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**An evaluation of the life-cycle effects of minimum  
pensions on retirement behavior**

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# An evaluation of the life-cycle effects of minimum pensions on retirement behavior. \*

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## Abstract

In this paper we explore the distortions that minimum pensions generate on individual decisions, paying special attention to their impact on retirement behavior. This is done with the help of a stylized life-cycle model, which provides a very convenient analytical characterization of the optimality conditions, and a very easy *qualitative* exploration of the impact of pension rules on optimal behavior. In this context we show that a standard life cycle model, that does not consider minimum pensions, is unable to fit the data. This anomaly is resolved once the mechanism of the minimum pension is taken into account. We follow two steps in order to *quantitatively* assess the contribution of minimum pensions to early retirement patterns. We first recovered the preference parameters using the model as the data generating process in a structural econometric estimation. We then simulated the change in the aggregate retirement distribution induced by the minimum pension scheme. We found that 3 out of 4 workers leave the labor force before 65 under the minimum pension scheme, while this ratio is 3 in 5 without it. This result suggests that minimum pensions should be carefully considered in any attempt to reform the Spanish pension system. The same conclusion could be extended to other countries with similar systems.

Keywords: Retirement, life cycle model, minimum pension, structural estimation.  
JEL Class: D91, J26, H55

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# 1 Introduction

It is generally agreed that the aging of the population represents a major challenge to the financial sustainability of current Pay As You Go (PAYG) Social Security Systems. This has led most OECD countries to reform their pension regulations, trying to reduce their generosity and to provide older workers with larger incentives to remain in the labor force. This state of affairs has spurred academic economists to explore the effects of pension rules on individual behavior and on the aggregate performance of the economy. This paper is a contribution to that effort. We focus on the behavioral impact of minimum pension schemes of the type commonly embedded in contributory, Defined Benefit, pension systems (see Kalisch and Aman (1998) for a thorough review of pension regulations in OECD countries).

Minimum pensions are particularly important in Spain. In this country, 37.6 percent of the contributive old-age pensions were being topped up under the minimum pension scheme in 1999.<sup>1</sup> In that year these complements represented 8.5 percent of disposable pension income for men, and 15.2% for women. Successive governments have granted widespread support to the program on the grounds of its popular re-distributive properties. In contrast, its disincentive side-effects have received very little attention. Its tendency to exacerbate the pre-retirement of low-income workers is a paramount example: in our sample of Social Security administrative records almost 70 percent of people retiring at the age of 60 were enjoying a top up of their pensions. This has been no obstacle for the current government to weaken the program's eligibility conditions (the 2002 amendment to the 1997 reform extended the right to early retire to all cohorts of workers, abolishing the existing limitation -which confined that right to those who contributed to the system before 1967) and to announce substantial increases in the generosity of these pensions as part of its general strategy to cope with the problem of the aging population.

In this paper we quantitatively assess the impact of the Spanish pension rules, especially the minimum pension scheme, on the retirement and savings patterns of Spanish workers. This task is undertaken with the help of a life cycle model with an endogenous retirement decision *and* a credit constraint. As a part of calibrating the model, we recovered the preference parameters through a structural econometric estimation (i.e., we used our model as the data generation process in a standard maximum likelihood estimation). This estimation is carried out over a unique, very large sample of labor records obtained from the Spanish Social Security administration (HLSS). Once the model is endowed with explicit preference values, it provides explicit predictions of individual savings and retirement behavior, which we aggregate to derive conclusions about the overall economy. In this context we show that a standard life cycle model that does not consider minimum pensions is unable to fit the data. This anomaly is resolved once the mechanism of the minimum pension is taken into account.

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<sup>1</sup>See chapter 9 in Boldrin, Jiménez-Martín, and Peracchi (2001) for a detailed exploration of the size of the system.

The disincentive effects on savings and labor supply stemming from minimum pensions have passed largely unnoticed in previous literature.<sup>2</sup> They have a clear connection with several previous studies on the inefficiency created by “flat” (i.e. unrelated to the individual’s working history and age) pensions on labor supply. The impact on hours worked is addressed in Kenc and Perraudin (1997a) and has received special attention in the applied general equilibrium literature (Auerbach and Kotlikoff (1987), De Nardi, İmrohoroğlu, and Sargent (1999) or Huggett and Ventura (1999)). In contrast, Sheshinski (1978) analyzes the effect on discrete *retirement* behavior.

The computation of public pension *accruals* and implicit *tax rates* for some selected representative agents in Boldrin, Jiménez-Martín, and Peracchi (1999) and Jiménez-Martín and Sánchez-Martín (2001) are the only previous quantitative evaluations available of the impact of the Spanish pension system on retirement decisions. The first paper mentioned shows that low-income workers have very few incentives to stay active at the Early Retirement Age (ERA, 60 in Spain), in sharp contrast with the situation for average income workers. The authors conjecture that the minimum pension is behind this phenomenon, a fact confirmed (using the same methodology) in the second paper mentioned.

Our structural estimation exercise is related to the econometric literature on retirement behavior. The state of the art is represented by the maximum likelihood approach in Rust and Phelan (1997) and the Method of Simulated Moments implemented in French (2000), French and Jones (2001) and Gustman and Steinmeier (2002).<sup>3</sup> However, as our data generation process is a continuous time life-cycle model, our estimation procedure is closer to that employed in Hurd (1989) structural assessment of bequest motives and in Gustman and Steinmeier (1986) analysis of the effects of wage reductions on partial retirement.

Finally, the effect of credit constraints (the prohibition of anticipating the consumption of future pension flows) on life cycle savings has been explored in Leung (1994) and Leung (2000), while Crawford and Lilien (1981) and Fabel (1994a) discuss its impact on retirement. Our work integrates both approaches.

As stated before, in this work we extend the standard life cycle model with a retirement decision *and* a credit constraint. This type of model is extremely well suited to exploring the impact

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<sup>2</sup>Some authors have stressed the opportunity that the prospect of financial difficulties provides for a general re-design of the systems. Kenc and Perraudin (1997b) and Engen and Gale (1997) are good examples, but the role the minimum pensions can play on this has not been explored so far.

<sup>3</sup>Rust and Phelan (1997) show that size of the retirement flows in USA (particularly the discontinuities at the key ages of the pension system, 62 and 65) can be entirely rationalized on economic grounds. They are the optimal reply to old-age pension rules, health shocks (in form of out-of-pocket medical costs) and the insurance mechanisms available for that risk. French (2000) extends the previous work by considering the optimal savings decision (although in a different estimation framework). In contrast, this paper does not analyze the role of the insurance mechanisms included in Rust and Phelan. This drawback has been solved in French and Jones (2001), a paper that assesses the relative importance of Medicare and pension rules on the retirement flows at the age of 65.

of pension rules on savings and labor supply. In particular, its closed-form first order condition for the retirement age significantly simplifies reviewing the qualitative predictions of the model. We then propose a maximum likelihood estimation procedure for the preference parameters, based on our previous theoretical model. Our method largely avoids the computational burden involved in the estimation of standard Dynamic Programming Models. Finally we *simulate* the impact of minimum pensions and borrowing constraints on retirement behavior in Spain.

Our main findings can be summarized as follows:

- Our model predicts that minimum pensions drive low-income workers out of the labor force as soon as the pensions become available for the first time.
- Our life-cycle model does a satisfactory job in reproducing actual empirical behavior. In particular, it has significantly better explanatory power than its reduced-form probit counterpart.

The estimated preference parameters are close to the values reported in the previous literature. In particular, our estimates compare favorably with those obtained in Hurd (1989), where the predictions (about optimal savings) of a similar model are used as the data generation process.

- Three out of four workers leave the labor force before 65 under the minimum pension scheme, while this number is three in five without them. That is a 20% increase in the incidence of early retirement. This result is robust to changes in the interest rate and the generosity of the minimum pensions.
- Our model predicts a moderate success for the labor-incentive package introduced in 2002, combining pension bonuses and the elimination of contributions for people working beyond 65. Alternatively, a policy consisting of actively subsidizing workers to stay after the age of 60 can significantly increase participation rates before the Normal Retirement Age (NRA).
- Finally, in absence of *recursive* uncertainty, prohibiting borrowing from future pensions has very little impact on retirement incentives. In this environment, the main force driving low earning workers out of the labor force at the age of 60 is the minimum pension scheme.

Our quantitative findings are specific to the Spanish case, but the general conclusions reached in our experiments could be applied more broadly. The strong disincentive effect of minimum pensions on older workers' participation should be a reality in most countries with similar pension systems. It should also be taken into account when assessing the overall impact of proposals to privatize the system that include a minimum benefit guarantee (see Smetters (2002) for an example of the currently available studies).

The rest of the paper is as follows. In section 2 we describe the Spanish pension rules, and the stylized facts of retirement in Spain. We also show how they can be interpreted as the optimal response to the incentives provided by the pension rules. In section 3 we introduce our life cycle model and briefly review its basic theoretical predictions. Section 4 deals with the structural estimation experiment. Firstly, we describe how to use the life cycle model as a data generation process; then we present the maximum likelihood estimations, and finally we comment on the properties of the preferences revealed throughout this experiment. We quantify the effect of minimum pensions and perform some other experiments in section 5. Finally, section 6 concludes the paper with some general comments.

## 2 Minimum pensions and retirement behavior

In this section we briefly review the basic features of the Spanish pension system, explore the main labor supply patterns for older workers and provide an intuitive explanation of the impact of the former on the latter.

### 2.1 Spanish Old Age pension rules

Public pensions is the largest welfare program in Spain, absorbing almost 70 percent of the total expenditure for social protection programs and representing around 10% of GDP in 2001. The system is of the Pay As You Go, Defined Benefit type. It provides five types of contributory pensions (old age, disability, widows and widowers, orphans and other relatives), and it is organized around three basic schemes: the General Regime (private sector employees and some public servants), the Government Employee Scheme (central government public servants) and some Special Regimes, with the Self-employed Scheme being the most important one. In this paper we deal with old age pensions granted by the General Social Security Regime, under the 1985 rules.<sup>4</sup> A brief description of the basic features of the 1985 system now follows. For a thorough explanation of the details of the system under both the 1985 and 1997 rules and 2002 Amendment we refer to Boldrin and Jiménez-Martín (2002).

**Financing:** The System is financed through contributions from employers and employees. 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 to the professional category. The current contribution rates are 23.6 and 4.7 %, for employers and employees, respectively.

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<sup>4</sup>A distinguishing feature of the Spanish pension system from its very beginning has been the existence of a variety of Regimes. However, all recent reform efforts feature reductions in the system dispersion, making the General Regime its cornerstone. As a result, 73.9% of the workers affiliated to the system in 2001 already belong to the General Regime, although 45% of the existing pensions in the same year had been awarded under a different regime.

**Pension formula:** Eight years of contributions (15 after the 1997 reform) are needed to be entitled to a pension. A complete withdrawal from the labor force is also a requirement to start collecting the benefit. The initial amount is obtained by multiplying a *benefit base* and a replacement rate. The *benefit base* is a moving average of the contribution bases in the 8 years immediately before retirement (15 after the 1997 system). The replacement rate depends on age and the number of years of contributions. An individual receives 100% of the *benefit base* if he retires at the age of 65 (Normal Retirement Age,  $\tau_N$ ) having contributed for more than 35 years. It is possible to start collecting the pension at the age of 60 (ERA) under a 40% penalty on the benefit base (35 % penalty for workers with at least 40 years of contributions after 1997). This corresponds to an 8% annual penalty for bringing forward the retirement age (7% with 40 years of contribution after 1997).<sup>5</sup> There is also a penalty for insufficient contributions if the length of the working career is less than 35 years. The *benefit base* is reduced by a 2% for every year the contribution record is short of that number. The purchasing power of the initial benefit is kept constant according to the evolution of the CPI.

**Minimum and maximum pensions:** There are lower and upper limits on the pension benefit. Their values in 2000 were roughly equal to minimum wage and four times the minimum wage. The minimum pension depends on age (they are higher for people older than 65) and on the presence of a dependent spouse. In 1999 almost 35% of old age pensions were topped up to the guaranteed minimum (23.7% in the General Regime), while the incidence of maximum pensions was much lower. Historically the behavior of both limits, which are annually fixed by the government, has been very different. Over the last 15 years, minimum pensions have grown at approximately the same rate as nominal wages, while maximum pensions have been kept roughly constant in real terms.

## 2.2 Labor supply patterns of older workers in Spain and its interpretation

Most Spanish workers withdraw from the labor force either at the ERA (60) or at the NRA (65). This results in sharp discontinuities in the empirical retirement hazard at the pension system's key ages (figure 1). This is a very robust empirical pattern, shared by most countries running PAYG, Defined Benefit (DB) pension systems.<sup>6</sup> Figure 2 explores the composition of the hazard peaks according to an individual's labor income. It displays a non-parametric estimation of the retirement hazard at selected ages, as a function of the expected labor income at the age of

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<sup>5</sup>A minor change in the way the penalties are computed came into force in January 2002. The new rule marginally reduces the early retirement penalty for individuals with very long contribution records.

<sup>6</sup>Our data come from a sample of administrative records from the Spanish Social Security in 1995, see the section E of the appendix, but virtually identical patterns can be found in all other available databases (the European Household Panel (EHP), the Family Income Survey (EPF) or the Labour Force Survey (EPA)). Cross country comparisons of retirement hazards are presented, for instance, in Gruber and Wise (1999) (for eleven developed countries).

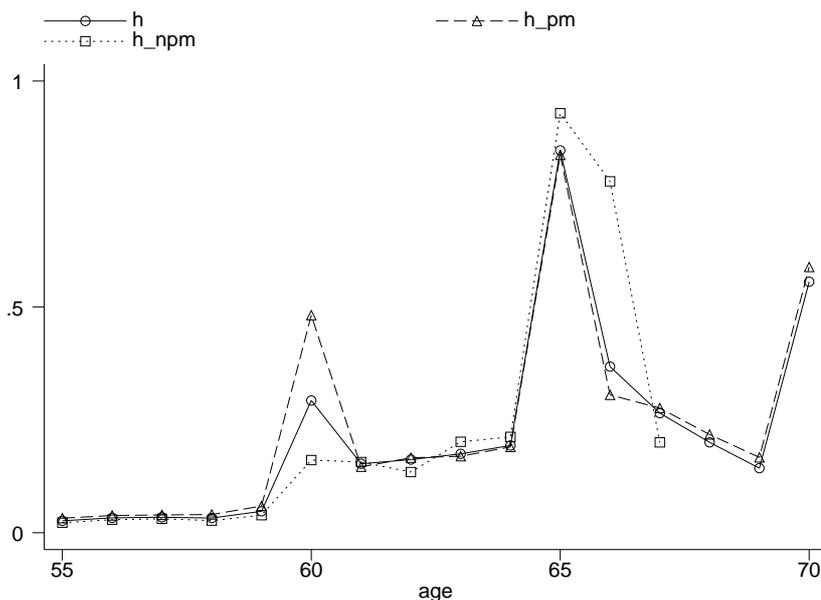


Figure 1: Retirement hazard by age: total population (-), perceptrors of minimum pensions (- -) and non-perceptrors ( $\cdot$ ). Source: HLSS, 1995

60. We find that, while the probability of leaving the labor force at the NRA is unaffected by the salary level, there is a clearly decreasing pattern at the ERA. A pattern that is basically independent of the educational achievement of the individual.<sup>7</sup> It means that most early retirees are low-income workers who qualify for a minimum pension top-up. We also find that 67.7% of the people who retire at the exact age of 60 are actually receiving the minimum complement. Finally, it is quite revealing that the retirement hazard at the age of 60 for those affected by the minimum pension is 5 times larger than that for those who do not receive it (see figure 1).

### An informal explanation of the empirical regularities

To explore the incentives underlying the pension regulations imagine a worker who decides to stay working at a specific age  $\tau$ . He faces two marginal disincentives for doing so: the reduction in leisure time and, provided the eligibility conditions are met, the foregone pension benefit. On the other hand, staying working allows the individual to collect a salary and implies a change in the pension benefit he is entitled to in the future. This latter change depends on two elements. Firstly, delaying retirement in the age range  $\{\tau_m, \dots, \tau_N\}$  reduces the early retirement penalty (and the insufficient contributions penalty, if the number of years of contribution is lower than 35). Secondly, the *benefit base* changes as current gross labor income moves into the averaging

<sup>7</sup>The education level is not observable in our sample of social security records, but can be approximated by the contribution group, with which the education level is highly correlated (see Boldrin, Jiménez-Martín, and Peracchi (2002) for an illustration).

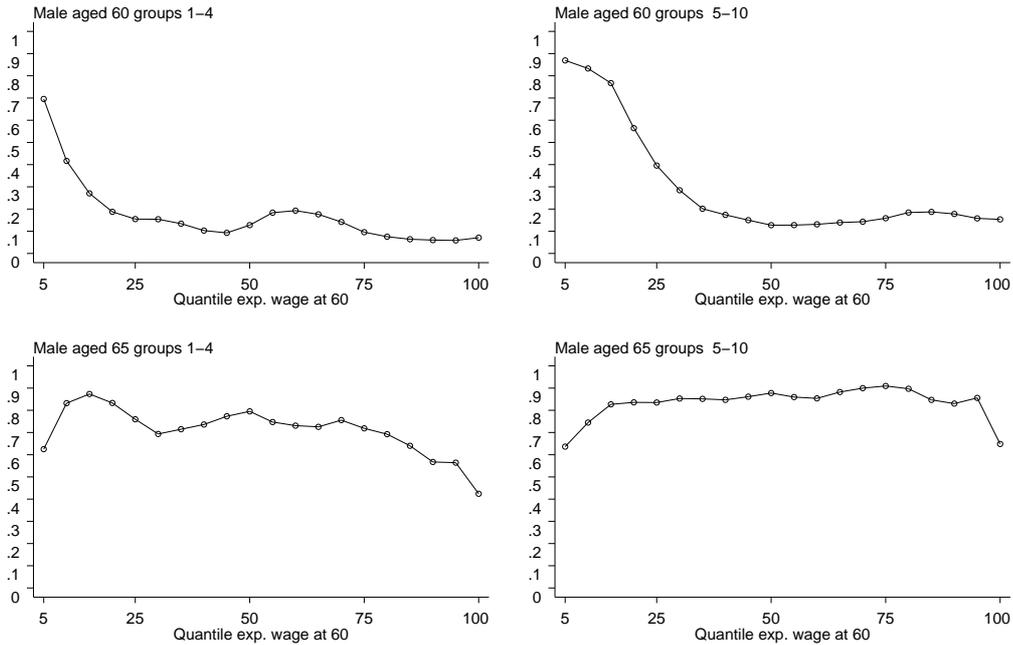


Figure 2: Retirement hazard at the ages of 60 (top panels) and 65 (bottom panels) for high (left panels) and low (right panels) educated workers, by wage level at the age of 60. Source: HLSS, 1995

period and substitutes the value observed 8 years before (15 years under the 1997 system). Note that while the first effect always results in higher benefits, the concavity of the life cycle profiles of labor income can make the second have the opposite effect.

Keeping all this in mind, it is not difficult to explain the peaks in retirement hazard. The age 65 peak is an optimal reply to (1) the lack of an actuarial adjustment of pension benefits after the NRA, (2) the drop in the *benefit base* induced by labor income dynamics at such advanced ages, (3) the low incentive provided by a decreased salary and (4) the fact that the opportunity cost of the foregone pension typically reaches its maximum at that age. It is also quite easy to rationalize the ERA peak of Spanish workers as a result of the minimum pension mechanism. As the size of the minimum pension is independent from the individual's circumstances, it completely eliminates the incentives to work due to the pension formula. In particular, it wipes out the strong incentives associated with the early retirement penalties, while increasing the opportunity cost of the foregone pension. Boldrin, Jiménez-Martín, and Peracchi (1999) and Jiménez-Martín and Sánchez-Martín (2001) assess the strength of the *incentives* provided by the minimum pensions by computing their associated accruals and implicit tax rates. There is, however, no previous evaluation of the optimal behavioral response to these incentives. That assessment is undertaken in the next section.

### 3 The behavioral model

Our behavioral model is an extension of the standard life cycle model of Modigliani and Brumberg (1980), including life uncertainty and the prohibition of borrowing from future pension income. This credit constraint is relevant in the absence of a bequest motive, an aspect first established in Yaari (1965) and treated thoroughly in Leung (2000). We follow this latter paper in the treatment of the model with a fixed retirement age, while our analysis of the retirement decision is similar to that in Crawford and Lilien (1981) and Fabel (1994b).

The length of individual life,  $t$ , is a continuous random variable distributed on  $[0, \bar{T}]$  according to the survival function  $S(t)$  and mortality hazard  $h(t)$ .<sup>8</sup> This is the only source of uncertainty the individuals face in the model. Their preferences for consumption,  $c(t) : [0, \bar{T}] \rightarrow \mathcal{R}_+$  and leisure,  $l_\tau(t) : [0, \bar{T}] \rightarrow [0, 1]$  (with  $l_\tau(t) = 1 \quad \forall t \in [\tau, \bar{T}]$ ) are represented by a standard, additively separable utility function:

$$V(c, l_\tau) = \int_0^{\bar{T}} e^{-\delta t} v(c(t), l_\tau(t)) dt$$

where  $\delta$  is a discount factor. The period utility function is also additively separable in its two arguments:  $v(c, l) = u(c(t)) + \nu(l(t))$ , with both components exhibiting the usual properties.<sup>9</sup> Individuals choose the consumption path and a unique retirement age  $\tau$  in order to maximize the expected discounted flows from the previous utility function, under the constraints imposed by the institutional environment. This includes two market imperfections: the lack of an insurance market for life uncertainty (i.e. absence of private annuities) and the prohibition of borrowing from future pension income (i.e., accumulated assets  $a(t)$  must not be negative after retirement age in order to avoid people dying with standing debts).

Working individuals receive a gross labor income  $w(t)$  and must pay social contributions at a constant rate  $\varsigma$ .<sup>10</sup> After retirement, the consumer's income consists of a flow of pension benefits,  $b(t, \tau)$ , which depends on both age and the retirement age (see details of the system in section 2.1). We also assume that there is no bequest motive for savings and that the public sector fully taxes involuntary bequests. The formal statement of the intertemporal problem is as follows:

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<sup>8</sup>We assume that  $h(t) > 0 \quad \forall [0, \bar{T}]$  and  $\lim_{t \rightarrow \bar{T}} h(t) = \infty$ . Applying standard results it is easy to show that the survival function can be expressed as a non-linear discount function:  $S(t) = \exp\left(-\int_0^t h(s) ds\right)$

<sup>9</sup>They are twice continuously differentiable, strictly increasing and concave. We also assume that  $\lim_{c \rightarrow 0} u'(c(t)) = \infty$ .

<sup>10</sup>In this section we omit some of the institutional details in order to ease the exposition. For a complete list of the institutional details modelled in our empirical application see Table 1

$$\begin{aligned}
& \max_{c(t), a(t), \tau} \quad E[V(c, l)] = \int_0^{\bar{T}} e^{-\delta t} S(t) [u(c(t)) + \nu(l_\tau(t))] dt \\
& \quad \dot{a}(t) = r a(t) + \tilde{w}(t, \tau) - c(t) \\
& \quad \tilde{w}(t, \tau) = w(t)(1 - \varsigma) \mathcal{I}(0, \tau) + b(t, \tau) \mathcal{I}(\tau, \bar{T}) \\
& \quad l_\tau(t) = l(t) \mathcal{I}(0, \tau) + 1 \mathcal{I}(\tau, \bar{T}) \\
& \quad a(0) = a_0 \quad a(\bar{T}) = 0 \quad a(t) \geq 0 \quad \forall t \geq \tau
\end{aligned} \tag{1}$$

where  $\mathcal{I}(t_0, t_1)$  is the indicator function for the event  $t \in [t_0, t_1]$ . For the sake of simplicity we abstract from private pensions (quite irrelevant in the Spanish case), work with a constant real interest rate,  $r$ , and take the life cycle profile of labor hours  $l(t)$  as exogenously fixed.<sup>11</sup>

Under the previous assumptions, the borrowing constraint always becomes binding before the maximum life span (see proposition 1 in Leung (2000)). We denote this “wealth depletion time” by  $\bar{t} \in [\hat{\tau}, \bar{T}]$ , where  $\hat{\tau} = \max\{\tau_m, \tau\}$  (ie. the maximum between the individual retirement age and the ERA). Following Crawford and Lilien (1981) and Fabel (1994b) we can use this result to transform the original constrained problem into a new un-constrained problem including  $\bar{t}$  as a new decision variable:

$$\begin{aligned}
& \max_{c(t), \tau, a(t), \bar{t}} \quad \int_0^{\bar{T}} e^{-\delta(t)} u(c(t)) dt + \int_{\bar{t}}^{\bar{T}} e^{-\delta(t)} u(b(t, \tau)) dt + \int_0^{\bar{T}} e^{-\delta(t)} \nu(l_\tau(t)) dt \\
& \quad \text{st.} \quad a'(t) = r a(t) + \tilde{w}(t, \tau) - c(t) \quad t \in [t_0, \bar{t}] \\
& \quad \tilde{w}(t, \tau) = w(t) (1 - \varsigma) \mathcal{I}(0, \tau) + b(t, \tau) \mathcal{I}(\tau, T) \\
& \quad \bar{t} \in [\hat{\tau}, \bar{T}] \quad l_\tau(t) = l(t) \mathcal{I}(0, \tau) + 1 \mathcal{I}(\tau, \bar{T}) \quad \hat{\tau} = \max\{\tau_m, \tau\} \\
& \quad a(0) = a_0 \quad a(t) = 0 \quad t \in [\bar{t}, \bar{T}]
\end{aligned} \tag{2}$$

We deal with this problem in three stages. Firstly, we analytically characterize the optimal profiles of consumption and accumulated assets for a *given* retirement age and a *given* binding age for the credit constraint. Using these conditional solutions we compute in a second stage the optimal binding age for any given retirement age. Finally, we employ the information of the previous two stages to characterize the optimal retirement age.

### 3.1 Optimal conditional consumption and savings

When both the retirement,  $\tau$ , and the wealth depletion age,  $\bar{t}$ , are fixed, a straightforward application of Optimal Control Theory allows for a complete characterization of the optimal *conditional* consumption function  $c_\tau(\cdot | \bar{t})$ . If we further restrict ourselves to the CES case (the general case is discussed in appendix A.1), where  $u(c) = c^{1-\eta}/(1-\eta)$ , the optimal *conditional* consumption takes the following explicit form:

$$c_\tau(t | \bar{t}) = \frac{[S(t)d(t)]^\gamma}{\mathcal{C}_c(\bar{t})} Y(\tau, \bar{t}) \quad \text{with} \quad \mathcal{C}_c(\bar{t}) = \int_0^{\bar{t}} e^{-r t} [S(t) d(t)]^\gamma dt \tag{3}$$

<sup>11</sup>A fixed profile of hours worked can be motivated as the result of a very inflexible labor market. Some evidence can be found in Sánchez-Martín (2002)

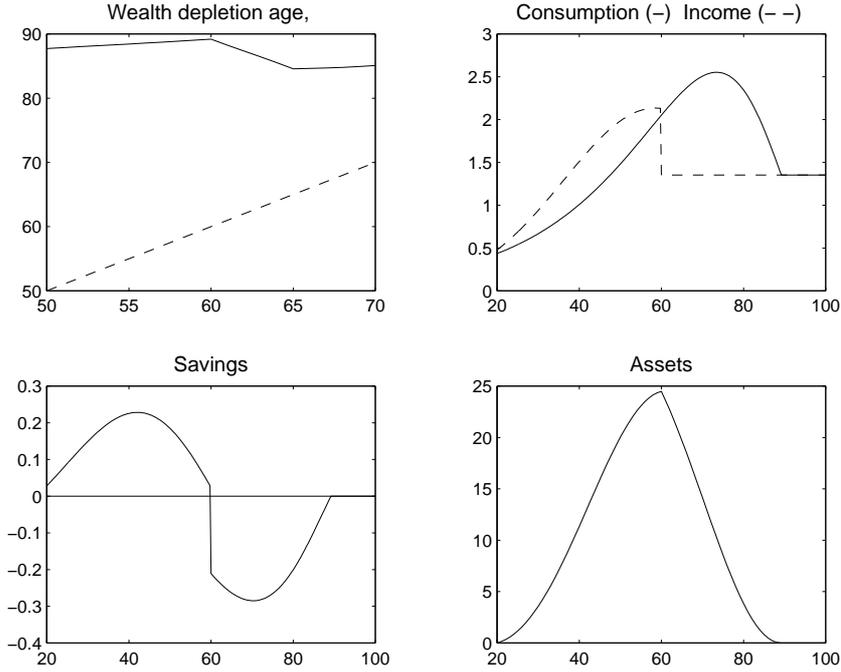


Figure 3: Optimal wealth depletion age  $\bar{t}$ , and optimal life cycle behavior (consumption, savings and accumulated assets) for the Spanish economy’s median worker in case of retirement at the age of 60.

where  $\gamma$  stands for the intertemporal elasticity of substitution  $\gamma = 1/\eta$ ,  $d(t) = \exp\{(r - \delta)t\}$  is the net discounted factor,  $C_c(\bar{t})$  is an integrating constant (ensuring that the present discounted values of earnings and consumption are equal), and  $Y(\tau, \bar{t})$  is the *Conditional Life-cycle Wealth*:

$$Y(\tau, \bar{t}) = \int_0^\tau e^{-rt} w(t)(1 - \varsigma) dt + \int_{\hat{\tau}}^{\bar{t}} e^{-rt} b(t, \tau) dt \quad (4)$$

Expressions (3) and (4) make it easy to study the dependence of optimal consumption on individual preferences, life cycle income and the survival profile, given a specific institutional environment. They also allow the optimal conditional consumption profile to be calculated very quickly.

As the survival probability eventually goes to zero as age increases, the optimal *conditional* consumption profile must be eventually decreasing. Intuitively, there must be an age  $t^*$  where the constant or increasing pension benefits equal the decreasing *conditional* consumption, i.e.  $c_\tau(t^* | \bar{t}) = b(\tau)$ . Assume we represent this relation via the function  $h_\tau(\bar{t})$ . Of course, there is no guarantee that  $t^* \equiv h_\tau(\bar{t}) = \bar{t}$  for an arbitrary wealth depletion age  $\bar{t}$ . As we show in the next paragraph, this condition defines the “optimal” binding age for the credit constraint. Therefore, finding the right *unconditional* optimal consumption function (for every retirement age) requires finding the unique fix point of  $h_\tau(\cdot)$ .

## The optimal binding age for the credit constraint

If we particularize the previous optimal *conditional* consumption function  $c_\tau(t|\bar{t})$  in problem (2) objective function, we are left with the following “concentrated” problem, which provides the optimal wealth depletion age for a given retirement age:

$$\begin{aligned} \max_{\bar{t} \in [\hat{\tau}, \bar{T}]} \quad & V(\bar{t}) = \int_0^{\bar{t}} e^{-\delta(t)} u(c_\tau(t|\bar{t})) dt + \int_{\bar{t}}^{\bar{T}} e^{-\delta(t)} u(b(t, \tau)) dt \\ \text{Given} \quad & \tau, \quad c_\tau(t|\bar{t}) : [0, \bar{t}] \rightarrow \mathcal{R}_+ \text{ and } \hat{\tau} = \max\{\tau_m, \tau\} \end{aligned} \quad (5)$$

It is easy to check (see appendix A.2) that, under our assumptions, the solution to this problem coincides with the intuitive proposal we stated at the end of the previous section: the optimal  $\bar{t}$  is implicitly defined as a fixed point of the function  $h_\tau(\cdot)$

$$t^* \equiv h_\tau(\bar{t}) = \bar{t} \quad (6)$$

In practice, we obtained the optimal  $\bar{t}$  by applying a root finding routine to the equation  $t - h_\tau(t)$  in the interval  $[\hat{\tau}, \bar{T}]$ .<sup>12</sup>

Figure 3 displays the optimal  $\bar{t}$  as a function of retirement age for a Representative Agent (RA) of the Spanish economy.<sup>13</sup> It also reproduces the optimal life-cycle consumption and saving behavior. We see that although consumption grows for most of the individual’s life, it eventually starts to decrease, leading to a rather advanced wealth depletion age. Therefore, the credit constraint becomes binding only for the very elderly. Median workers accumulate assets right after the entrance into the labor market, and start depleting assets only after retirement.

## 3.2 Optimal retirement behavior

After the first two stages of our solution procedure we are left with the optimal *unconditional* consumption function,  $c_\tau(t)$ , and optimal binding age  $\bar{t}(\tau)$  for any fixed retirement age. We can then characterize the optimal retirement behavior as the solution to the following static optimization problem:

$$\tau = \arg \max_{\tau \in [t_0, t_1]} V(\tau) \quad (7)$$

where  $0 < t_0, t_1 < \bar{T}$  and  $V(\tau) = V(c_\tau, l_\tau)$ , ie:

$$V(\tau) = \int_0^{\bar{t}(\tau)} e^{-\delta(t)} u(c_\tau(t)) dt + \int_{\bar{t}(\tau)}^{\bar{T}} e^{-\delta(t)} u(b(t, \tau)) dt + \int_0^\tau \nu(l(t)) dt + \int_\tau^{\bar{t}(\tau)} \nu(1) dt$$

<sup>12</sup>There can be corner solutions ( $\bar{t} = \hat{\tau}$ ) to the problem if  $c_\tau(\hat{\tau}|\hat{\tau}) < b(\hat{\tau})$ .

<sup>13</sup>To illustrate the qualitative properties of optimal behavior, we construct representative agents for both average and low earnings workers. In order to construct their respective labor income profiles, we used the median and the 10th percentile of the empirical distribution in 1994 wave from the European Community Household Panel (ECHP). The survival probabilities and all the other environmental parameters are identical to those used in the estimation of the model (see section 4.2). The preference parameters employed are our maximum likelihood estimations in section 4.

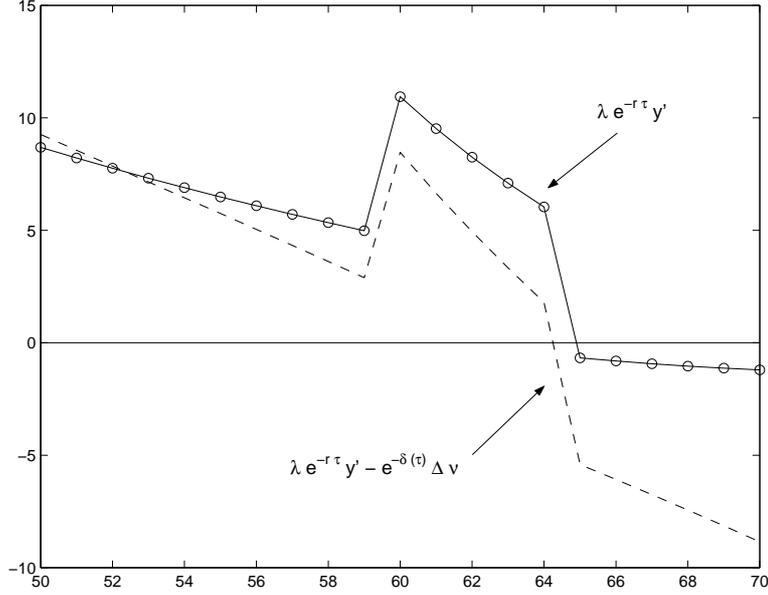


Figure 4: Marginal utility of working by age for the Spanish median worker. We separately show marginal changes in life cycle wealth  $\lambda e^{-r\tau} y'(\tau)$ , and the total marginal change implied, including the impact of leisure reductions.

Some discontinuities introduced by the pension regulations (see below) imply that  $V(\tau)$  is only piecewise continuously differentiable. Therefore, local optimum  $\tau^*$  can be either interior:

$$\frac{dV}{d\tau}(\tau^*) = 0 \quad \frac{d^2V}{d\tau^2}(\tau^*) < 0$$

or corner solutions, i.e., ages where the marginal utility of working changes its sign in a discrete, negative drop. Finding the best retirement age involves a comparison among the utility levels achieved with every local optimum.

In our life cycle context, the optimal retirement is driven by a relatively simple income/leisure trade-off. This can be shown by exploring the marginal utility of staying employed at any age  $\tau$ :

$$\frac{dV}{d\tau}(\tau) = \lambda e^{-r\tau} y'(\tau) - e^{-\delta(\tau)} \Delta \nu(\tau) \quad (8)$$

where  $\lambda$  is the lagrange multiplier associated with the implicit Intertemporal Budget Constraint,  $y'(\tau)$  is the present value of the marginal changes in  $\tau$ -conditional life cycle wealth, and  $\Delta \nu(\tau) = \nu(1) - \nu(l_\tau)$  is the current utility cost of the foregone leisure. Expression (8) formalizes the intuitions on marginal cost and benefits from continuing work previously discussed in section 2.2. Pension rules have a critical influence on retirement by shaping the life cycle profile of  $y'(\tau)$ , as we review in the next section.

### 3.3 The effects of pension rules on individual behavior

By continuing working at age  $\tau$ , the individual's life cycle wealth is modified in three different ways. On the one hand, if the eligibility criteria are met pension benefits are replaced by labor income. On the other hand, the pension benefit the worker is entitled to receive in the future changes. This latter effect can be very important, as it alters the income to be perceived at every single year after retirement. The analytical expression of these changes is given by:

$$y'(\tau) = w(\tau)(1 - \varsigma) - b I(\tau \geq \tau_m) + b' \tilde{\mathcal{A}}(\hat{\tau}, \bar{t}) \quad (9)$$

where  $I(\cdot)$  is a standard indicator function and  $\tilde{\mathcal{A}}(\hat{\tau}, \bar{t})$  captures the effect, accumulated over the individual's entire remaining life, of marginal changes in the benefit:

$$\tilde{\mathcal{A}}(\hat{\tau}, \bar{t}) = \int_{\hat{\tau}}^{\bar{t}} e^{-r(t-\tau)} dt + e^{-r(\bar{t}-\tau)} \int_{\bar{t}}^{\bar{T}} e^{-(\delta(t)-\delta(\bar{t}))} dt$$

The first term represents the impact along the interior optimal consumption path, while the second captures the direct impact of changes in  $b$  in the utility function after the optimal wealth depletion age. Notice that the second term does vanish under perfect capital markets. The trade off is slightly different in the presence of corner solutions, i.e. when  $c_\tau(\tau|\tau) < b(\tau)$ . However, as this is not a very common situation, we have confined the details to appendix B, where a general expression for the marginal utility of working is presented.

The incentives the pension rules create for an average Spanish worker (characterized by a concave wage profile) are displayed in figure 4 and can be summarized as follows:

- Before the ERA,  $\tau_m$ , workers have very significant incentives to keep working, stemming basically from a relatively high salary and the fact that they do not suffer the marginal cost of the foregone pension (this is revealed by the indicator function,  $I(\tau \geq \tau_m)$ , in (9)).
- In the age range  $[\tau_m, \tau_N)$  individuals have strong incentives to keep working. This is a direct consequence of the early retirement penalties: by staying employed, individuals are granted the equivalent of an 8% annual increase in the replacement rate. This more than offsets the opportunity cost of the foregone pension, resulting in a positive jump in the marginal utility of working along this time interval.
- Once the individual reaches the NRA, that is, when there are no further premia for delaying retirement, the incentive to work vanishes (recall the arguments given in section 2.2)

#### 3.3.1 The effects of the minimum pension scheme

Low-income workers qualify for a top up of their old age pensions to the annually legislated guaranteed minimum. This results in substantially different retirement incentives to those described in the previous section. The marginal change in life cycle wealth is now:

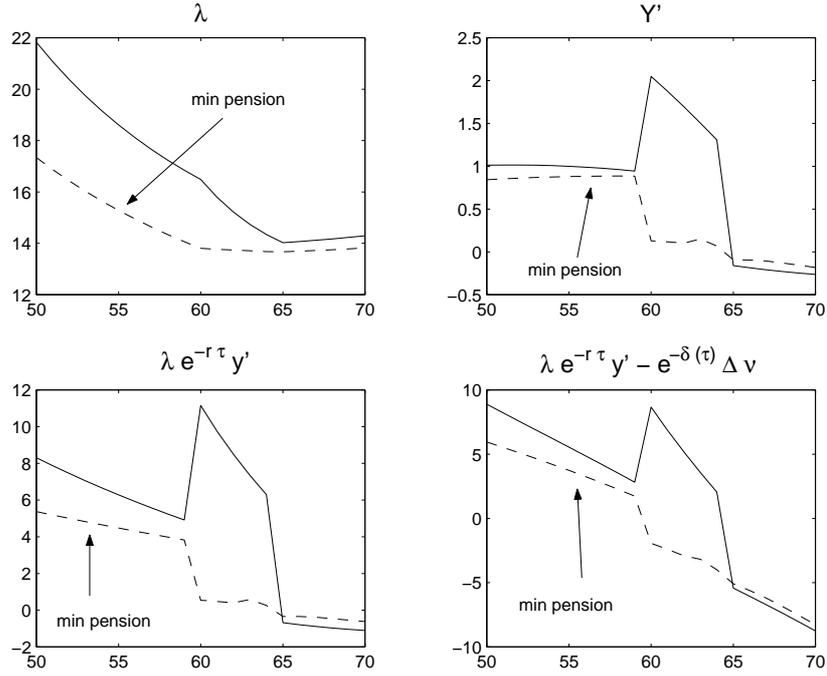


Figure 5: Income and substitution effects induced by the minimum pension scheme on a worker in the 10th quantile of the income distribution.

$$y'(\tau) = w(\tau)(1 - \varsigma) - bm I(\tau \geq \tau_m) \quad (10)$$

It is most apparent that the minimum pension utterly eliminates the incentive to work due to the age penalties, making it optimal for most low-income workers to retire at the earliest possible age (i.e., the ERA). The magnitude of this *substitution effect* can be fully appreciated in the right upper panel of figure 5, which shows the age profile of marginal changes in life cycle wealth for a worker in the 10th quantile of the income distribution, with and without the minimum pension scheme. Minimum pensions also have an *income effect*, as they effectively increase the individuals' life cycle wealth. This is reflected in the optimality condition (8) through lower values of the lagrange multiplier  $\lambda$ , which also weaken the incentive to keep working in the pre-retirement ages (left top panel of figure 5). The overall impact on the marginal utility can be appreciated in the bottom panels of figure 5.

Workers in higher quantiles of the earnings distribution may not be entitled to any top up of their initial pension. However, minimum pensions can become binding later in the life-cycle if the real value of the minimum pension goes up as the individual gets older. The marginal changes in life-cycle wealth when the minimum pension becomes binding at the age  $J(\tau) > \hat{\tau}$ , takes the form:

$$y'(\tau) = w(\tau)(1 - \varsigma) - b I(\tau \geq \tau_m) + b' \tilde{\mathcal{A}}(\hat{\tau}, J(\tau)) \quad (11)$$

This is clearly an intermediate case: minimum pensions weaken the incentive effects stemming from age penalties, but do not make them disappear completely.

## 4 Econometric estimation of the preference parameters

In this section we design a method to recover the preference parameters by comparing optimal retirement (as predicted by the previous section’s theoretical model) with actual retirement data (from our HLSS database, which is described in appendix E).<sup>14</sup> We start by reporting the way we introduce variability in individual retirement ages, by assuming a specific form of unobserved heterogeneity within our sample. We then describe the details of our maximum likelihood estimation procedure. We conclude the section by presenting the estimation results followed by a discussion.

### 4.1 Unobserved heterogeneity

In order to introduce variation in the retirement decisions of individuals who are identical in their observable characteristics, we assume a distribution of the (unobservable) relative value of leisure across the population. In particular, we assume that the leisure component in the utility function takes the form:

$$\Delta\nu(t) = \Delta\nu_D(t) + \varepsilon \quad \varepsilon \sim F_\varepsilon(\cdot)$$

where  $F_\varepsilon$  stands for the population distribution of  $\varepsilon$  and  $\nu_D(t)$  is a deterministic component which depends on observable characteristics. Therefore, the marginal utility of working  $(\partial V/\partial\tau)(\tau)$ , which will hereafter be denoted by  $\phi(\tau)$ , can be split into a deterministic and a stochastic term:

$$\phi(\tau) = \phi_C(\tau) - \Delta\nu_D(\tau) - \varepsilon = \phi_D(\tau) - \varepsilon$$

By using the optimal retirement conditions (section 3.2), we can establish a functional relationship between the unobserved “type”,  $\varepsilon$ , and the retirement age,  $\tau$ :

$$\varepsilon = \phi_D^*(\tau)$$

The asterisk reminds us of the need for discarding *local* optima in order to have a one-to-one relationship between the two variables. Once this has been accounted for, a change of variable in the  $\varepsilon$  distribution function leads to the retirement age distribution for any individual (conditional on the observables):

$$F_\tau(t) = P[\tau \leq t] = P[\phi_D^{*-1}(\varepsilon) \leq t] = P[\varepsilon \geq \phi_D^*(t)] = 1 - F_\varepsilon(\phi_D^*(t)) \quad (12)$$

Finally, we make this specification operative by making  $\tau$  discrete and considering the existence of lower and upper limits in the retirement age ( $\bar{\tau}$  and  $\underline{\tau}$  respectively). Then, from

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<sup>14</sup>We refer to Boldrin et al. (2002) for a comprehensive description of the statistical properties of this sample.

Table 1: Stylized version of the Spanish RGSS pension rules. 1985 system.

Provision	Expression	Definitions
Elegibility	$\tau \geq \tau_m = 60 \quad a(\tau) \geq 15$	$\tau_m$ is the ERA $a(\cdot)$ denotes years of contributions
Covered wages	$c(t) = \min\{cx(t), \max\{w(t), cm(t)\}\}$	$cx, cm$ are respectively the Max and Min. covered wage $\varsigma.c(t)$ denotes contributions
Benefit Base	$\bar{w}(\tau) = (1/R) \int_{\tau-R}^{\tau} c(t) dt$	$\bar{w}(\tau)$ is the benefit base R is the number of y.c. in the formula (8 in 1995)
Age Penalty	$\alpha(\tau) = \begin{cases} \alpha_0 & \text{if } \tau < \tau_m \\ \alpha_0 + \alpha_1(\tau - \tau_m) & \text{if } \tau_m \leq \tau \leq \tau_N \\ 1 & \text{otherwise} \end{cases}$	$\tau_N$ is the NRA $\alpha_0 = .60$ $\alpha_1 = .08$
History Penalty	$\kappa(a(\tau)) = \begin{cases} \kappa_0 & \text{if } a(\tau) < a_m \\ \kappa_0 + \kappa_1(a(\tau) - a_m) & \text{if } 15 \leq a(\tau) \leq 35 \\ 1 & \text{otherwise} \end{cases}$	$\kappa_0 = .60$ $\kappa_1 = .02$
Pension	$b(t, \tau) = \min\{bx(t), \max\{\alpha(\tau) \kappa(a(\tau)) \bar{w}(\tau), bm(t)\}\}$	$b(t, \tau)$ is the pre-tax pension $bx$ is the maximum pension $bm$ is the minimum pension
Further assumptions	Maximum contributions and pensions are constant in real terms The minimum pension real growth rate is 0.5 %.	

the viewpoint of the analyst, retirement is a discrete stochastic variable  $\xi \in \{\underline{\tau}, \underline{\tau} + 1, \dots, \bar{\tau}\}$ , distributed according to the following law:

$$F_{\xi}(a) = \begin{cases} 1 - F_{\varepsilon}(\phi_D^*(\underline{\tau})) & a = \underline{\tau} \\ 1 - F_{\varepsilon}(\phi_D^*(a)) & a \in \{\underline{\tau} + 1, \dots, \bar{\tau} - 1\} \\ F_{\varepsilon}(\phi_D^*(\bar{\tau})) & a = \bar{\tau} \end{cases} \quad (13)$$

## 4.2 Maximum Likelihood estimation method

Using the retirement age distribution (12), we can easily write the likelihood of the vector of preference parameters  $\theta$ , given individual  $i$  retirement decision:

$$L^i(\theta) = (1 - d^i) \Phi[\phi_i^*(t^i, x_i, \theta)] + d^i (1 - \Phi[\phi_i^*(t^i, x_i, \theta)]) \quad (14)$$

where,  $t^i$  is the age of the individual,  $d^i$  is an indicator function taking value one if the individual retires and zero otherwise, and  $\phi_i^*(t^i)$  is the individual's deterministic component of the marginal utility (which depends on the vector of observable characteristics  $x_i$  and on the preference

parameters).

The model needs to be closed in several dimensions before we can use the previous expression in a maximum likelihood estimation method. Firstly, we have to fully specify the individual utility function. Besides the CES assumption we have already mentioned, we impose the following linear structure on the deterministic value of leisure:

$$\Delta\nu_D(\tau) = \nu_0 + \nu_t \tau + \nu_e d(e) + \nu_{et} \tau d(e) + \nu_s d(s)$$

This specification considers four controls (in addition to a constant): the age  $\tau$ , the education ( $d(e)$  is a dummy taking the value of one for highly educated workers and zero otherwise), and the perception of temporary benefits ( $d(s)$  is a dummy taking 1 if a worker is observed receiving temporary benefits, either related to unemployment or to illness). We also allow for an interaction term between age and education. Consequently, the vector of the preference parameters to be estimated is  $\theta = (\nu_0, \nu_e, \nu_{et}, \nu_t, \nu_s, \delta, \eta)$ .

Secondly, we have to specify the economic environment, including the institutional setting, the wage process, the interest rate, the survival process, the heterogeneity dimensions and their population distributions. All these elements are specified as follows:

- We assume normality of the distribution of leisure across the population. This Normality assumption  $\varepsilon \sim N(0, 1)$  converts our empirical model into a “Non-linear” (in parameters) version of the well-known Probit model.
- For the survival probabilities, we assume all individuals in the sample share the same survival probabilities, estimated from the 1995, National Statistics Institute (INE) mortality data.
- We include in our simulations a stylized version of the 1985 pension rules of the Spanish *General Regime*. Table 1 shows all the elements included in the model, along with their relevant parametric values.

We implement the estimation procedure in three economies of increasing institutional complexity. The first one, E1, only includes the pension rules relevant for the “average” individual (i.e.; it excludes the upper and lower limits on pensions and contributions). On top of this we consider a second economy, E2, in which there is a minimum guaranteed income level ( $bm$ ) available for workers older than the ERA. We refer to the rate of growth of the minimum pension as the *level of generosity* of the system. Finally, on the top of E2 we look at economy E3, in which there is a unique maximum pension ( $bx$ ), and a minimum and maximum level of contributions ( $cm$  and  $cx$  respectively), which vary across individuals according to their professional qualification. The comparison of the results under E2 and E3 will allow us to evaluate the marginal contribution of the set of rules included in E3 (and not in E2) in explaining observed retirement patterns.

- The base value for our constant interest rate is 3%.

Table 2: Pseudo ML non-linear Probit estimates ( $N = 16359$ )

	$\hat{\theta}$	t-ratio	$\hat{\theta}$	t-ratio	$\hat{\theta}$	t-ratio
Economy	E1		E2		E3	
$\nu_0$	-4.790	-21.68	-5.210	-23.43	-5.214	-23.76
$\nu_e$	6.177	9.23	2.584	3.93	2.229	3.599
$\nu_{et}$	-0.157	-9.33	-0.069	-4.261	-0.061	-4.00
$\nu_t$	0.118	21.23	0.117	21.28	0.118	21.58
$\nu_s$	0.503	16.82	0.452	14.85	0.435	14.418
$\delta_0$	-0.015	-5.38	-0.030	-7.62	-0.029	-7.481
$\eta$	0.648	42.68	1.065	35.28	1.121	41.174
lnl	4901.118		4718.56		4711.909	

- The other components of the vector of observable information  $x_i$  (wages, education and labor history) are taken from HLSS. Appendix E.1 includes a description of how we use them to impute the marginal utility  $\phi(\tau)$  for every individual in the estimation sample.

We perform sensitivity analysis with respect to the generosity of the minimum pension scheme as well as to the real interest rate. We also explore the dependence of our estimations results on our borrowing constraint assumption.

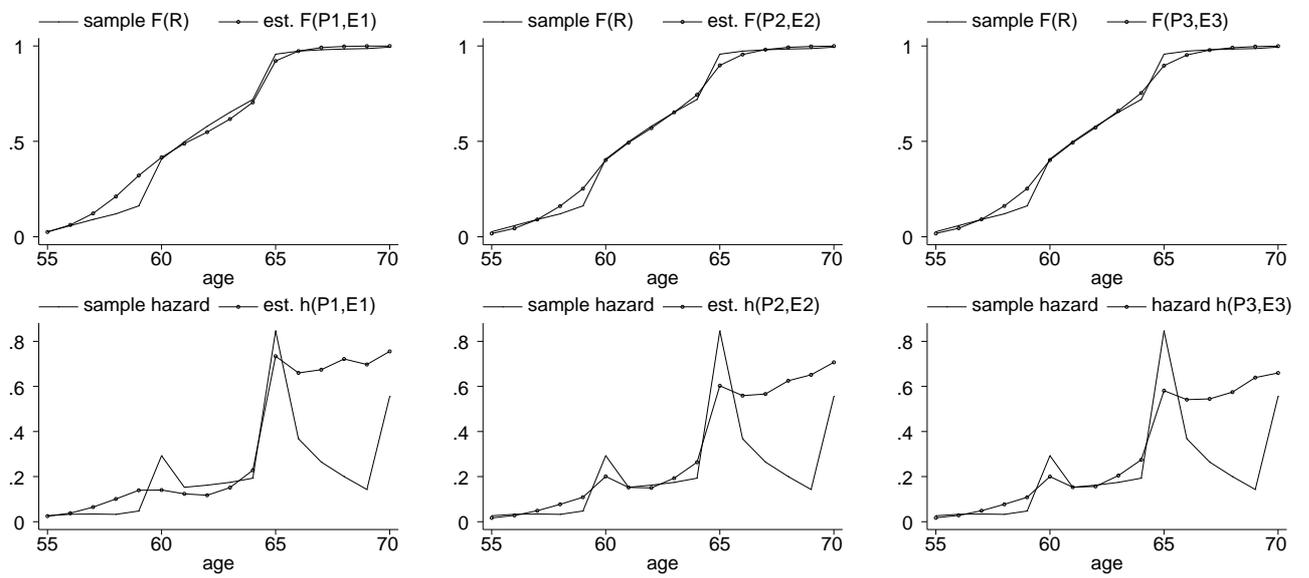
### 4.3 Estimation Results

The set of parameters which best fits the retirement behavior of the individuals in our sample for each economy is reproduced in Table 2. The aggregate hazard predicted by our theoretical model under this set of parameters is shown in Figure 6. The parameter estimates under the more “realistic” economy E3 *reveal* the following properties about individual preferences: (1) a low degree of relative risk aversion to life uncertainty; (2) Individuals seems to be extremely patient, showing a clearly *negative* time discount factor; and (3) the relative value of leisure varies significantly with age and education: highly educated people value leisure less, and this value grows with age at a slower rate (see Figure 7).

Neither of these findings should come as a surprise, as all of them have already been reported in previous structural estimations. A negative discount factor as well as a small degree of risk aversion are key findings in Hurd (1989).<sup>15</sup> This comparison is particularly important, as his

<sup>15</sup>In Hurd’s paper, which only includes uncertainty regarding the life span,  $\eta = 1.12$  and  $\delta = -0.01$ . In Gustman and Steinmeier (2002), where the rate of time preference is heterogeneous, the estimated value of  $\eta$  is 1.26. The comparison with models including other sources of uncertainty is less straightforward. The estimated values are, however, relatively close: in Rust and Phelan (1997) (who specify several sources of uncertainty) the elasticity of intertemporal substitution ( $1/\eta$ ) is found to be 0.93; in French (2000) (who specifies income and health uncertainty) the estimated value is  $\eta = 1.42$ . In Gustman and Steinmeier (1986) deterministic model,  $1/\eta$  is estimated in the

Figure 6: Retirement hazard,  $h$ , and cumulative distribution,  $F$ . Theoretical predictions and empirical (HLSS) estimations.



estimations are obtained from a life-cycle model which is very close to ours. The main difference is that Hurd's results stem from the model's predictions about optimal savings, while ours come from the implications of the model in terms of optimal retirement. In Hurd's paper, a negative  $\delta$  helps the model to reproduce the observed amounts of accumulated assets at advanced ages. In our work the degree of time impatience determines the sign and magnitude of the incentives provided by the pension regulations. Very patient workers value the financial gains stemming from delayed retirement a great deal. This keeps them active until the NRA, unless minimum pensions block this incentive. Therefore, a negative  $\delta$  emerges in our estimations as a form to express the high attachment to the labor force shown by average and above average Spanish wage-earners.

Highly educated workers usually have better working conditions and more pleasant occupations, which result in a higher attachment to activity. Our extremely stylized model has only one way to reflect these facts: by lowering the estimated relative value of leisure for these workers. On the other hand, a pattern of strong increase in leisure value as individuals grow older is quite common in the literature (see for instance Gustman and Steinmeier (1986)).

### **The adjustment of the model**

The life cycle approach is very well suited to the purpose of this paper (exploring the incentives provided by the pension regulation). Of course, it is not intended to be a complete theory of retirement behavior and, consequently, we should not expect it to be *the best* empirical model. Interestingly, our estimation procedure gives a chance to test the performance of the life cycle theory along this dimension. This is summarized in the third column of Figure 6, where the estimated cumulative distribution and conditional hazard functions are compared to their empirical counterparts.

Loosely speaking, the life cycle model does a rather satisfactory job at reproducing the empirical retirement *distribution*. Summing up, we have observed that our base model (E3): (1) slightly overestimates retirement flows immediately before 60; (2) reproduces a spike in retirement flows at 60, but its size is lower than that in the data; (3) overstates the number of people retiring in the age range (62, ..., 64); and, finally, generates a large spike at the NRA, although, again, it is of a smaller magnitude than the empirical one. Overall, the model predicts smoother transitions out of the labor force than what is actually observed in the real world. This is easy to understand as some relevant economic processes are missed in our stylized life-cycle model. First, there is no health uncertainty or unemployment shocks. Clearly, both factors can contribute to the age 60 spike: Individuals who receive mild health shocks at any age before 60 and fail to qualify for a disability pension may well decide to keep working till the retirement benefit first becomes available. A similar story could be applied to people who have been fired before 60: they could keep active claiming the unemployment benefit and start

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range 0.6/1.18.

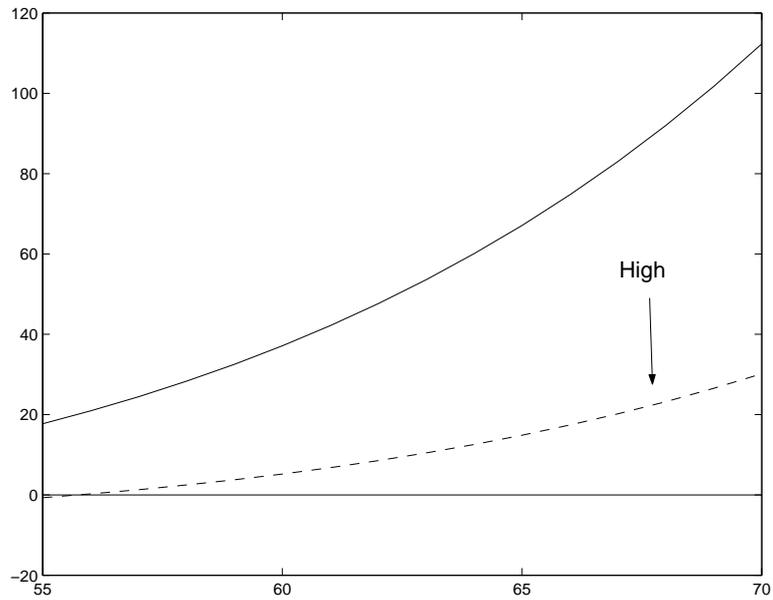


Figure 7: Relative value of leisure by age ( $e^{-\delta(\tau)} \Delta \nu(\tau)$ ) for highly educated workers (- -) and for the rest of the sample (-).

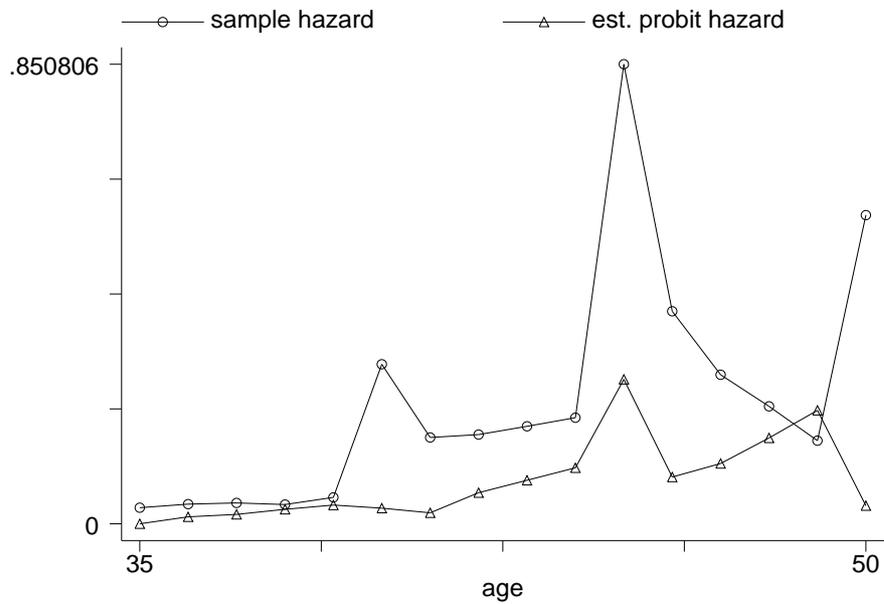


Figure 8: Hazard out of the labor force: sample vs probit predictions.

collecting the pension as soon as possible. The underestimation of the age 65 peak could stem from the combination of institutional factors (collective agreement clauses) and firms decisions. In absence of these elements, our model tends to shift some of the retirement flows from the NRA to the ages immediately before 65.

From our sequence of simulations (E1 to E3) we extract two key implications. Firstly, the comparison between E1 and E2 shows that the economy without minimum pensions (E1) is utterly incapable of reproducing the pre-retirement and early retirement empirical patterns. And, secondly, the coincidence between the estimated hazard for economies E2 and E3 tells us that it is the minimum pension and not another mechanism (either maximum pension or min/max of contributions) that explains early retirement patterns.

As a token of curiosity, we have compared the predicting power of a reduced form probit including the same information we use in our structural estimation experiment.<sup>16</sup> Figure 8 shows the results: the general predicting power of the probit is very limited, and its performance is extremely poor at capturing the discontinuities in the data. This comparison evidences the potential advantages of using an explicit economic theory in order to explain empirical patterns.

## 5 Simulation results

### 5.1 Impact of the minimum pension scheme

To quantify the impact of the minimum pension scheme on the aggregate distribution of retirement ages we carried out the following experiment: we constructed two model economies differing in the existence of a guaranteed minimum scheme as part of the public pension system (E1 and E3, respectively); we calibrated them to the Spanish economy, incorporating our ML preference estimations; finally we simulated the economies and compared their predictions in terms of retirement behavior. Note that, in order to isolate the effect of the change in the institutional structure, we performed this comparison with fixed preference parameters (ie, the parameters estimated under E3). Our findings are reported in table 3 and illustrated in figures 9 to 10.

It is most apparent from Figure 9 that the minimum pension scheme alters the *shape* of retirement distribution in a fundamental way, shifting substantial amounts of probability mass from 65 and subsequent ages to *pre-retirement* ages (before 60) and, especially, *early retirement* ages (between 60 and 64). As minimum pensions carry the retirement age of large groups of individuals forward, the distribution changes from a uni-modal shape (with a single peak at 65) to a bi-modal one (with peaks at both 60 and 65). More precisely:

- There is an appreciable increase in the incidence of *pre-retirement*: the unconditional

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<sup>16</sup>In addition to the set of linear regressors, we have included the inverse of lifetime wealth and the marginal change in lifetime Wealth. These are standard regressors in the financial incentives literature. See, for example Samwick (1998).

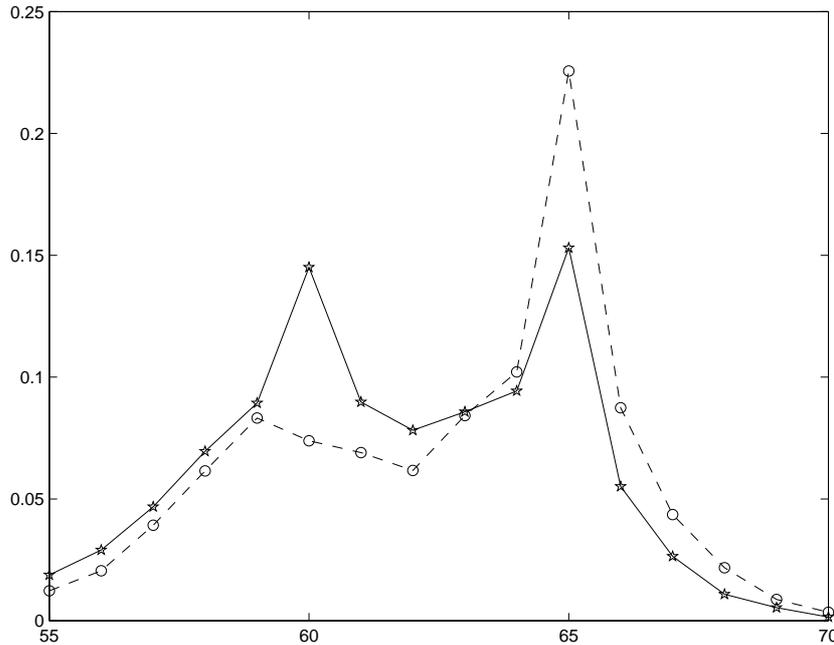


Figure 9: Marginal distribution of aggregate retirement age in simulated economies with (-) and without (- -) the minimum pension scheme. The simulations are carried out using the parameters estimated under economy E3.

retirement probability with the minimum pension is higher at every age before 60. This results in a 20 % increase in the retirement probability accumulated at the age of 59 (21.7 in E1 vs. 25.7% in E3).

- The probability of retiring at the ERA doubles (7.4% in E1 vs. 14.4 % in E3), with a remarkable spike emerging at the age of 60.
- There are substantial increases in the probability of *early Retirement* at 61 and 62, and more moderate gains at 63. Overall, 3 out of 4 workers leave the labor force before 65 under the minimum pension scheme, while this number is 3 in 5 without them.
- The spike at the NRA (65) is substantially reduced ( 22.6 in E1 vs. 15.2 % in E3)
- As a summary measure, the introduction of minimum pensions (and other caps and ceilings) reduces the average retirement age by almost one year, from 62.6 to 61.7.

Ceiling and floors on benefits have a very selective impact on individuals at both ends of the income distribution. This can be readily appreciated in figure 10, which shows the optimal retirement hazard according to the individual’s income quantile, in the institutional environments E1 and E3.<sup>17</sup> The impact of the minimum pension can be traced by exploring

<sup>17</sup>To construct this graph, individuals in the sample have been ordered according to their expected income at the age of 60.

age	f(E1,P3)	f(E3,P3)	F(E1,P3)	F(E3,P3)	h(E1,P3)	h(E3,P3)
55	0.012	0.020	0.012	0.020	0.012	0.020
56	0.021	0.030	0.033	0.049	0.021	0.030
57	0.039	0.048	0.072	0.097	0.041	0.050
58	0.061	0.070	0.134	0.167	0.066	0.078
59	0.083	0.090	0.217	0.257	0.096	0.108
60	0.074	0.144	0.291	0.401	0.094	0.194
61	0.069	0.090	0.360	0.491	0.097	0.150
62	0.062	0.078	0.421	0.569	0.096	0.153
63	0.084	0.086	0.506	0.655	0.146	0.198
64	0.102	0.094	0.608	0.748	0.207	0.271
65	0.226	0.152	0.833	0.901	0.575	0.605
66	0.087	0.053	0.921	0.954	0.525	0.535
67	0.044	0.027	0.964	0.981	0.550	0.589
68	0.022	0.011	0.986	0.992	0.612	0.584
69	0.009	0.005	0.995	0.998	0.635	0.686
70	0.003	0.002	0.998	0.999	0.687	0.622

Table 3: Discrete retirement probability,  $f$ , cumulative distribution,  $F$ , and conditional hazard,  $h$ , in two institutional environments: E1 (without minimum pensions) and E3 (with minimum pension). P3 denotes parameters estimated under economy E3.

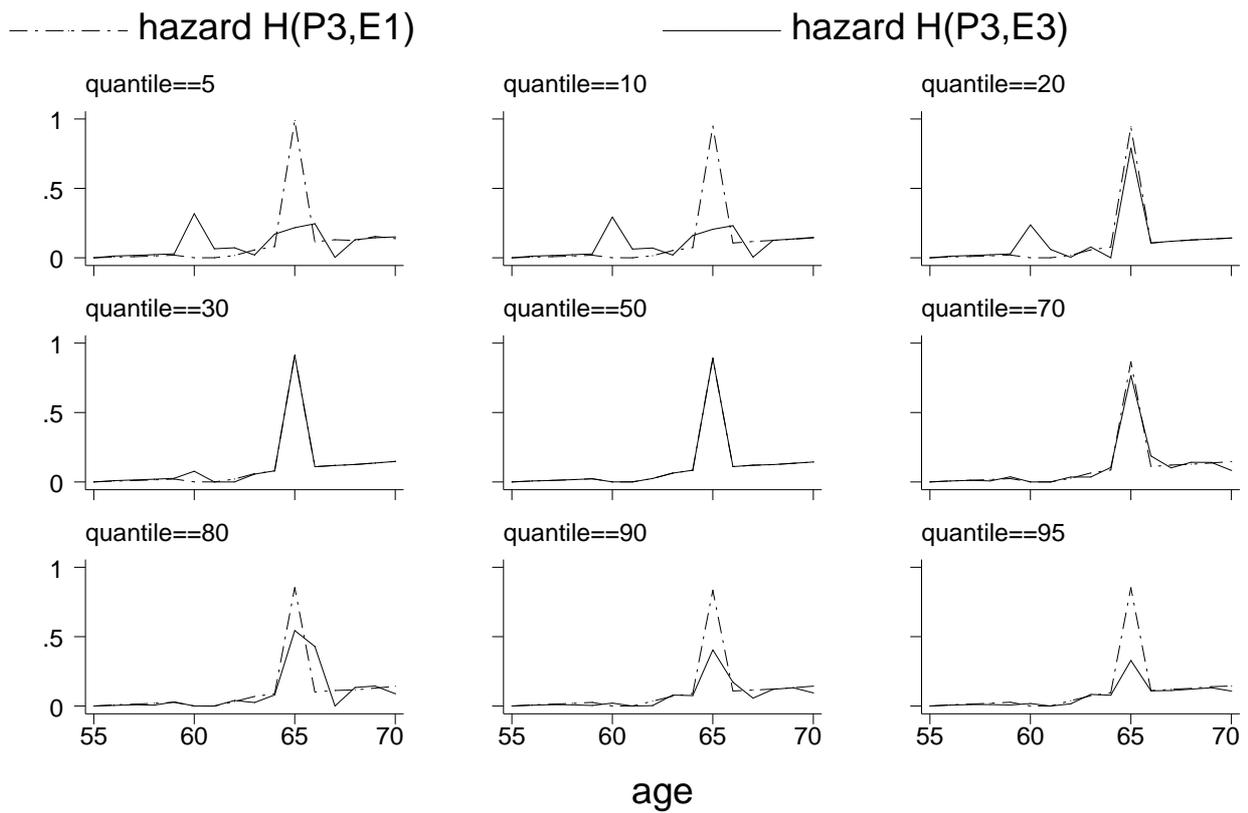


Figure 10: Predicted Hazard conditional on the individual's quantile of the income distribution, in two institutional environments: E1 and E3(including upper and lower bounds on pension benefits)

the changes experienced by individuals in the lowest quantiles of the income distribution. All the aggregate effects noted in the previous enumeration can now be properly attributed to lower income workers. It is particularly interesting to check how the age 60 retirement spike weakens as the income level increases, until its complete disappearance for median income workers. This graph also shows that the basic effect of upper limits in pension benefits and pensionable income is the weakening of the age 65 retirement spike. This is not surprising, as reaching the age of 65 does not have any particular effect on the pension income of individuals affected by the maximum pension.

Finally, the robustness of all these results to the particular rate of interest and degree of the pension system's generosity is reviewed in appendix C.

## 5.2 Experiments

In this section we use our simulation framework to perform three experiments. In section 5.2.1 we assess the sensitivity of *pre* and *early retirement* patterns to changes in the minimum pension's generosity; in section 5.2.2 we evaluate the contribution of the borrowing constraint to the incidence of early retirement; and, finally, section 5.2.3 explores the partial equilibrium impact of several reform proposals.

### 5.2.1 Changes in the minimum pension's generosity

In our base case we consider an annual real growth rate of the minimum pension benefit of 0.5%. This figure is significantly lower than recent historical values (the average growth rate between 1980 and 1998 was 0.9%). However, it is difficult to believe that the (very generous) policy followed in the past can be kept unaltered in a context of an aging population and increasing pension expenditures. It is, in any case, interesting to explore the cost of such a policy (easily justified on redistributive grounds) in terms of labor supply reductions. Alternatively, it is also quite interesting to explore the impact on early retirement of a reduction in generosity. With this aim we simulate the aggregate retirement distribution when the real value of the minimum pension is kept constant, clearly a more prudent policy when the financial condition of the pension system is under severe pressure.

Our findings are summarized in table 4. Under the enhanced generosity scenario the incidence of *pre-retirement* (before 60) increases slightly (0.3%) while *early retirement* (61 to 64) shows a more substantial increase (1.2 %). When reducing the generosity level, pre-retirement is reduced by 1.2 percent and early retirement is marginally increased. All together, the cut in minimum pension generosity only achieves a very modest reduction (0.4%) in accumulated retirement before 65. In our view, these results show that the magnitude of the distortions induced by the current minimum pensions scheme is so high that only very substantial changes in the generosity (in either way) can have a really sizeable impact on the labor supply behavior of Spanish workers.

age	f(0.005)	f(0.01)	f(0.000)	F(0.005)	F(0.01)	F(0.000)
55	0.020	0.0184	0.0159	0.020	0.0184	0.0159
56	0.030	0.0293	0.0261	0.049	0.0477	0.0420
57	0.048	0.0480	0.0446	0.097	0.0958	0.0867
58	0.070	0.0718	0.0683	0.167	0.1676	0.1550
59	0.090	0.0922	0.0896	0.257	0.2598	0.2447
60	0.144	0.1493	0.1492	0.401	0.4092	0.3940
61	0.090	0.0921	0.0907	0.491	0.5014	0.4848
62	0.078	0.0803	0.0788	0.569	0.5817	0.5636
63	0.086	0.0870	0.0867	0.655	0.6688	0.6504
64	0.094	0.0914	0.0936	0.748	0.7602	0.7440
65	0.152	0.1386	0.1484	0.901	0.8989	0.8924
66	0.053	0.0548	0.0580	0.954	0.9537	0.9505
67	0.027	0.0252	0.0268	0.981	0.9790	0.9773
68	0.011	0.0120	0.0129	0.992	0.9910	0.9903
69	0.005	0.0056	0.0061	0.998	0.9967	0.9965
70	0.002	0.0021	0.0022	0.999	0.9989	0.9988

Table 4: Policy experiments: simulated retirement distribution under different degrees of generosity in the provision of the minimum pensions: high generosity (1% annual increase), average generosity (0.5%) and low generosity (fixed value).

## 5.2.2 The impact of the borrowing constraint on early retirement

The impossibility of borrowing from future pension income has been frequently blamed as the major factor explaining the intense retirement flows at the ERA. This stems from the following observation: with no loans available, workers without enough accumulated assets have hardly any option but to keep working until the age when the pension is first available. As pointed out by Hurd (1989), pag 592, “*someone on the basis of lifetime wealth and the wage rate may desire to retire at 61; but if he cannot finance consumption at 61 he will wait to retire at 62. He is liquidity constrained*”. Note that the ERA in the USA is 62. It is little wonder then, that structural econometric models usually point to borrowing constraints as the major force leading to early retirement: in these models retirement decisions are taken conditionally on the observed accumulated assets, and empirical data show a significant fraction of older workers with very little financial wealth.

In our view, this way of thinking does not represent a major improvement as long as the low levels of accumulated assets, showed by some groups of early retirees, remain unexplained. The real challenge is to understand how rational agents who have a high propensity for early retirement (driven either by their preferences or by the properties of their life cycle income processes), can end up with so few assets that they cannot implement their optimal retirement plans.

In this section we contribute to this inquiry in the following way: we show that, in absence of any form of *recursive* uncertainty, it is actually optimal for individuals with a high propensity for early retirement to accumulate enough assets to leave the labor force before the pension is available. In other words, in a world where life span is the only source of uncertainty, borrowing constraints do not significantly alter the incentives to retire early, even after accounting for the strong saving effort it imposes at early stages of the life cycle. This means that the presence of *recursive* uncertainty (i.e. health, unemployment or income shocks) is instrumental for making the credit constraints the key factor after the intense retirement flows observed at the ERA (as emphasized in French (2000)).

We achieve this conclusion by solving the model with perfect credit markets and comparing the marginal utility from working in that case with the one found in section 3.2.<sup>18</sup> The results are displayed in Figure 11 (in the institutional environment of the economy E3 and with our maximum likelihood preference parameters). They make it clear that the presence of borrowing constraints does not fundamentally alter the predicted retirement behavior. They slightly *reduce* pre-retirement flows, leaving the size of the age 60 peak untouched, and producing a mild increase in the tendency to early-retirement in the age range (60,65). A theoretical explanation of these changes is provided in appendix D, including comparative graphs of the marginal utility of

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<sup>18</sup>The Optimal retirement behavior in the presence of perfect capital markets has been repeatedly described in the literature (eg Sheshinski (1978), Kahn (1988), Samwick (1998)). This situation can be envisaged as a particular case of our model in section 3.2, when the first binding age for the credit constraint  $\bar{t}$  is the maximum length of life  $\bar{T}$ .

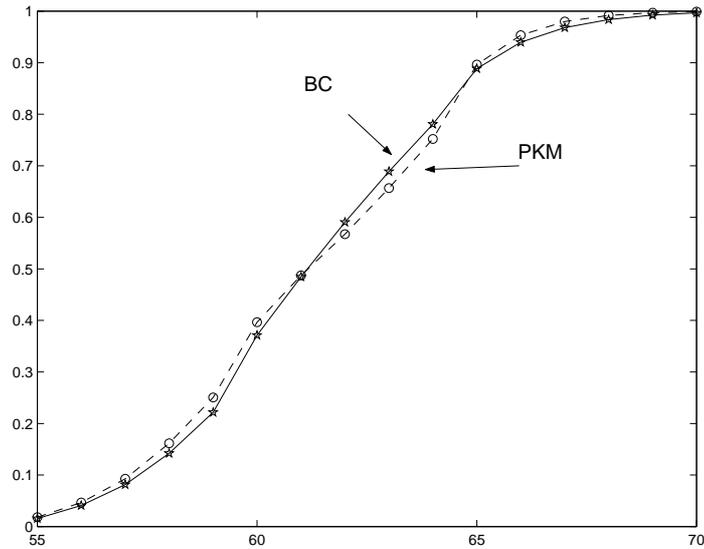


Figure 11: Cumulative distribution of retirement ages with (-) and without (- -) credit constraint. The simulations are carried out using the parameters estimated under economy E3.

working in both cases. The overall conclusion is that the presence or absence of credit availability does not significantly alter the basic trade-off determining optimal retirement behavior.

### 5.2.3 Reform Analysis

Our calibrated life-cycle model is a valuable tool to explore the partial equilibrium effects of policy changes. This is interesting, as several changes in the pension regulations have been recently introduced or are currently under debate in Spain. In particular, we simulate the following modifications:

REFORM A: The number of years of contribution included in the benefit base is increased from 8, as prescribed by the 1985 legislation, to 15 years, as prescribed in the 1997 reform.

REFORM B: A 2 % annual premium for active workers after 65 is introduced. This is combined with the elimination of the workers' social contributions (6.4 %) <sup>19</sup> after that age. This proposal was one of the crucial measures introduced in the 2002 Amendment of the 1997 reform.

REFORM C: A lump sum payment is granted to low wage earners (up to 1.5 the minimum wage) who decide to keep working at any age. The size of the monetary incentive is equivalent to a 15% of the annualized minimum wage.

The changes in retirement behavior generated by the proposed policies can be appreciated in Figure 12. The change in the length of the pension averaging period in Reform A has virtually no

<sup>19</sup>The sum of the 4.7 percent pension contribution rate plus the 1.7 unemployment fund contribution rate

effect on retirement patterns. In contrast, the two other reforms have significant consequences. The age 65 peak in retirement flows entirely disappears under Reform B. Most workers who would have previously retired at the NRA find it more advantageous to stay in the labor force under the new incentives scheme. Overall, 18 percent of the population remains at work after 65 with the new regulation (10.3% in the base case), and the average retirement age goes up from 61.7 to 62.1 years. The “active labor market policy” implemented in Reform C also delivers some sizeable reductions in the incidence of *pre-retirement*. Accumulated retirement at the age of 60 is 3 percentage points lower under the proposed policy, which results in an increase of 0.3 years in the average retirement age.

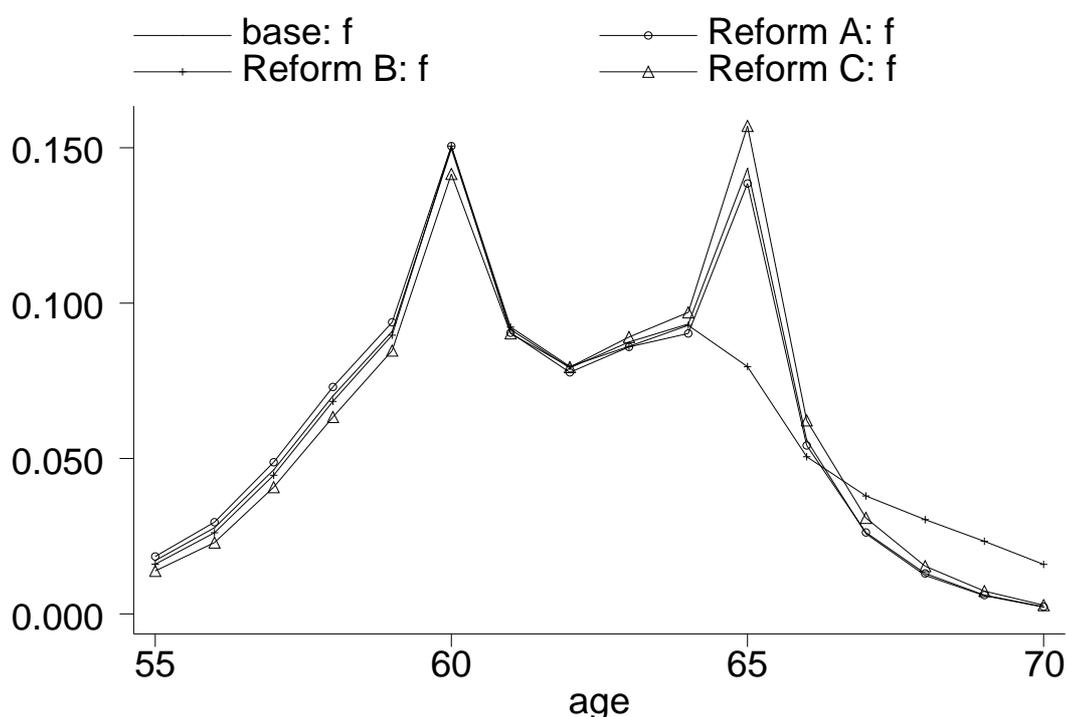


Figure 12: Effect of reforms A to C in retirement density ( $f$ ). The simulations are carried out using the parameters estimated under economy E3.

## 6 Conclusions

The minimum pension scheme is one of the largest programs of the Spanish Old Age pension system. It provides substantial income support for a large number of Spanish pensioners, which has gained it widespread popularity. The efficiency properties of this mechanism, however, have received little attention so far. In this paper we quantify the magnitude of the distortions generated by this piece of regulation on the retirement decisions of the individuals. We undertake this analysis with the help of a stylized life cycle model, which allows for a very convenient analytical characterization of the optimality conditions, and which can be solved with much less

computational effort than what is needed with a standard Dynamic Programming model. We use this model as the data generation process of a structural estimation exercise, finding that our stylized model provides a rather good approximation of empirical retirement behavior, using a minimum amount of information. Furthermore, the estimated preference parameters are quite close to the values reported in the previous econometric literature.

Once these maximum likelihood estimations are fed into the model, we are left with a fully operative tool for policy analysis. Our main experiment is a quantitative evaluation of the impact of the minimum pension on early retirement. We find that, overall, 3 out of 4 workers leave the labor force before 65 under the minimum pension scheme, while this value is 3 in 5 without it. We also explore the impact of several policy changes already implemented or currently under debate in Spain.

Our findings make it clear that minimum pensions should receive more attention in the current debate about the reform of the pension system in Spain (or any country with a similar system). Particularly, that their role should not be confined to a merely redistribute one. It is clearly a contradiction to discuss changes aimed at fostering older workers' labor participation and, at the same time, to ignore the strong disincentive effects of minimum pensions.

We conclude with a few remarks about some drawbacks of the current experiment and some future lines of research. Firstly, the magnitude of the behavioral changes induced by the minimum pensions is high enough for general equilibrium effects to be sizeable. An evaluation of the quantitative importance of these effects would be desirable (see Sánchez-Martín (2002) for a first evaluation in an OLG context). A second aspect of our model that demands a serious reconsideration is the absence of any form of recursive uncertainty. Health and unemployment shocks are particularly well worth considering, as they can have a strong influence on retirement decisions in economies with imperfect insurance. Extending the life-cycle model to include these features is a promising, although quite demanding, research effort for the immediate future.

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## APPENDIX

### A The solution of the individual problem

In section 3 we show how the original constrained problem in (1) is transformed into the unconstrained one in (2). This new problem is dealt with in three stages. In the next section we review how to analytically characterize the optimal profiles of consumption and accumulated assets for a *given* retirement age and a *given* binding age for the credit constraint. In section A.2 we show how to use these conditional solutions to compute the optimal binding age for any given retirement age.

#### A.1 The conditional consumption/savings problem

Standard Optimal Control techniques can be applied to problem (2).<sup>20</sup> Omitting the dependence on  $\tau$  and  $\bar{t}$  to make notation easier, the Hamiltonian of the system is:

$$H(a(t), c(t), \lambda(t), t, \tau) = e^{-\delta(t)} [u(c(t)) + \nu(l_\tau(t))] + \lambda(t) (r a(t) + \tilde{w}(t) - c(t))$$

Denoting a solution by  $x = \{a, c, \lambda\}$ , it must satisfy the following first order conditions,  $\forall t \in [0, \bar{t}]$ :

$$\frac{\partial H(x(t), t, \tau)}{\partial c(t)} \equiv e^{-\delta t} \frac{du}{dc}(c(t)) - \lambda(t) = 0 \quad (15)$$

$$\frac{\partial H(x(t), t, \tau)}{\partial a(t)} \equiv r \lambda(t) = -\dot{\lambda}(t) \quad (16)$$

$$\dot{a}(t) = r a(t) + \tilde{w}(t) - c(t) \quad (17)$$

$$a(0) = a_0 \quad ; \quad a(\bar{t}) = 0 \quad (18)$$

It is easy to check that these conditions are also sufficient for our problem. To obtain expression (3) we proceed as follows:

1. We integrate (16) to obtain  $\lambda(t)$  as a function of  $\lambda(0)$  (just  $\lambda$  in our notation). If this is particularized in (15), we obtain:

$$e^{-\delta(t)} \frac{du}{dc}(c(t)) = \lambda e^{-rt} \quad (19)$$

2. If we integrate (17) we obtain the *conditional* Intertemporal Budget constraint (IBC).
3. In the CES case, we can express the optimal conditional consumption  $c(t)$  as an explicit function of  $\lambda$  from (19). This, in turn, can be particularized in the *conditional* IBC. Obtaining (3) is then straightforward.

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<sup>20</sup>Our problem differs from the standard formulation (as stated in eg. Chiang (1992), pag 165, or Seierstad and Sydsæter (1987), pag 84) due to the existence of a couple of discontinuities in the retirement age. The first one appears in the objective function, as a result of the leisure component; while the second one shows up in the system's dynamic equation, stemming from the pension rules. The optimality conditions are, however, standard as all the relevant regularity conditions apply to our problem (see note 6 in Seierstad and Sydsæter (1987), pag 87).

## A.2 Optimal binding age for the credit constrain

The first order condition associated with the *optimal wealth depletion* problem in equation (5) is  $(dV/d\bar{t})(\bar{t}^*) \equiv e^{-\delta(\bar{t}^*)}\psi(\bar{t}^*) = 0$ , where:

$$\psi(\bar{t}) = \bar{\lambda}(\tau, \bar{t}) e^{-r\bar{t}} [c_\tau(\bar{t}|\bar{t}) - b(\tau)] + u(c_\tau(\bar{t}|\bar{t})) - u(b(\tau))$$

Under concavity of the utility function, the only root to this equation is obtained from condition (6). This result was established in Crawford and Lilien (1981). The second order sufficient condition is guaranteed by a monotone decreasing conditional consumption on  $\bar{t}$ ,  $c_\tau(\bar{t}|\bar{t})$ . This condition is satisfied when the net discount factor grows faster in  $\bar{t}$  than the lagrange multiplier, i.e.  $e^{(\delta-r)t}\lambda(\bar{t})$  is monotone increasing, which is the usual case. Finally, when  $c_\tau(\hat{\tau}|\hat{\tau}) < b(\tau)$  the optimal solution is the corner  $\bar{t} = \hat{\tau}$ , as  $\psi(\bar{t}) < 0 \quad \forall \bar{t} \in [\tau, \bar{T}]$ .

## B General expressions for the marginal utility of working

The general procedure to obtain the analytical expression for the marginal utility of working at any age  $\tau$  is as follows:

1. Differentiate the expression of  $V(\tau)$  with respect to consumption.
2. Particularize the consumption first order condition (19).
3. Differentiate the conditional intertemporal budget constraint with respect to  $\tau$ , and gather all the terms containing  $dc_\tau/d\tau$ . The same expression also appears in  $dV/d\tau$ . Substitute to get the general expression.

The general analytical expression (omitting the leisure component) when there are no minimum pensions is:

$$\begin{aligned} \frac{dV}{d\tau}(\tau) = & \lambda(\tau, \bar{t}) d(\tau) [ilb(1 - \varsigma) - I(\tau = \hat{\tau}) I(\hat{\tau} < \bar{t}) b + b' \mathcal{A}(\hat{\tau}, \bar{t}) + \\ & e^{-r(\bar{t}-\tau)} (I(\hat{\tau} < \bar{t}) b - \bar{c}(\bar{t})) \frac{d\bar{t}}{d\tau}] + \\ & e^{\delta(\tau)-\delta(\bar{t})} (u(\bar{c}) - u(b)) \frac{d\bar{t}}{d\tau} + b' u'(b) \mathcal{A}_\delta(\bar{t}, \bar{T}) \end{aligned}$$

where  $\bar{t} = \bar{t}(\tau)$ ,  $ilb = ilb(\tau)$ ,  $b = b(\tau)$ ;  $b' = b'(\tau)$ , and  $\bar{c}(\cdot) = c_\tau(\cdot|\bar{t})$ . When the pension system includes a guarantee minimum the expression becomes a bit more complicated:

$$\begin{aligned} \frac{dV}{d\tau}(\tau) = & \lambda(\tau, \bar{t}, J) d(\tau) [ilb(1 - \varsigma) - I(\tau = \hat{\tau}) I(\hat{\tau} < \bar{t}) b + b' \mathcal{A}(\hat{\tau}, \bar{t}) + \\ & e^{-r(\bar{t}-\tau)} (I(\hat{\tau} < \bar{t}) b - \bar{c}(\bar{t})) \frac{d\bar{t}}{d\tau}] + \\ & e^{\delta(\tau)-\delta(J)} (I(\bar{t} < J) u(b) - I(J < F) u(bm_J)) \frac{dJ}{d\tau} + \\ & e^{\delta(\tau)-\delta(\bar{t})} (u(\bar{c}) - I(\bar{t} < J) u(b)) \frac{d\bar{t}}{d\tau} + \\ & b' u'(b) \mathcal{A}_\delta(\bar{t}, J) \end{aligned}$$

where  $J = J(\tau)$  is the age when the minimum pension becomes binding.

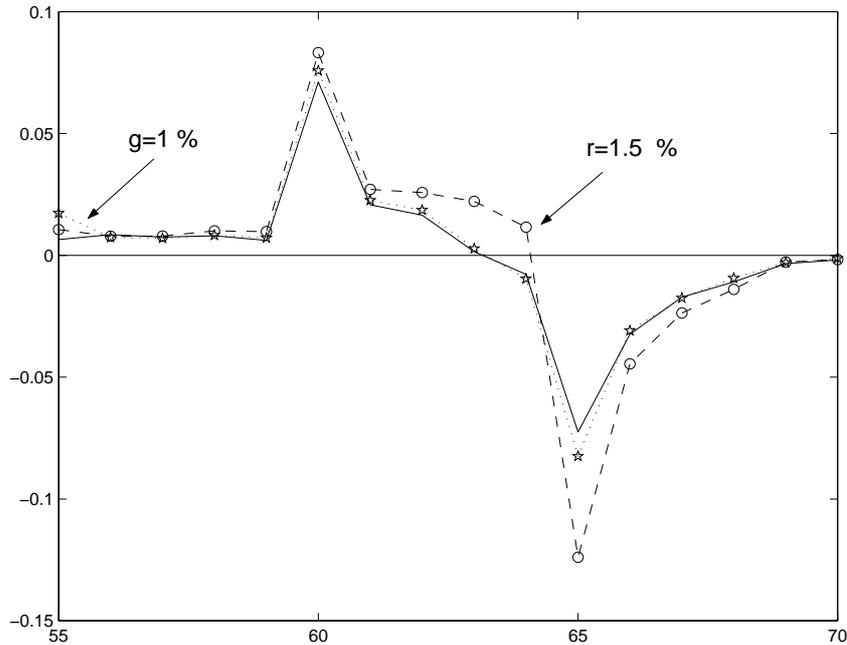


Figure 13: Sensitivity analysis of minimum pensions' impact: difference in retirement probability with and without minimum pensions  $f(\tau|with) - f(\tau|without)$  in three economic environments: Base (-),  $r=1.5\%$  (-) and higher minimum pension generosity,  $g=1\%$  (.). The simulations are carried out using the parameters estimated under economy E3.

## C Sensitivity analysis

Figure 13 explores the robustness of our basic analysis (section 5.1) with respect to changes in some of the parameters of the economic environment. In particular, we simulate the change in the retirement distribution with and without the minimum pension scheme under a lower interest rate (1.5% vs. 3% in our base simulation) and with a higher degree of generosity in the provision of the minimum pensions (annual growth rate of 1% instead of 0.5% in the base case). In this figure we compare the change induced by the introduction of a minimum pension scheme in the retirement's marginal distribution under the different values of  $r$  and generosity. It is clear from the graph that neither the qualitative pattern (shifts in probability mass to earlier ages) nor the size of the quantitative changes are significantly affected by the variations in the environment we have considered. An exception to the general robustness of our simulations appears in the change in retirement probability at the age of 65, which seems to be sensitive to the interest rate prevailing in the background economy.

## D Optimal retirement with and without credit constraints

Figures 14 and 15 reproduce the marginal utility from continuous work for our median and low-earnings representative agents, in two institutional environments: with and without credit constraints. It is apparent from the graphs that the presence of liquidity restrictions does not have an important effect on retirement incentives. We can safely conclude that the key force giving shape to the marginal utility from working is the pension regulations. Changes in the credit availability have hardly any impact on the incentives to work according to age. The most noticeable change is a significant reduction in the incentive to keep active in the age range 61/64 for average income workers. This stems from a combination of income (life-cycle wealth increases and  $\lambda$  decreases) and substitution effects (drops in  $y'$ ). This implies that, contrary to the usual conjecture, credit constraints slightly foster early-retirement (between 61 and 64) rather than pre-retirement (60 and before).

## E HLSS Database

Our main microeconomic data set is based on administrative records from the Spanish Social Security Administration (HLSS: *Historiales Laborales de la Seguridad Social*). The sample consists of 250,000 individual work histories randomly drawn from the historical files of SS affiliates (*Fichero Histórico de Afiliados* or FHA). It includes individuals aged 40+ on July 31, 1998, the date at which the files were prepared. The sample contains individuals from the General Regime and from the special regimes covering self-employed, agricultural workers and small farmers, domestic workers, sailors and coal miners). Civil servants are not covered by the SS Administration and are not considered in this study.

The data set consists of three files. The first file (“History file”, or H file) contains the work history of the individuals in the sample. Each record in this file describes a single employment spell of the individual. These work histories are very accurate for spells or histories which began after the mid-1960s. The second file (“Covered Earnings file”, or CE file) contains (annual averages) of covered earnings (*bases de cotización*) from 1986 to 1995. The third file (“Benefits file”, or B file) contains information on the lifetime SS benefits received by the individuals in the sample. Benefits are classified by function (retirement, disability and survival) and initial amount received. To be more precise, the benefits file contains the initial benefit amount and the length of the period during which the benefit was received.

For each individual in the sample who contributed to SS during the 1986-1995 period, the CE file reports the annual average of covered earnings together with the contributions paid. For individuals enrolled in either the General Regime or the coal miners regime, covered earnings are a doubly censored (from above and below) version of earnings. What this means is that covered earnings have both ceilings and floors: contributions must be paid over some legislated minimum wage, no matter what actual earnings are. Further, earnings above a certain legislated ceilings

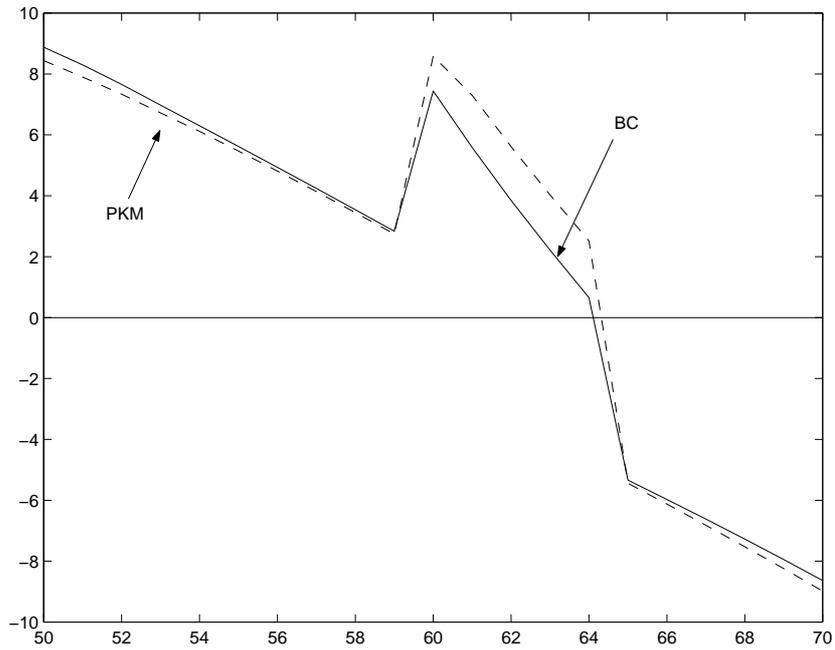


Figure 14: Marginal utility of working with (-) and without (- -) credit constraint. Representative (median) agent.

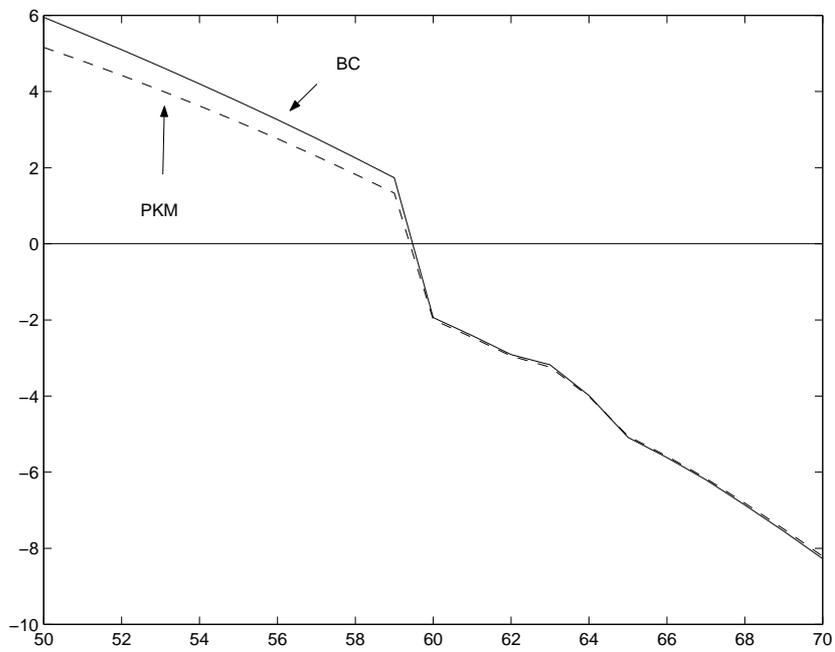


Figure 15: Marginal utility of working with (-) and without (- -) credit constraint. Agent in the 10% quantile of the income distribution.

are not covered, that is, they do not generate any future right and, as such, are not reported in the SS Administration files. Notice, though, that they are taxed for contributions, which is important for retirement incentives. For people enrolled in other SS regimes, covered earnings are chosen by the individual within given ceilings and floors and, consequently, there is no clear link between covered and actual earnings in this case.

For each employment spell in the H file, we know the age, sex and marital status of the person, the duration of the spell (in days), the type of contract (in particular, we can distinguish between part-time and full-time contracts), the social security regime, the contributive group, the cause for the termination of the spell, the sector of employment (4-digits SIC), and the region of residence (52 Spanish provinces). We refer to Boldrin, Jiménez-Martín, and Peracchi (2002) for a detailed description of the variables and for summary statistics of the history, covered earnings and benefits files. As in (Boldrin, Jiménez-Martín, and Peracchi 2002), we restrict our empirical analysis to the sample of male workers enrolled in the General Regime in 1995, that have been working continuously from 1986 to 1994.

## E.1 Earnings distribution, earnings histories and projections

As commented in the previous section, we do not observe earnings directly but only covered earnings (i.e. a doubly censored version of earnings). To deal with the top-censoring problem, we proceed as follows. First we estimate a Tobit model for covered earnings. Then we use the estimated parameters to impute the earnings of the censored observations and estimate an earning function using imputed earnings for those affected by the ceilings. Finally, we generate “true earnings” for all the individuals in the top censored groups, by using the estimated regression function and adding an individual random noise component.

From the individual profile of covered earnings  $c_t$  between year 1996 and year 1995 =  $T$  we impute the individual profile of “true” real earnings ( $w_t$ ,  $t = 1986, \dots, 1995$ ). Given this information, we “smoothly” project earnings forward and backward in the following way:

$$\hat{w}_{T+k} = w_T + g(a_{T+k}) \quad \text{for } k = -K_L, \dots, 0, \dots, +K_H$$

the function  $g(\cdot)$  corrects the growth of log earnings imputable to age  $a$  and is defined as:

$$g(a_{T+k}) = \beta_1 * a_{T+k} + \beta_2 * a_{T+k}^2 - \beta_1 * a_T - \beta_2 * a_T^2.$$

The  $\beta$  are the estimated coefficients from a pooled LS regression, the details of which are available upon request. The correction is specific for each combination of sex and contributive group. In summary, we project backward and forward using the wage in 1995 as a point of support. However the results from our exercise are robust to an earnings profile which combines observed information from 1986 to 1995 and project earnings for the rest of the period. Again, the results of this exercise are available upon request.