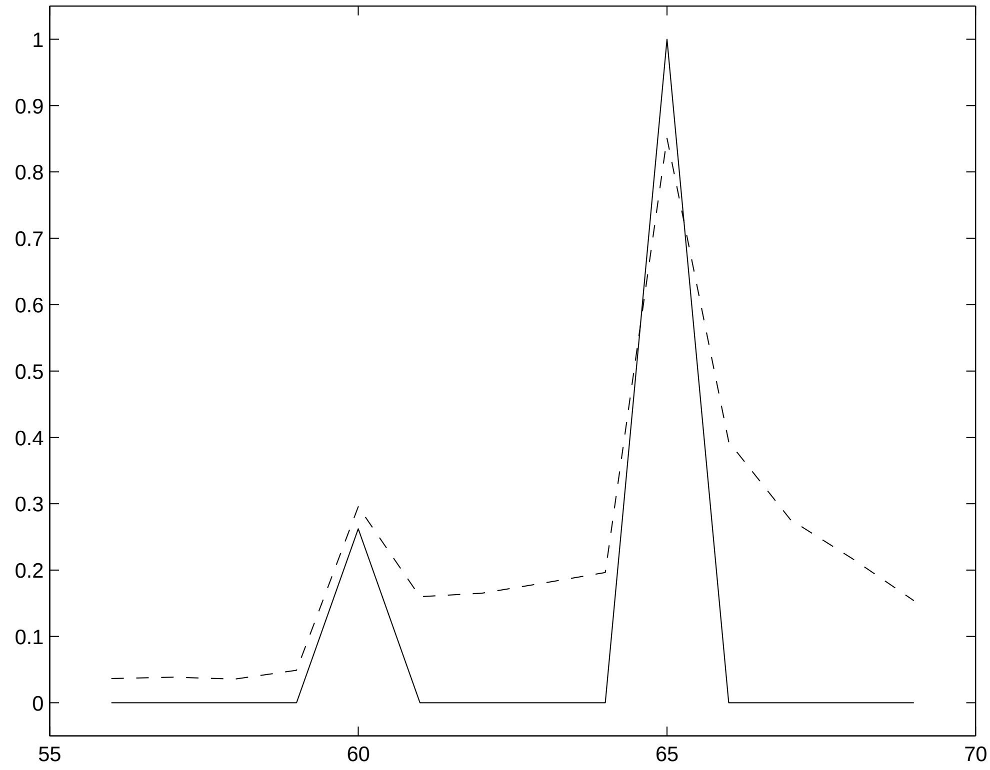

Figure 4: Retirement hazard by age in the initial balanced growth path (-) and in the data (- -) HLSS-95

Education	ω_j	τ_j	$J_j(\tau)$	$\bar{t}_j(\tau)$	IRR_j
High	24.6	65	-	89	2.17
Average	49.2	65	79	89	1.80
Low	26.2	60	60	87	3.16

Table 3: Intra-generational distribution by education, ω_j, and optimal discrete decisions in the initial balanced-growth path: retirement ages τ_j, starting binding age for the minimum pensions $J_j(\tau)$ and optimal binding age for the borrowing constraint $\bar{t}_j(\tau)$. The IRR_j are the internal rates of return of social security contributions.

Table 4: Macroeconomic calibration targets and parameter choices: Average 1970-1995 basic basic macroeconomic ratios according with the Spanish National Accounts, CNA86, and their calibrated counterparts in the model, along with the implemented parameter values.

	data	model	parameters
$rK/Y\%$	34.7	34.7	$\zeta = 0.347$
K/Y	2.57	2.59	$\beta = 0.983$
$I/Y\%$	23.6	23.4	$\delta = 0.064$
$CP/Y\%$	13.3	13.3	$c\_p = 0.133$
$\Delta lnC\%$	2.12	2.12	$\rho = 2.12$

- **Life cycle profiles by education (iv):** The information about income, hours worked and education is obtained from the 1994 cross section of the ECHP. In this database we can precisely identify the life-cycle profiles of income and working-hours of up to three educational levels (high (j=1), average (j=2) and low (j=3)). Their empirical distribution is presented in the second column of table 3.[17] The smooth quadratic curves fitted to the empirical data have the usual concavity properties.[18]

- **Macroeconomic aggregates (v):** We choose β and δ to target the average capital/output and investment/output ratios respectively. ζ in the production function is set to reproduce the average capital income share (as measured in Puig and Licandro (1997)) while the exogenous productivity growth rate, ρ, is set to the average growth rate of *per capita* consumption. Finally, the government expenditure to output ratio is directly reflected in the parameter c_p. All empirical values are 1970/1995 averages from the Spanish National Accounts (CNA86) with the excep-

contributions than in the RGSS (in the Self-employed Regime, for example, affiliates can choose the level of their contributions independently of their income. A large part of this heterogeneity, however, is bound to disappear with the progressive extinction of the old regimes after 1997); and, finally, (3) it also reflects the absence of unemployment and non participation in the model.

[17]The distribution by education has been remarkably non-stationary in the last decades. In order to reproduce the average behavior along our calibration interval, we include in the model the distribution for the cohorts born between 1955 and 1975 (ie. individuals aged 40 years in 1994 or younger).

[18]As we abstract from unemployment or non participation, the age profiles of labor income and hours worked by educational type correspond to the average profiles in the entire working-age population. We first estimate the participation rates and the profiles of hours worked by employees, according to age and education. We then multiply them to get the empirical profiles of hours worked by age for each of our educational types. A smoothed version of those profiles, fitted by OLS, is finally included in the model. The productivity profiles have been recovered in a similar way (we estimate the age profile of labor income for employed workers by education, compute the empirical profiles for our representative agents by weighting them with the employment rates and finally include in the model an smooth version fitted by OLS).

tion of the capital stock (obtained from BBV (2001)). The overall macroeconomic scenario resulting from these choices is presented in table 4.

- **Average retirement age (vi):** The parameter controlling the relative value of consumption and leisure is fixed in such a way (σ=0.2) that the average retirement age in the initial balanced growth path is as close as possible to the empirical value (62.98 in 1978-1995, according to EPA data). The results obtained are shown in the third column of table 3. Low-educated workers find it optimal to early retire, while all other workers wait till the normal retirement age. The crucial element forcing low-income workers out of the labor force at the early retirement age is the minimum pension scheme (fourth column of table 3). Overall, the endogenous behavior of the agents in the model implies an average retirement age of 63.69, just a little higher than the value observed in the data. Figure 4 compares the retirement hazard in the model with its empirical counterpart. The model approximately reproduces the stylized facts of retirement in Spain: the spikes at the *early* and *normal* retirement ages and the pattern of early retirement of low income workers (low educational level in the model), induced by a generous minimum pension scheme.

5 Findings

In this section we discuss the basic results obtained in the simulation of our calibrated economy in a number of institutional environments. The benchmark model represents a projection of how the system in effect before 1997 would have evolved in absence of any legislative reform. The results are presented in section 5.1. In section 5.2 we explore the reforms implemented in 1997 and 2001 and propose two more ambitious strategies to improve the prospects of the system.

5.1 Base simulation

The first column of table 5 reproduces the parameters of the pension formula in the benchmark simulation. They are intended to reflect the institutional environment in place before the recent legislative changes in Spain (second and third columns of table 5). The aggregate performance of the benchmark economy is characterized by a progressive contraction in the offer of capital and labor, resulting in a reduction in the economy growth rate and a mild process of capital deepening. Pension expenditure almost doubles between 2010 and 2045, under the effect of the strong demographic changes described in section 4.1. This leads to dramatic changes in the financial condition of the pension system (illustrated in figure 5). The initial decade is favorable (thanks to large immigration flows), but the condition of the system experiences a continuous deterioration thereafter. The initial surplus vanishes by 2023, and the ensuing deficit reaches a maximum equivalent to 10.7 % of the aggregate product in 2048. To cope with this imbalance, the fiscal burden placed on the individuals increases continuously, doubling in size by 2050. Overall, the financial

	Base	R97	R01	D=40	$\tau_N = 68$
Legal Retirement Ages:					
Normal	65	65	65	65	68
Early	60	60	61	61	61
Cohorts entitled to Early retirement	<1947	<1947	All	All	All
Pension formula:					
Annual Penalty, α_1	8%	7%	7 %	7 %	7%
Initial Replacement Rate, α_0	0.6	0.65	0.65	0.65	0.51
Bonus for working after τ_N	0	0	2%	2%	2%
Averaging period, D	8	15	15	40	15

Table 5: Alternative institutional environments. Pension system parameters in our different simulations: base (pre 1997), 1997 reform (R97), 2001 Reform (R01), R01 + 40 years in the formula's averaging period (D=40) and R01 + delay in the normal retirement age to 68 years ($\tau_N = 68$).

imbalance in the interval 2000/2050 amounts to more than 3% of the GDP, and the size of the total unfunded liabilities at the beginning of the simulation amounts to a 120% of the aggregate output (first column of table 6).[19] According to our simulation results, then, the financial prospect of the pre-reformed system was severely compromised.

5.2 The reform of the Spanish pension system

We consider four variations to the institutional environment in our base simulation. We explore first the changes introduced in 1997, when the length of the averaging period D was extended form 8 to 15 years and the annual early retirement penalty was slightly reduced from 8 to 7%. In our simulations we refer to this new parametric scheme as R97 (second column in table 5), and assume that all changes in this and other reforms take place from the beginning of the simulation. A second and considerably more significant collection of changes was implemented in 2001. Amid mild modifications in the pension formula, the cornerstone of the reform was the extension of the early-retirement option to all cohorts. Note that until 2001 only those cohorts who had made contributions before 1967 were entitled to claim the pension before the Normal age of 65. In compensation, the new early retirement age was delayed by one year to 61. In our stylized model (see under the R01-column in table 5), this 2001 reform materializes into a 2% bonus in the

[19]Our estimation of the system implicit liabilities is not different from the already available figures for the Spanish case (the equivalent figure in eg. Kalisch and Aman (1998) is 109%). To compute it we first calculate the net present value of all future expected pension payments and contributions for every cohort alive at the beginning of the simulation (using a 5% discount factor). We then add up the figures, weighting by the cohort's size share. The aggregate amount is finally expressed as a percentage of the GDP.

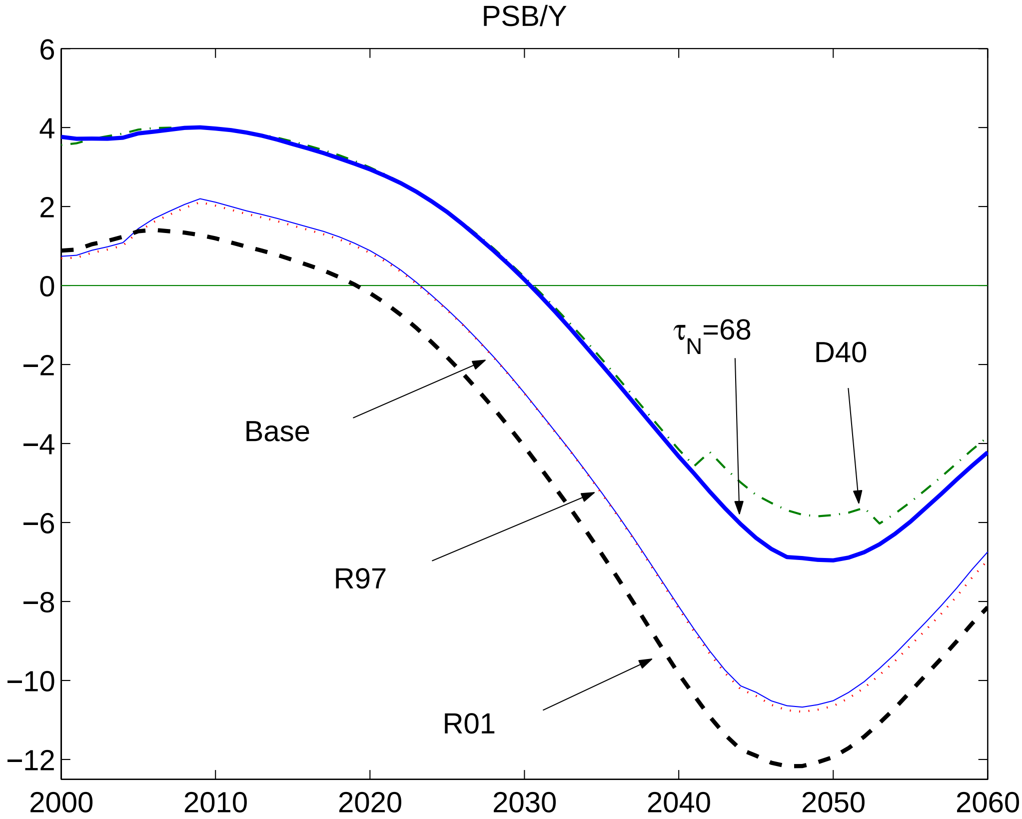

Figure 5: Simulated time series of the pension system's balance (aggregate contributions minus pension expenditures) as a percentage of the aggregate output. Simulations: Base (-), 1997 reform (·), 2001 reform (- -), extension of D to 40 (- · -) and delay of the normal retirement age to 68 (thick -).

	Base	R97	R01	D=40	$\tau_N = 68$
Total IL/Y	-118.42	-119.43	-127.12	-71.03	-65.19
Average PSB/Y	-3.63	-3.71	-4.77	-0.50	-0.80
Minimum PSB/Y	-10.67	-10.79	-12.17	-6.03	-6.96

Table 6: Pension system's balance: summary statistics of the financial condition in the interval 2000/2050 in our sequence of simulations. IL= Implicit Liabilities; PSB= Pension system balance.

benefit base for working beyond 65 and the adoption of 61 as the new early retirement age, now available to all cohorts. Besides the already implemented reforms, we explore two additional changes:

- A sharper generosity reduction, implemented through a further increase in the length of the averaging period in the *regulatory base*. To grasp the maximum potencial of this strategy we consider the inclusion of the full working career by rising D from 15 to 40 years. The institutional environment resulting after this parametric change is denoted as D=40.

- A delay in the *Normal retirement age*. This implies changing the early retirement penalties in such a way that individuals are awarded their full *regulatory bases* only at the new *Normal age*. Trying to combine considerations of political feasibility with our target to explore the maximum potential of reforms, we set the new Normal age to 68. Note that the other parameters of the early retirement penalty are left unchanged.[20] We refer to this new pension system as $\tau_N = 68$.

We next review the impact of these parametric changes in the financial condition of the pension system (recall figure 5), retirement behavior (figure 6) and life cycle welfare by educational type (figures 7 to 9). Welfare changes are measured with a corrected Equivalent Variation of life-cycle wealth.[21]

The 1997 reform

Increasing the averaging period D form 8 to 15 has small quantitative effects on the size of the pensions, and they tend to be of opposite sign depending on the educational type (favorable for highly educated workers, unfavorable for the rest). These effects are not enough to change retirement decisions and largely cancel out in the aggregate. Overall, the reform fails to achieve any improvement in the financial soundness of the system: it

[20]Keeping α_1 equal to 0.07 implies that α_0 (the replacement rate in the early retirement age of 61) should be reduce from 0.65 to 0.51. In this way, our delay of the normal retirement age also involves a reduction in generosity for early retirees.

[21]We proceed in two steps. Firstly we compute the standard equivalente variation associated with every reform, $\chi^r_{u,j}$: the change in the life-cycle profile of consumption (in the benchmark economy) that makes the individual indifferent between the benchmark and the reformed economies. This statistic is computed for every educational type (j), cohort (u) and institutional environment (r). As these measures refer to the specific consumption levels of heterogeneous individuals, they are not directly applicable for intra- or inter-cohort comparisons. For this reason, we correct the measurements in a second step. As we work with a homothetic utility function, the previous $\chi^r_{u,j}$ also represent percentage changes in individuals' life-cycle wealth. Consequently, we can convert them into objective wealth measures by multiplying them by the expected present value (at the time of birth) of their labor endowment in the benchmark economy. To achieve inter-generational comparability we conclude by normalizing the correction factors by the average present value of labor endowment in 1995. Summing up, the reported figures are the percentage change in the (1995-average of the) expected present value of labor endowment needed to make the individuals indifferent to the reforms under the benchmark case.

generates a small rise in the pension expenditure to output ratio and a hardly noticeable *upward* shift in the time series of social security *deficit* and taxes. The welfare changes are also tiny: most cohorts of high income workers are slightly better off after the reform, as a result of the higher pensions provided; all other individuals experience small welfare losses, either as a result of lower pensions (average income workers), or as a result of the negative macroeconomic impact of the reform (which reduces the minimum pensions enjoyed by low income workers).

The 2001 reform

The most important change introduced in 2001 was the extension of the entitlement to retire early to all cohorts, irrespectively of when they started to make contributions. Although this is compensated to some extend by the one-year-increase in the early retirement age, the overall effect is a clear drop in the average retirement age (from 65 to 63.95 years for cohorts born after 1947), as younger cohorts of low income workers benefit from the opportunity of leaving the labor force early. As minimum pensions make the early retirees significantly more expensive than the normal ones, this change in behavior pushes the aggregate pension expenditure up. This is despite the very mild effect of the reform on pension benefits (very similar to those generated by the 1997 reform). Note also that the 2% bonus provided to prolongue the working career over the age of 65 proves essentially ineffective. Overall, this reform drives the pension system further away from financial balance, increasing the implicit liabilities at the beginning of the simulation by almost 8 percentage points. Finally, the welfare impact is almost uniformly negative, hitting future cohorts of low income workers specially hard.

Extending the averaging period in the pension formula to 40 years

Accounting for most of the working career (40 years) when computing the initial pension benefit has strong direct and indirect effects. Pensions available at the age of 65 for high income workers are 20 to 25% lower than in the base case (depending on the cohort). The optimal individual response to this change includes staying in the labor force till the age of 70, and so collecting the 2% annual bonus provided after the legal retirement age. This mitigates the impact of the reform but, still, this group ends up with lower pensions (6 to 9% lower than in the benchmark) which, combined with the longer working careers, implies a substantial cut in their associated pension expenditure. Average income workers also experience large reductions in benefits (in the range 15/18%), but most cohorts still find it optimal to retire at 65 (cohorts born in the interval 1978/1988 are the exception, delaying retirement by one additional year). In contrast, the unchanged minimum pension scheme protects low income workers from any reduction in their effective pensions. The overall consequence is a substantial reduction in aggregate pension expenses, leading to higher levels of personal savings and capital accumulation and big improvements in the financial condition of the pension system. The latter are well illustrated by the reduction

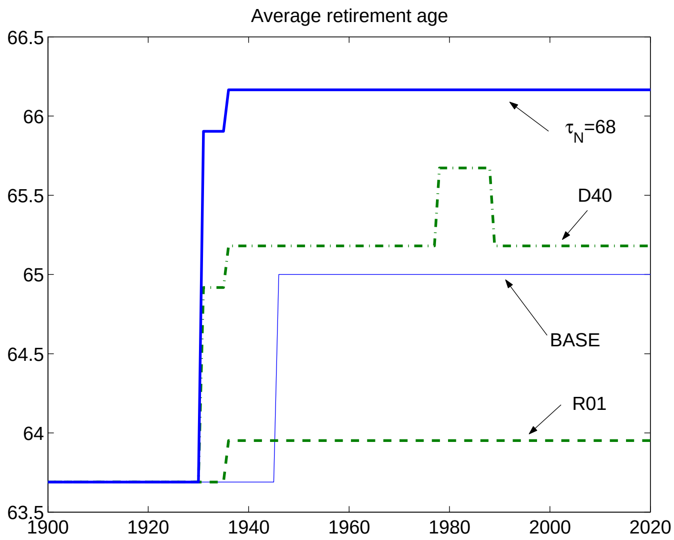

Figure 6: Average retirement age by cohort in our sequence of economies: Base (-), 1997 reform (·), 2001 reform (- -), extension of D to 40 (- · -) and delay of the normal retirement age to 68 (thick -)

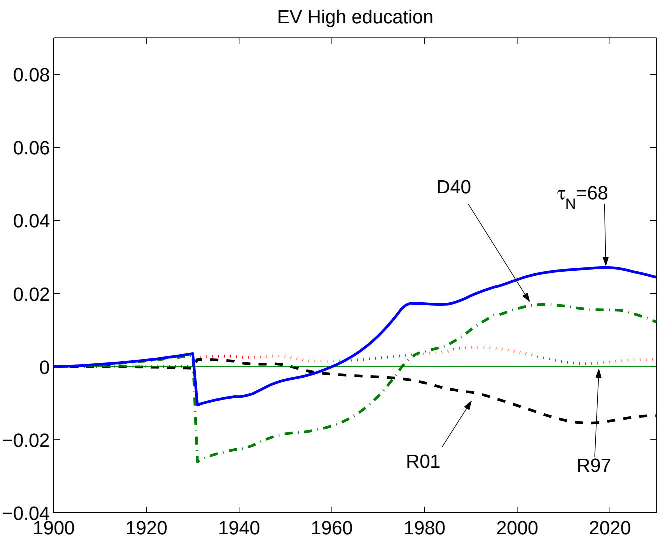

Figure 7: Welfare change by cohort for highly educated workers. Corrected Equivalent Variation associated with 1997 reform (·), 2001 reform (- -), extension of D to 40 (- · -) and delay of the normal retirement age to 68 (thick -)

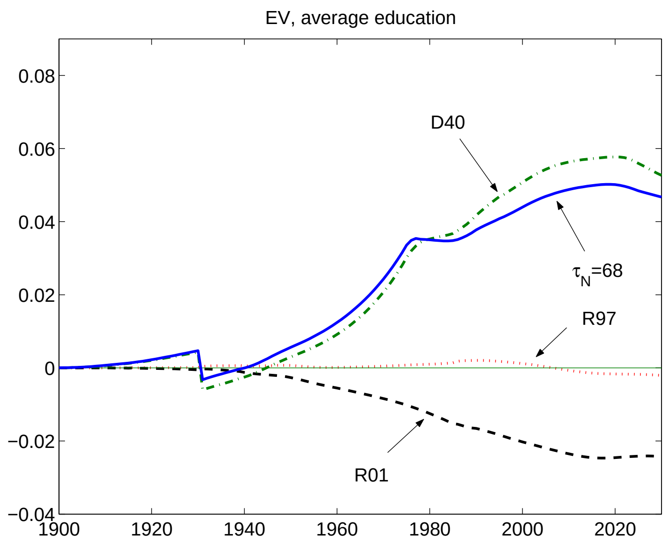

Figure 8: Welfare change by cohort for average educated workers. Corrected Equivalent Variation associated with 1997 reform (·), 2001 reform (- -), extension of D to 40 (- · -) and delay of the normal retirement age to 68 (thick -)

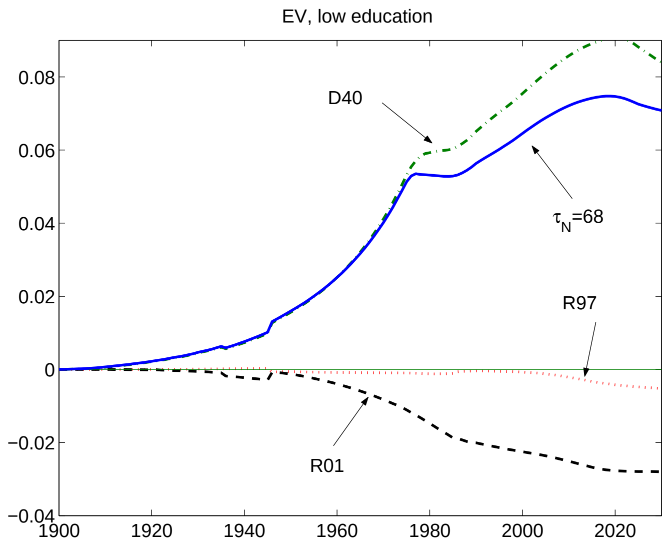

Figure 9: Welfare change by cohort for low educated workers. Corrected Equivalent Variation associated with 1997 reform (·), 2001 reform (- -), extension of D to 40 (- · -) and delay of the normal retirement age to 68 (thick -)

in the average *deficit* of the system along the interval [2000,2050] (0.5% of GDP vs 3.6% in the benchmark) and by a remarkable 40% reduction in the size of unfunded liabilities. The welfare gains from the reforms are very unequally distributed. High income workers are net losers of the reform, but there is substantial inter-cohort variation even within this group. For individuals born after 1975, the lower taxes and higher labor income prevailing under the new system more than compensate for the lower pensions and longer working careers. A small number of cohorts of average income workers (those born before 1945) are in a similar situation, although the extent of their losses is much smaller. Finally, and in sharp contrast, all cohorts of low income workers enjoy important welfare gains. According to our Equivalent Variation measure, the gains for cohorts born after the reform are as high as 8% of the (1995 average of the) present value of life time resources.

Delaying the normal retirement age till 68

An alternative strategy to curb the increase in pension expenditures pursues delays in the effective retirement age (resulting in larger working careers, more life-cycle contribution and less pension payments). In our simulations we explore the impact of making 68 the new *normal* retirement age (the age when a 100% of the regulatory base is granted). We find this change very effective: only low income workers stick to the practice of leaving the labor force early, despite the new institutional environment. Everybody else prefer to stay in the labor force till the new *normal* age, pushing the average retirement age up to 66.2 years. Average pensions also go down slightly (decreasing life-cycle earning profiles result in lower pensions at 68 than at 65), producing additional savings for the pension system. All in all, we observe reductions in the aggregate pension expenses of the same order of magnitude than those created by fixing D in 40 years. The distributional impact is, however, considerably different, as this reform treats the cohorts of current workers in a significantly less severe way. Still, senior workers in the high and average income groups cannot escape suffering welfare losses after the reform.

6 Conclusions

This paper uses a calibrated OLG model to examine the impact of several parametric reforms on the financial sustainability of the Spanish PAYG pension system. We find that the changes introduced in 1997 and 2001 completely fail on this ground, as they actually lead to larger pension liabilities. In contrast, extending the averaging period in the pension formula to 40 years and delaying the Normal retirement age till 68 are effective measures to reduce the generosity of the system and to foster longer working careers. As a result, both *additional* changes reduce the future imbalances of the pension system substantially, although they are not enough to make them disappear. Our calculations also predict important welfare gains stemming from sizable pension cuts, although there are strong differences in the distribution of these gains within and across cohorts. A common feature of the extended reforms is the shift of a large part of the burden associated with population aging to the current cohorts of workers, specially to their most senior members. Therefore, they fit nicely with the (far from uncontroversial) view that the cost of the Baby-Boomers pensions should not be placed on the shoulders of future taxpayers. We also find strong intra-generational differences in the welfare impact of the application of the reforms. If, as seems most plausible, the minimum pension scheme is not subject to parallel benefit reductions, it would effectively protect low income workers from any short-run welfare loss during the implementation of the reforms. Finally, it is worth mentioning that, according to our simulations, delaying the legal retirement age is substantially less damaging for current senior workers than direct pension reductions. We have tested the robustness of the findings to changes in some of the simplifying assumptions in our model economy[22].

We finish the paper by mentioning some posible extensions. Firstly, increases in the female participation rates and reductions in unemployment rates could significantly alleviate the condition of the system during the first decades of the century. Extending large scale OLG models to include these two features will improve the quality of their predictions about the pension system's levels. It is, however, a major challenge given our current modeling and computing capabilities. Secondly, getting a more detailed reproduction of the institutional environment is a less ambitious but also quite relevant improvement. In particular, the consideration of survival pensions (typically in conjunction with gender heterogeneity), the inclusion of the Self-employed Regime and the enrichment of the current representation of the General Regime, will help to improve the calibration of the *levels* of the system and the reproduction of the empirical retirement patterns. Finally it would be important to account for the differences between natives and immigrants in dimensions like income processes and fertility. As the share of the immigrants in total population is going to experience a substantial hike in the future (it is already going up noticeably), these differences are due to play a significant role in the future evolution of the pension system's financial condition.

[22]Changes in the fiscal system, the public expenditure policy, and the "close" economy assumption. We have also confirmed the importance of an endogenous retirement decision for a precise quantitative evaluation of these type of reforms. The details are not reported here to keep the length of the paper within reasonable bounds.

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APPENDIX

A-1 Formal definition of the equilibrium of the model

An *equilibrium path* over the time interval $\mathcal{T}$ consists of the following objects:

- Population aggregates $\{N^t, M^t, P^t, F^t\}$ and population distributions by age and education, $\mu^t_{i\,j}$ for all $\quad i \in \mathcal{I}, \quad j \in \mathcal{J}, \quad t \in \mathcal{T}$
- Assignments of consumption, savings and working hours $\{\, c^t_{i\,j},\ a^t_{i\,j},\ 1 - l^t_{i\,j}\}$ for all cohorts alive in $t \in \mathcal{T}$ and all education types $j \in \mathcal{J}$. [23]
- Inputs employed by the competitive firms $(K^t, L^t) \quad t \in \mathcal{T}$
- A Public Policy $\{\varphi^t, bm^t, CP^t\} \quad t \in \mathcal{T}$.
- A price system: $\{r^t, w^t\} \quad t \in \mathcal{T}$

such that the following properties apply:

1. Endogenous population dynamics

   Population aggregates and distributions are generated by equations (3) and (4), given exogenous profiles for fertility, mortality and flows of immigrants.

2. Individual Rationality.

   Individual assignments are optimal given the price system and the public policy.

3. Factor markets' clearance.

   The capital and labor effectively employed by firms come form the aggregation of individual savings and labor supply:

$$L^t = A^t\, H^t \qquad H^t = \sum_{j=1}^{J} \sum_{i=20}^{\tau_j - 1} P^t_{i\,j}\, \varepsilon_{i\,j}\, (1 - l_i) \qquad K^t = \sum_{j=1}^{J} \sum_{i=20}^{I-1} P^t_{i\,j}\, a^t_{i\,j}$$

4. Competitive prices.

$$r + \delta = \frac{\partial F}{\partial K}(K^t, L^t) \qquad w^t = \frac{\partial F}{\partial H}(K^t, L^t)$$

[23] Note that the working hours depend on the retirement ages τ^u of cohorts alive in t.

5. Balanced Public budget.

$$FI^t(\varphi^t) + PSB^t = CP^t$$

where the fiscal income, FI^t, and the income from bequest, BI^t, take the form:

$$FI^t(\varphi^t) = \varphi^t P^t + BI^t \qquad BI^t = \sum_{j=1}^{J} \sum_{i=20}^{I-1} (1 - hs_{i,j}^{t-i})\, P_{i\,j}^{t-1}\, a_{i+1\,j}^{t-1}$$

the pension system's balance is given by

$$PSB^t = \varsigma w^t L^t - PP^t \qquad PP^t = \sum_{j=1}^{J} \sum_{i=\tau_j}^{I} P_{i\,j}^t\, ib_{i\,j}^t(\tau_j)$$

where PP^t stands for the aggregate pension expenditures.

6. Aggregate feasibility

$$Y^t + (1-\delta)\, K^t + BI^t = K^{t+1} + BI^{t+1} + \sum_{j=1}^{J} \sum_{i=20}^{I} P_{i\,j}^t\, c_{i\,j}^t + CP^t$$