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

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Abstract

In this paper we explore the effects of the minimum pension program on welfare and retirement in Spain. This is done with a stylized life-cycle model which provides a convenient analytical characterization of optimal behavior. We use data from the Spanish Social Security to estimate the behavioral parameters of the model and then simulate the changes induced by the minimum pension in aggregate retirement patterns. The impact is substantial: there is threefold increase in retirement at 60 (the age of first entitlement) with respect to the economy without minimum pensions, and total early retirement (before or at 60) is almost 50% larger.

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. We contribute to that effort by exploring the welfare and behavioral impact of minimum pension schemes, with special emphasis on their labor supply consequences. Either in the form of minimum guaranteed benefits in earning-related schemes (of the type commonly found in continental Europe) or as the basic benefits in flat-rate pension systems (frequently found in Nordic and Anglo-Saxon countries, with the exception of US), the presence of minimum pensions is a remarkable regularity all over OECD economies[1]. See Kalisch and Aman (1998) for a thorough review of pension regulations in OECD countries.

The Spanish pension system is a case in point. In this country, 37.6 % of the contributive old-age pensions were topped up under the minimum pension scheme in 1999. In that year these minimum pension supplements represented 8.5 % 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, to the point of letting its value grow beyond that of the minimum wage, from year 2000 onwards. 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 % of people retiring at the age of 60 were enjoying a top up of their pensions. This has been no obstacle for recent reforms to increase the program's generosity and to weaken its eligibility conditions[2].

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 the prohibition to borrow from future pension income. This model is used as the data generating process in a structural maximum likelihood estimation, carried out over a unique, very large sample of labor records obtained from the Spanish Social Security administration (HLSS).

Our paper has connections with a number of different strands of the literature. First, it has obvious links with the (by now) very large literature that explores the efficiency properties of different pension designs. In our view, the effects of minimum pensions on savings and labor supply have receive relatively little attention so far, although we do not try to elaborate this

[1]In countries like Germany, where minimum pensions are formally missing, it is common to find some form of minimum guaranteed benefit, legislated in an indirect way (like eg. minimum contributions rules).

[2]The 2002 amendment to the 1997 reform extended the right to early retire to all the employees, abolishing the previous limitation of this right to those who contributed to the system before 1967.

intuition, as the number of works involved is simply too large to be properly revised here. Instead, we just mention that the immediate inspiration for this development came from the analysis of the *accruals* and implicit *tax rates* generated by the Spanish pension system in Boldrin et al. (2004) and Jiménez-Martín and Sánchez-Martín (2004).

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 (1995) and the Method of Simulated Moments implemented in French (2005), French and Jones (2001) and Gustman and Steinmeier (2002). [3] However, as our data generating process is a continuous time life-cycle model, our estimation procedure is more closely related to the study of the strength of bequest motives in Hurd (1989) or to the classical analysis of the effects of wage reductions on partial retirement in Gustman and Steinmeier (1986).[4] Note that, since the Spanish public pension program is universal, the endogeneity of financial incentives and the issue of selection into particular pension arrangements are not relevant for our econometric experiment.

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, 2000), while Crawford and Lilien (1981) Fabel (1994a) discuss its impact on retirement. Our work integrates both approaches. The resulting model is extremely well suited for exploring the impact of pension rules on savings and labor supply. More generally, its closed-form optimal behavioral rules are very convenient for analysis with a strong expositional or computational content. In this paper we use the model as the data generating process in a maximum likelihood estimation procedure, assuming the existence of unobserved heterogeneity in the relative value of leisure. The life-cycle methodology has two main advantages in this context. On the one hand, it largely avoids the computational burden involved in the estimation of standard Dynamic Programming Models. On the other hand, the ability to solve the model at any point in the individuals life cycle is valuable in situations where data on accumulated assets are not available (as is the case in our estimation database). Unfortunately, this way of working weakens our ability to measure the relative contribution of minimum pensions and borrowing constraints to early retirement flows. The scope of our life-cycle experiment is discussed at length in section 3.3.

Our main findings can be summarized as follows:

[3] 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 (2005) explore retirement behavior within a different estimation framework and taking optimal savings decision into account. French and Jones (2001) assesses the relative importance of Medicare and pension rules on the retirement flows at the age of 65.

[4] Note, however, that our model and those in Hurd (1989) and Gustman and Steinmeier (1986) are substantially different. We rely on the labor supply predictions of the model rather than on the predicted saving behavior in Hurd's work. With respect to the latter, our model includes life uncertainty, borrowing constraints and discrete retirement (rather than a continuous-hours decision).

- Our theoretical model shows that minimum pensions create very strong incentives for low-income workers to leave the labor force as soon as they become first available.

- When taken to the data, our model does a satisfactory job in reproducing actual empirical behavior.

- Our calibrated simulations reveal a very significant quantitative impact for minimum pensions: the incidence of retirement at the age of first entitlement (60) almost triples with respect to that in the economy without minimum pensions. Total early retirement (before or at 60) is almost 50% larger with minimum pensions. Welfare gains for the affected individuals can also be quite large.

- In our basic life-cycle framework prohibiting borrowing from future pensions has very little impact on retirement incentives. This suggests that our approach may overstate the role of minimum pensions in fostering early retirement. We simulate a model with heterogeneous discount factors to check the robustness of our main finding, with positive results.

- Finally, our model predicts a strong behavioral response to the labor-incentive package introduced in 2002, combining pension bonuses and the elimination of contributions for people working beyond 65. The effectiveness of this reform package can be strengthen by combining it with a delay in the age when minimum pension is first available.

Although our findings are specific to the Spanish case, they surely apply more broadly. For instance, for countries with flat-rate pension schemes or in the assessment of proposals to privatize the current PAYG systems, which normally include some form of minimum benefit guarantee. Even in countries where the access to the minimum is delayed until the normal retirement age (like France and US), this mechanism could result in low income workers leaving the workforce early, as they correctly anticipate their catching up with the minimum benefit in a few years time.

The rest of the paper is as follows. In section 2 we describe the Spanish pension rules, and present some key facts. In section 3 we introduce our life cycle model, briefly review its basic theoretical predictions and discuss its adequacy for the purposes of the paper. Section 4 deals with the structural estimation experiment. Firstly, we describe how to use the life cycle model as a data generating process; then we present the maximum likelihood estimations and comment on the properties of the preferences revealed throughout the experiment. Our main experiment (the quantification of the effects of minimum pensions) is reported in section 5. The role of borrowing constraints, the robustness of our results and the effects of several changes in current pension rules are also explored there. Section 6 concludes with some final remarks. At the end of the paper, several appendices enlarge the main text substantially, by getting into additional discussions and/or more detailed presentations of derivations and results.

2 Minimum pensions and retirement behavior

In this section we briefly review the basic features of the Spanish pension system, and explore the main labor supply patterns for older workers.

2.1 Spanish Old Age pension rules

Public pensions is the largest welfare program in Spain, absorbing almost 70 % of the total social protection expenditure, 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 is organized around three basic schemes: the General Regime (private sector employees and some public servants), the Central Government civil servants Scheme, 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 Regime, which covers around 74 % of the total,

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.

Pension formula: Eligibility requires a minimum of 8 years of contributions (15 after the 1997 reform) and complete withdrawal from the labor force. The initial amount is obtained by multiplying a *benefit base* and a replacement rate. The *benefit base* is a moving average of the individual's 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, τ_N) having contributed for more than 35 years. It is possible to start collecting the pension at the Early Retirement Age (ERA, 60 in Spain) under a 40% penalty on the benefit base. This corresponds to an 8% annual penalty for bringing forward the retirement age (7% with 40 years of contribution after 1997).[5] There is also a penalty for insufficient contributions (2 % of the benefit base per year below 35 years) 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 and four times the minimum wage respectively. The minimum pension varies in presence of a dependent spouse and/or with age brackets, since it is greater for individuals above 65. They are compatible with early retirement, as they can be awarded immediately after the ERA. In 1999 almost 35% of the stock 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

[5] A further reduction of this penalty for very long contributive careers came into force in 2002

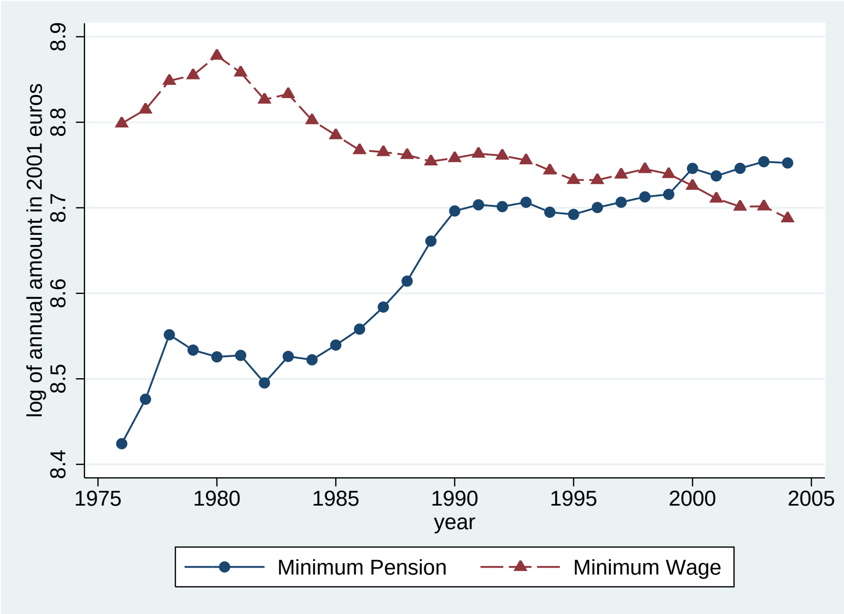

Figure 1: Minimum Pension for married individuals aged 65+ and Minimum Wage ("Salario Mínimo Interprofesional"): log of real values in 1976–2004.

annually fixed by the government, has been very different: while maximum pensions have been kept roughly constant in real terms over the last 15 years, minimum pensions have grown at approximately the same rate as nominal wages. As a result of this policy, the minimum pension (for married individuals aged 65+) is larger that the legislated Minimum Wage since 2000, and that their values have continued to diverge ever since.

2.2 Labor supply patterns of older workers in Spain

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 2). This is a very robust empirical pattern, shared by most countries running PAYG, Defined Benefit (DB) pension systems.[6] Figure 3 explores the composition of the hazard peaks according to the labor income of the worker. It displays a non-parametric estimation of the retirement hazard at some selected ages (59, 60 and 65), as a function of the expected labor income at the age of 60. We find striking differences. The probability of leaving the labor force at the ERA is a clearly decreasing function of the salary level, while it is virtually flat at the other ages (although, logically, at very different levels). These patterns are basically

[6]Our data come from a sample of administrative records from the Spanish Social Security in 1995, see the section D of the appendix, but virtually identical patterns can be found in all other available databases (the European Household Panel (ECHP), the Family Income Survey (EPF) or the Labour Force Survey (EPA)). Cross country comparisons of retirement hazards are presented, for instance, in ?) (for eleven developed countries).

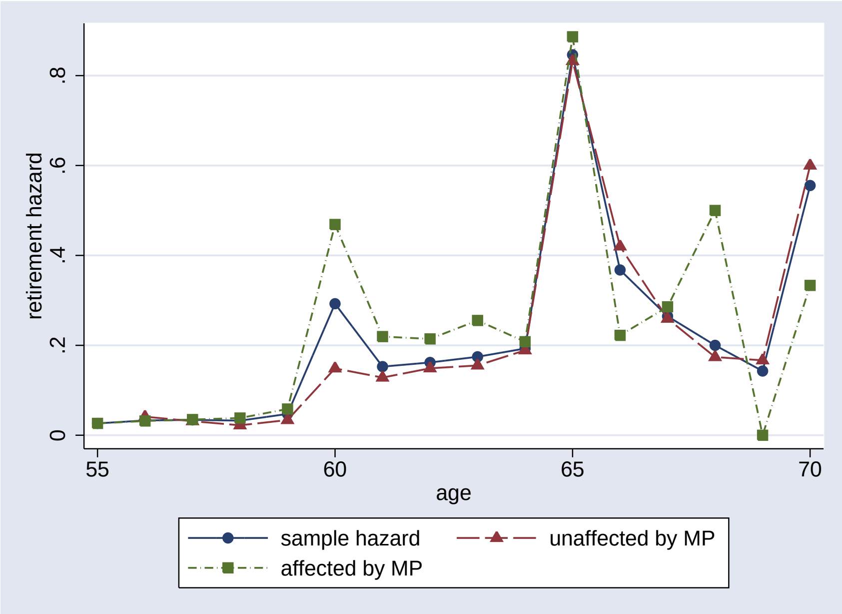

Figure 2: Retirement hazard by age in the full sample and in the subsamples of workerst that qualify and fail-to-qualify for the minimum benefit (MP). Source: HLSS, 1995

independent of the educational achievement of the individual.[7] 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 2).

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 τ. 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 $\{\tau_m, \ldots, \tau_N\}$ 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 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 result in the second having the opposite effect.

[7]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 **?**) for an illustration).

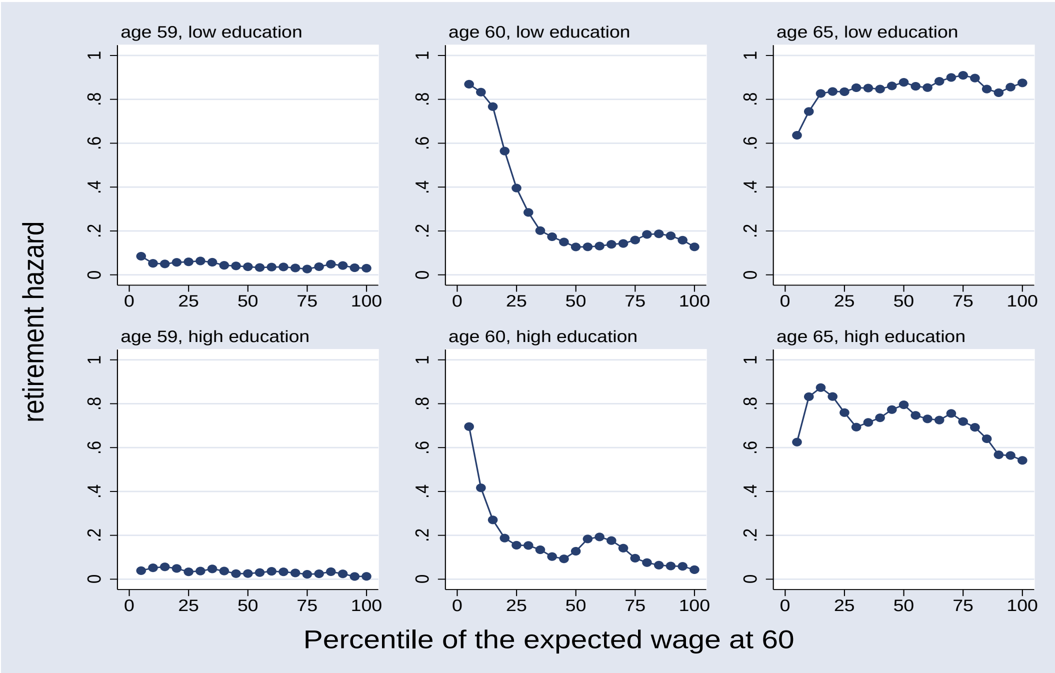

Figure 3: Retirement hazard at key ages (59, 60, 65) by level of education and expected wage at age 60. Source: HLSS, 1988–1995

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 et al. (2004) and Jiménez-Martín and Sánchez-Martín (2004) 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 Brumber (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).

Time in the model (ie, the age of the individual) is represented by t, while T stands for the length of the individual life. T is a continuous random variable distributed on $[t_0, \overline{T}]$ according to the survival function $S(.)$ and mortality hazard $h(.)$[8]. The length of life is the only source of uncertainty included in the model. We consider an individual of age t_0 and study his/her optimal decisions for what remains of the life-cycle. Their preferences for consumption, $c(t) : [t_0, T] \rightarrow \mathcal{R}_+$ and leisure, $l_\tau(t) : [t_0, T] \rightarrow [0, 1]$ (with $l_\tau(t) = 1 \;\; \forall\, t \in [\tau, T]$, ie. taking τ as the age of full withdrawal from the labor force) are represented by a standard, additively separable life-cycle utility function:

$$V(c, l_\tau, T) = \int_{t_0}^{T} e^{-\delta\,(t-t_0)}\; \upsilon(c(t),\; l_\tau(t))\; dt$$

where δ is a discount factor. The period utility function is also additively separable in its two arguments: $\upsilon(c, l) = u(c(t)) + \nu(l(t))$, with both components exhibiting the usual properties.[9] Individuals choose the consumption path and the retirement age τ that maximize expected utility under the constraints imposed by two market imperfections: the lack of an insurance market for life uncertainty (i.e. the 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 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 ς.[10] 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 as discussed in section 2.1. We also assume that there is no bequest motive for savings and that the public sector fully taxes involuntary bequests. 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. The formal statement of the intertemporal problem is, then, as follows:

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[8]We assume that $h(t) > 0 \;\forall[0, \overline{T}]$ and $\lim_{t \to \overline{T}} h(t) = \infty$. Applying standard results it is easy to express the survival function (conditional on being alive at the age of t_0) as the non-linear discount function: $S(t) = exp\left(-\int_{t_0}^{t} h(s)\, ds\right)$.

[9]They are twice continuously differentiable, strictly increasing and concave. We also assume that $\lim_{c \to 0} u'(c(t)) = \infty$.

[10]In this section we omit some of the institutional details to ease the exposition. For a complete record of the institutional details we refer to table 1.

$$\begin{array}{llll} & max & & E[V(c,l)] = \int_{t_0}^{\overline{T}} e^{-\delta\,(t-t_0)}\; S(t)\; [u(c(t)) + \nu(l_\tau(t))]\; dt \\ c(t), & a(t), & \tau \quad st & \dot{a}(t) = r\,a(t) + \tilde{w}(t,\tau) - c(t) \\ & & & \tilde{w}(t,\tau) = w(t)(1-\varsigma)\,\mathcal{I}(t_0,\tau) + b(t,\tau)\,\mathcal{I}(\tau,\overline{T}) \\ & & & l_\tau(t) = l(t)\,\mathcal{I}(t_0,\tau) + 1\,\mathcal{I}(\tau,\overline{T}) \\ & & & a(t_0) = a_0 \quad a(\overline{T}) = 0 \quad a(t) \geq 0\;\forall\, t \geq \tau \end{array} \tag{1}$$

where $\mathcal{I}(t_1,t_2)$ is the indicator function for the event $t \in [t_1,t_2]$.

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 $\bar{t} \in [\hat{\tau},\overline{T})$, where $\hat{\tau} = max\{\tau_m,\tau\}$ (ie. the maximum between the ERA and the individual retirement age). Following Crawford and Lilien (1981) and Fabel (1994b) we use this result to transform the original constrained problem into a new un-constrained one including $\bar{t}$ as a new decision variable.

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

where $e^{\tilde{\delta}(t)}$ is a shorthand notation for $S(t)\,e^{\delta\,(t-t_0)}$. 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. As this is a well known step, we leave the algebraic details and a calibrated example to appendix A.1. 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. A detailed discussion of the entire procedure is available in Jiménez-Martín and Sánchez-Martín (2003).

3.1 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 what the individual envisages as the optimal retirement behavior (given the information available at age t_0) as the solution to the *static* optimization problem:

$$\max_{\tau \in [\tau_0,\tau_1]} \quad E[V(c_\tau,l_\tau)] \tag{3}$$

where $t_0 < \tau_0$, $\tau_1 < \overline{T}$ and

$$E[V(c_\tau,l_\tau)] = \int_{t_0}^{\bar{t}(\tau)} e^{-\tilde{\delta}(t)}\; u(c_\tau(t))\,dt + \int_{\bar{t}(\tau)}^{\overline{T}} e^{-\tilde{\delta}(t)} u(b(t,\tau))\;dt + \int_{t_0}^{\tau} \nu(l(t))\,dt + \int_{\tau}^{\overline{T}} \nu(1)\,dt$$

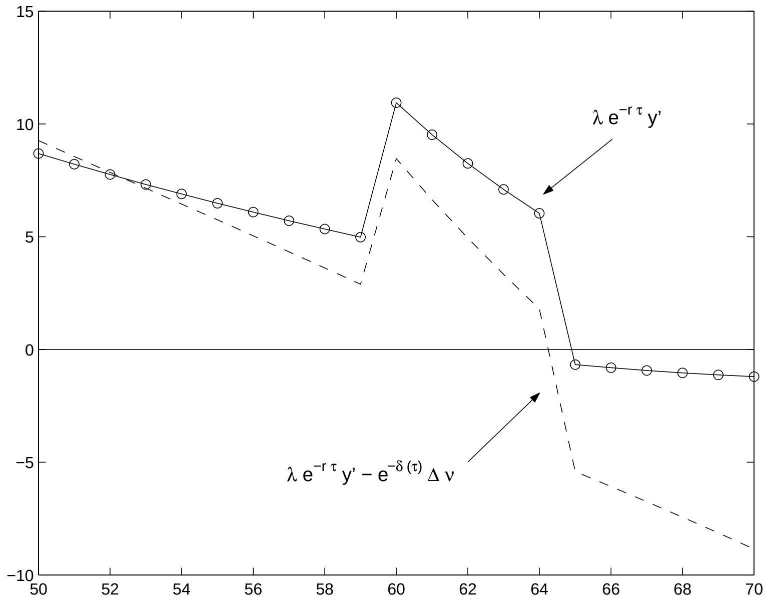

Figure 4: Marginal utility of working by age for the Spanish median worker. We separately show marginal changes in life cycle wealth $\lambda\, e^{-r\,\tau}\, y'(\tau)$, and the total marginal change implied, including the impact of leisure reductions.

$e^{\tilde{\delta}(t)}$ is a shorthand notation for $S(t)\, e^{\delta\,(t-t_0)}$. Some discontinuities introduced by the pension regulations (see below) imply that $V(\tau)$ is only piecewise continuously differentiable. Therefore, local optimum τ^* can be either interior ($\frac{dV}{d\tau}(\tau^*) = 0$ and $\frac{d^2V}{d\tau^2}(\tau^*) < 0$), or corner solutions, i.e., ages where the marginal utility of working changes its sign in a discrete, negative drop. Therefore, finding the best retirement age involves a comparison among the utility levels achieved in local optima and corner solutions.

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 age τ:

$$\frac{d\,V}{d\,\tau}(\tau) = \lambda\, e^{-r\,(\tau-t_0)}\, y'(\tau) - e^{-\tilde{\delta}(\tau)}\, \Delta\,\nu(\tau) \tag{4}$$

where λ is the lagrange multiplier associated with the implicit Intertemporal Budget Constraint, $y'(\tau)$ is the current value of the marginal changes in τ-*conditional* life cycle wealth, and

$$\Delta\,\nu(\tau) = \nu(1) - \nu(l_\tau) \tag{5}$$

is the current utility cost of the foregone leisure. Note that pension rules have a critical influence on retirement by shaping the evolution of $y'(.)$ with the retirement age, as we review in the next section.

3.2 The effects of pension rules on individual behavior

By staying in the workforce at age τ, the individual's life cycle wealth is modified in three different ways. On the one hand, current income takes the form of labor earnings, with the reception of pension benefits being deferred for at least one period (assuming the individual meets the eligibility criteria). 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:

$$y'(\tau) = w(\tau)(1-\varsigma) - b\, I(\tau \geq \tau_m) + b'\, \tilde{\mathcal{A}}(\hat{\tau}, \bar{t}) \tag{6}$$

where $I(.)$ 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:

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

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.[11]

Notice that the second term vanishes 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, τ_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 (6)).
- 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)

[11] Equation (6) is obtained from the first term of $dV/d\tau$ in (4) (the component derived from changes in consumption):

$$\lambda\, e^{-r\,(\tau-t_0)} \left[w(\tau)(1-\varsigma) - b\, I(\tau \geq \tau_m) + b'(\tau) \int_{\hat{\tau}}^{\bar{t}} e^{-r\,(t-\tau)}\, dt \right] + b'(\tau) \int_{\bar{t}}^{\overline{T}} e^{-\delta(t)}\, u'(b)\, dt$$

by using the first order condition for optimal consumption $e^{-\delta(\bar{t})} u'(c(\bar{t})) = \lambda\, e^{-r(\bar{t}-t_0)}$ and recalling that $c(\bar{t}) = b$.

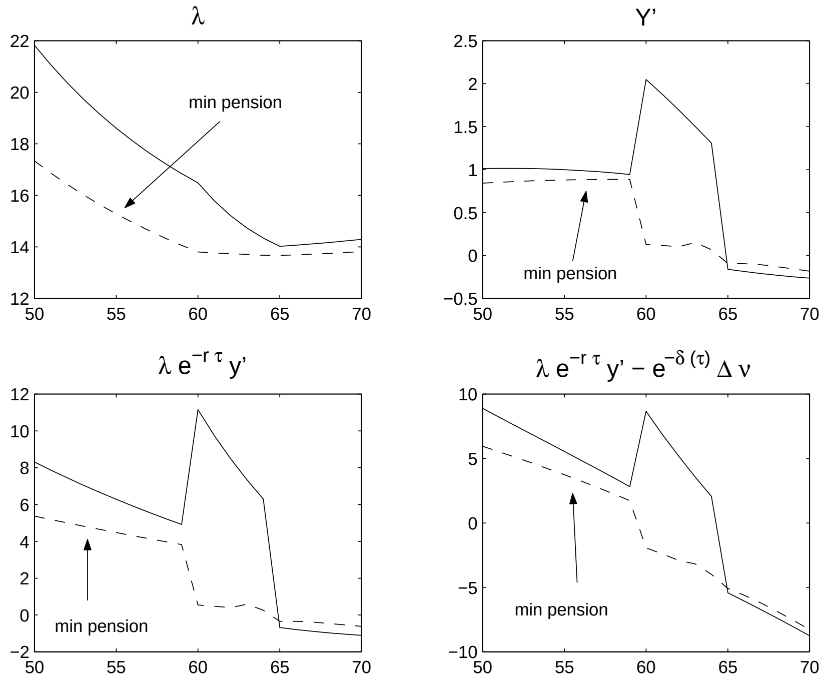

Figure 5: Income and substitution effects induced by the minimum pension scheme on a worker in the 10th quantile of the income distribution.

3.2.1 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:

$$y'(\tau) = w(\tau)(1 - \varsigma) - bm\, I(\tau \geq \tau_m) \tag{7}$$

It is most apparent that the minimum pension increases the opportunity cost of the forgone pension income and utterly eliminates the incentive to work due to the early retirement penalties. These two effects make 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 (4) through lower values of the lagrange multiplier λ, 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:

$$y'(\tau) = w(\tau)(1-\varsigma) - b\, I(\tau \geq \tau_m) + b'\, \tilde{\mathcal{A}}(\hat{\tau}, J(\tau)) \tag{8}$$

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

3.3 The applicability of the life cycle model

Although conceptually simple, the model developed in this section is a quite powerful analytical device. It allows for a very tractable exploration of the impact of pension rules, taxes, life-cycle profiles of labor productivity, survival probabilities and individual preferences (relative consumption/leisure value, the degree of risk aversion and time impatience) on a range of individual decisions (retirement, savings and, in a slightly generalized version of the model, hours worked).

The ability of the model to deliver closed-form analytical expressions makes it specially well suited for dealing with tasks with a strong computational or expositional content. Key for this tractability is, of course, the lack of consideration of any form of recursive uncertainty. This makes the model an unlikely candidate to analyze questions where time-changing uncertainty plays a central role. For questions hinging upon more permanent individual characteristics, in contrast, the model has serious advantages with respect to more standard (by now) dynamic programming methods. Consider, for instance, differences in labor income for individuals of similar observable characteristics like age, gender or education. They reflect recursive shocks (like shocks to their personal health or shocks to their sector of occupation) and more permanent differences associated with the average productivity of the individual, the educational background or the specific investments made right after the entrance in the labor market (specially in countries with very small labor mobility like Spain). From an *ex-ante* viewpoint, minimum pensions provide insurance for the latter type of variability, leading to a classical *moral hazard* problem.[12] The life cycle model provides an environment where the trade off between the insurance effect of minimum pensions and the distortions induced in savings and labor supply can be easily measured. We do not pursue this line any further here (to keep our analysis within reasonable length), but that is an area where the life-cycle model has clear competitive advantages with respect to other methods.

[12] Minimum pensions have only a marginal role in providing insurance against health shocks, as there is a specific scheme covering those shocks in the Spanish legislation ("pensiones de incapacidad laboral transitoria o permanente"). But other forms of income risk are undoubtedly hedged with the help of minimum pensions. The life cycle model is, admittedly, poorly equipped to study that type of insurance.

3.3.1 Assessing the impact of minimum pensions with the life cycle model

In this paper we apply the life cycle model for a relatively modest endeavor: to quantify the isolated impact of minimum pensions on welfare and retirement behavior, with special emphasis on early withdrawals from the labor force. This demands some additional clarification. The evidence presented in section 2.2 makes clear that flat pensions provide a plausible explanation for the spike in retirement hazard observed at the first pensionable age. However, it is traditionally argued that the large retirement flows at that particular age are largely due to credit constrained individuals.[13] In these circumstances the more natural next step seems to be to measure the relative contribution of both elements (which is of obvious importance for eg. policy purposes). Unfortunately, such an experiment is very difficult to undertake with the empirical information available in Spain. The main problem is the lack of data on asset holdings that can be combined with our database of Social Security administrative records. Note that it is only now (2006) that the results of the very first survey of asset holding by Spanish families (Encuesta Financiera de las Familias, EFF02) has been made available. It is, then, extremely difficult to impute this missing variable in our (or any other) structural econometric analysis.

In these circumstances two alternatively paths seem possible: (i) to remain within the recursive approach by resorting to a simulation-type estimator combined with some parametric assumptions on the form of the unobserved heterogeneity; or (ii) to abandon the sequential methodology altogether and follow a life cycle approach. This second route is attractive because life cycle models provide a theoretically consistent way around the problem: evaluate the retirement incentives at the age of entrance in the labor market, ie. at a point in life when we can assume that financial wealth is negligible. That's the approach we follow in this paper (ie, we set t_0 to 20 years and a_0 to 0 in the model of the previous section).

The downside of proceeding in this way is that the role of credit constraints at the end of the working life is very much diminished. This is (as explored in detail in section 5.2) the product of the lack of shocks in the economy and the rational long term planning implicit in the life-cycle model. The results of experiments in section 5.2.1 show that *solving the model at the beginning of the working career* makes it very hard to measure the relative contributions of credit constraints and minimum pensions to early retirement. [14] But we can still assess the

[13]The rationale is that, 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), page 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 62 is the ERA in the USA). Structural econometric models point to borrowing constraints as the major force leading to early retirement because 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.

[14]It is important to emphasize that this results does not stem from the model itself, but from the combination of very long term planning and homogeneity in the discount factor. When we compute the optimal decisions immediately before the ERA for individuals lacking enough accumulated wealth, we find that it is actually better to stay active till the pension is available. There would not be much differences with the predictions of standard

incidence of early retirement with and without the minimum pension and check the robustness of our findings. More precisely, our main experiment in this paper is as follows. We first extend the life-cycle model by considering one simple form of unobserved heterogeneity (the individual value of leisure); We then use the resulting probabilistic model as the data generating process for the estructural estimation of the preference parameters in the model; Finally, we compute how much early retirement is generated by the minimum pension in the life-cycle model (section 5.1). The robustness of these findings to the indirect omission of the impact of credit constraints is tested via simulations in section 5.2.

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 D). We start by reporting the way we introduce variability in individual retirement ages, by assuming a specific form of unobserved heterogeneity in the population. We then describe the details of our maximum likelihood estimation procedure, present the results obtained and discuss their implications.

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 value attached to the additional leisure obtained when the individual retires (ie. the change in the leisure term in the age-τ utility function (5), is a linear function of some observable characteristics and a time invariant, individual-specific shock ε:

$$\Delta\nu(\tau) = \Delta\nu_D(\tau) + \varepsilon \qquad \varepsilon \sim F_\varepsilon(.)$$

where F_ε stands for the population distribution of ε across the members of each cohort, and $\Delta\,\nu_D(t)$ is a deterministic component which depends on observable characteristics. Therefore, the marginal utility of working $(\partial V/\partial\tau)(\tau)$, expressed in current value terms and denoted hereafter by $\phi(\tau)$, can be split into a deterministic and a stochastic term. Recalling (4):

$$\phi(\tau) = \lambda\, e^{\tilde{\delta}(\tau)-r\,\tau}\, y'(\tau) - \Delta\nu_D(\tau) - \varepsilon = \phi_D(\tau) - \varepsilon$$

Using the optimal retirement conditions in section 3.1, we can establish a functional relationship between the unobserved "type", ε, and the optimal retirement age, τ:

dynamic programming models. This does not happen with long term planning because rational individuals do accumulate enough wealth to finance pre-retirement. However, a life-cycle model with heterogeneity in the discount factor can potentially produce endogenously credit-constrained individuals. A simulation along these lines is undertaken in section 5.2.2.

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

The asterisk reminds us of the need for discarding *local* optima in order to have a one-to-one relationship between the two variables. Note that individuals with different observable characteristics will have different age profiles of ϕ_D^*. Finally, a change of variable in the distribution function of ε leads to a (conditional on the observables) distribution law for the stochastic optimal retirement age. The unconditional probability of being retired at age t or before is then:

$$F_\tau(t) = P[\tau \leq t] = P[\phi_D^{*^{-1}}(\varepsilon) \leq t] = P[\varepsilon \geq \phi_D^*(t)] = 1 - F_\varepsilon(\phi_D^*(t)) \tag{9}$$

This continuous-time specification becomes operative by making τ discrete and considering the existence of lower and upper limits in the retirement age ($\overline{\tau}$ and $\underline{\tau}$ respectively). Then, from the viewpoint of the analyst, retirement is a discrete stochastic variable $\xi \in \{\underline{\tau}, \underline{\tau}+1, \ldots, \overline{\tau}\}$, distributed according to the following law:

$$F_\xi(a) = \begin{cases} 1 - F_\varepsilon(\phi_D^*(\underline{\tau})) & a = \underline{\tau} \\ 1 - F_\varepsilon(\phi_D^*(a)) & a \in \{\underline{\tau}+1, \ldots, \overline{\tau}-1\} \\ F_\varepsilon(\phi_D^*(\overline{\tau})) & a = \overline{\tau} \end{cases} \tag{10}$$

4.2 Maximum Likelihood estimation method

Using the retirement age distribution (9), we can easily write the likelihood of any vector of preference parameters θ, given individual i retirement decision:

$$L^i(\theta) = \left[1 - \frac{F(\phi_i^*(t^i, x_i, \theta))}{F(\phi_i^*(t^i-1, x_i, \theta))}\right]^{d_i} \left[\frac{F(\phi_i^*(t^i, x_i, \theta))}{F(\phi_i^*(t^i-1, x_i, \theta))}\right]^{1-d_i} \tag{11}$$

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 (we make explicit the dependence 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 procedure. Firstly, we have to fully specify the individual utility function. We restrict ourselves to the CES case, $u(c) = c^{1-\eta}/(1-\eta)$ and impose the following linear structure on the deterministic value of leisure:

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

This specification considers four controls (in addition to a constant): the age τ, the education ($d(e)$ is a dummy taking the value of one for highly educated workers and zero otherwise), and the receipt 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 $\theta = (\nu_0, \nu_e, \nu_{e\,t}, \nu_t, \nu_s, \delta, \eta)$.

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:

- The permanent component of the relative value of leisure, ε, is assumed to be normally distributed across individuals: $\varepsilon \sim N(0,1)$. This introduces some similarities between our empirical model and a reduced form probit model. Note, however, that our unobservable individual type ε is permanent rather than the annual shock included in the probit case. This accounts for the non standard denominator in our likelihood function (11).

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

Provision	**Expression**	**Definitions**
Elegibility	$\tau \geq \tau_m = 60 \qquad a(\tau) \geq 15$	τ_m is the ERA a(.) 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 $c(t)$ denotes contributions
Benefit Base	$\overline{w}(\tau) = (1/R)\sum_{\tau-R}^{\tau} c(t)\,dt$	$\overline{w}(\tau)$ is the benefit base R: length of the averaging period (8 in 1995)
Age Penalty	$\alpha(\tau) = \begin{cases} \alpha_0 & \text{if } \tau < \tau_m \\ \alpha_0 + \alpha_1(\tau - \tau_m) & \text{if } \tau_m \leq \tau \leq \tau_N \\ 1 & \text{otherwise} \end{cases}$	τ_N is the NRA $\alpha_0 = .60$ $\alpha_1 = .08$
History Penalty	$\kappa(a(\tau)) = \begin{cases} \kappa_0 & \text{if } a(\tau) < 15 \\ \kappa_0 + \kappa_1(a(\tau) - a_m) & \text{if } 15 \leq a(\tau) \leq 35 \\ 1 & \text{otherwise} \end{cases}$	$\kappa_0 = .60$ $\kappa_1 = .02$
Pension	$b(t,\tau) = min\{bx(t), max\{\alpha(\tau)\,\kappa(a(\tau))\,\overline{w}(\tau), bm(t,\tau)\}\}$	$b(t,\tau)$ 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 or *generosity* is 0.5 %.	

- 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 pension rules in the Spanish *General Regime*. The parameter values are those in effect before the 1997 reform (the estimation sample is the 1995 cross section of HLSS). These values are presented in Table 1.

  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 both 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 real growth of the minimum pension as the *generosity* of the system. Finally, on the top of E2 we specify the economy E3, in which there is a unique maximum pension, and a minimum and maximum level of contributions, 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 this last group of pension rules in explaining the empirical retirement patterns.

- The base value for our constant interest rate is 3%.
- The other components of the vector of observable information x_i (wages, education and labor history) are used to compute the marginal utility $\phi^*(t^i)$ for every individual in the sample. The key part for this task is to construct, for each individual in the sample, a smoothed life-cycle profile of labor earnings compatible with the observed information from 1986 to 1995. This is crucial in estimating the wages, pensions and wealth of each individual in the sample. The details are provided in appendix D and further explained in Boldrin et al. (2004).

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. In order to evaluate the fit of the model we report a pseudo-R^2 that compares the fit of each specification with respect to the constant only model with fixed preference parameters ($\delta = 0$ and $\eta = 1$). 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.

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).[15] This comparison is particularly important, as his

[15] In Hurd's paper, which only includes uncertainty regarding the life span, η= 1.12 and δ=-0.01. In Gustman and Steinmeier (2002), where the rate of time preference is heterogeneous, the estimated value of η 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 (1987) (where several sources of uncertainty are included) the elasticity of intertemporal substitution ($1/\eta$) is found to be 0.93; in French (2005) (where both income and health are uncertain) the estimated value is η =1.42. In Gustman and Steinmeier (1986) deterministic model, $1/\eta$ is estimated in the range 0.6/1.18.

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

Economy	E1		E2		E3	
	$\hat{\theta}$	t-ratio	$\hat{\theta}$	t-ratio	$\hat{\theta}$	t-ratio
ν_0	-8.478	-318.91	-8.084	-542.01	-8.439	-565.00
ν_e	5.156	250.14	1.654	110.91	3.541	237.07
ν_{et}	-0.128	-60.99	-0.047	-3.17	-0.090	-6.05
ν_t	0.224	308.36	0.205	13.73	0.214	14.32
ν_s	0.841	20.87	0.748	50.17	0.712	47.65
δ	-0.007	-3.06	-0.043	-2.90	-0.037	-2.45
η	0.644	35.13	0.995	66.74	1.016	68.01
lnl	-4839.594		-4494.832		-4482.236	
$pseudo - R^{2\aleph}$	0.0959		0.1603		0.1627	

$\aleph$: Log-l in model E_1 with $\delta = 0$; $\eta = 1$, a constant and an age trend.

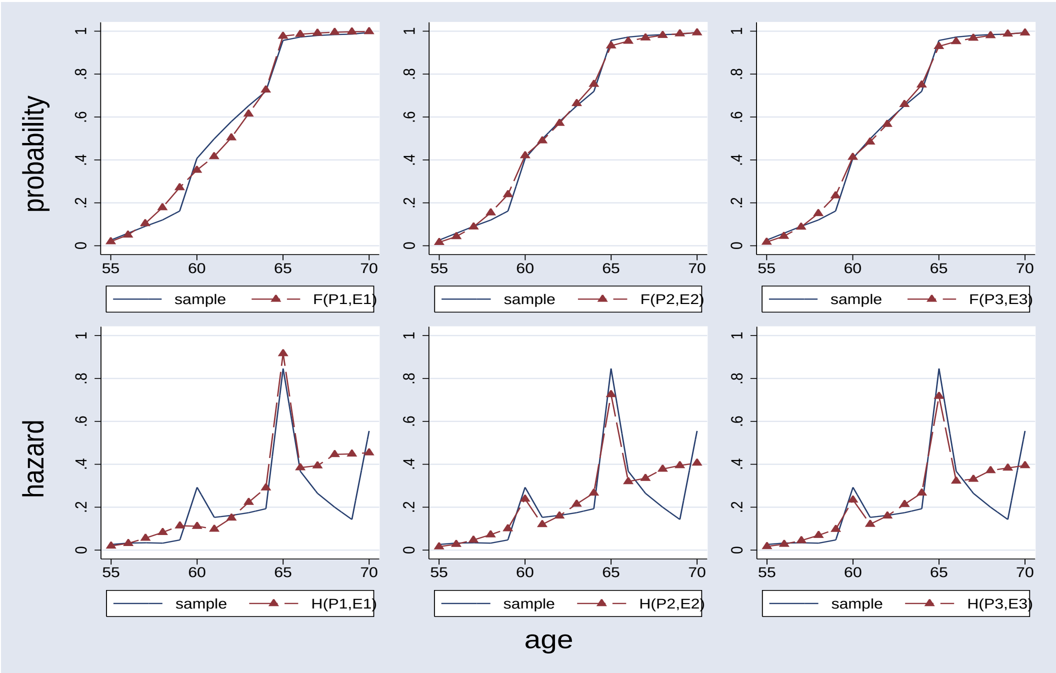

Figure 6: Fitted retirement hazard (H) and cumulative distribution (F) vs sample averages by age in the three institutional environments considered (Economies E1 to E3). Data: HLSS 1995.

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 δ 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 δ 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 well suited to our purpose of exploring the incentives provided by the pension regulation, but it is far from being a complete theory of retirement. It is clear that recursive models may provide a more comprehensive ground for empirical analysis. The estimation of our life cycle model is, however, a very valuable experiment as it gives us a set of parameters values that are fully consistent with our theoretical model. Furthermore, the estimation gives a chance to test the empirical performance of the life cycle theory. This is summarized in the third column of Figure 6, where the estimated cumulative distribution and hazard by age 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 observe 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 a bit lower than that in the data; (3) overstates the number of people retiring immediately before the Normal retirement age; and, finally, generates a large spike at the NRA, although, again, it is of a smaller magnitude than the empirical one. The relatively high post-65 hazards found are entirely due to the very small predicted probability of survival in the labor force beyond the NRA. The probability of retirement at those ages is actually very small and decreasing.

That we do not fully reproduce the size of the peaks 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 stay active claiming the unemployment benefit and start 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 relevant implications. Firstly, the comparison between E1 and E2 confirms that the economy without minimum pensions (E1) is utterly incapable of reproducing the empirical patterns of *pre-retirement* (withdrawals before or at the ERA) and *early retirement* (before 65). And, secondly, the coincidence between the estimated hazard for economies E2 and E3 identifies the minimum pension as the key factor shaping early retirement patterns, and play down the role of maximum pension and min/max of contributions.

We showed in section 2.2 that the age-60 retirement peak is basically due to the behavior of low income workers. To test the ability of the model to reproduce this observation we compare in figure 7 the retirement hazard by age in the data and in the model, for three wage groups (delimited by the 1/3 and 2/3 quantiles of earnings: 1.58 and 2.60 million pesetas respectively). We can appreciate how the life cycle model (once equipped with the minimum pension mechanism) successfully reproduces this empirical regularity.

Finally, and 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.[16] Figure 8 shows the results: the overall predicting power of the probit is very limited, and its performance is extremely poor at capturing the discontinuities in the data. This comparison provides further evidence (see Lumsdaine et al. (1992) for an early elaboration of this idea) of 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 on retirement and welfare

To quantify the impact of the minimum pension scheme on the aggregate distribution of retirement ages we simulated the economies with and without the guaranteed minimum scheme (economies E1 and E3, respectively) 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). Figure 9 illustrates our findings while Table 5 in appendix E provides additional details.

[16]In addition to the set of linear regressors already considered in the non-linear model, we have included the inverse of lifetime wealth and the marginal change in lifetime Wealth. These are standard regressors in the

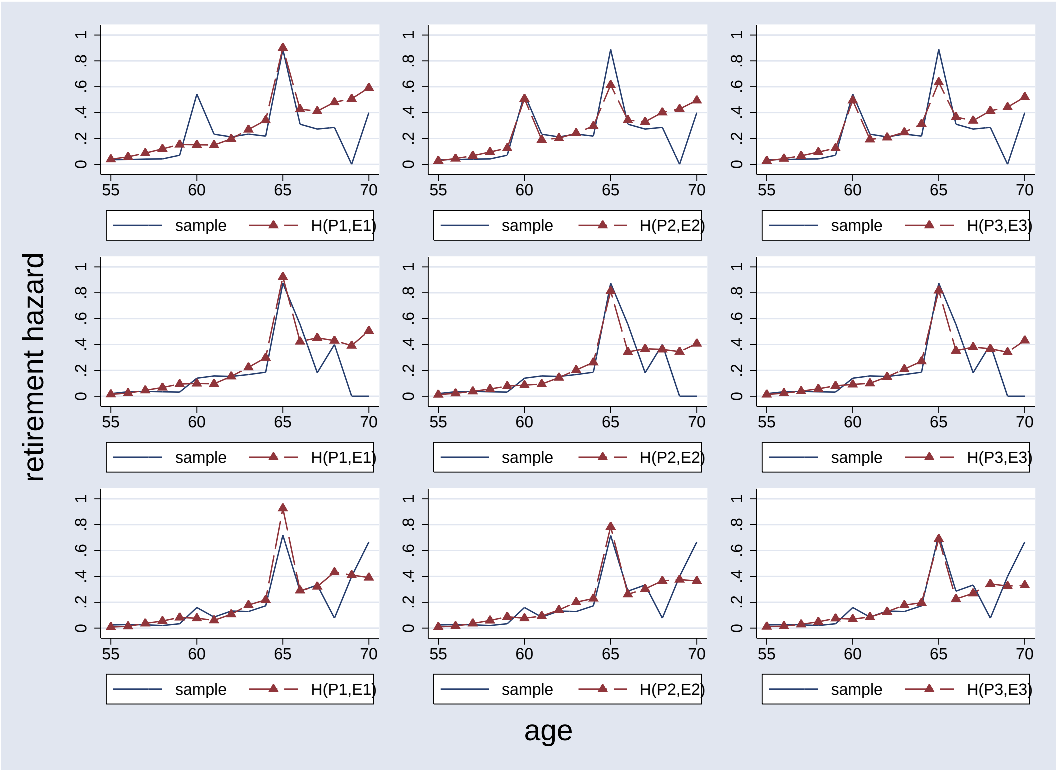

Figure 7: Retirement hazard by age and wage level in the three institutional environments considered (Economies E1 to E3). The wage levels (W1 to W3) are delimited by the percentiles 1/3 and 2/3 of the empirical distribution. Data: HLSS 1995.

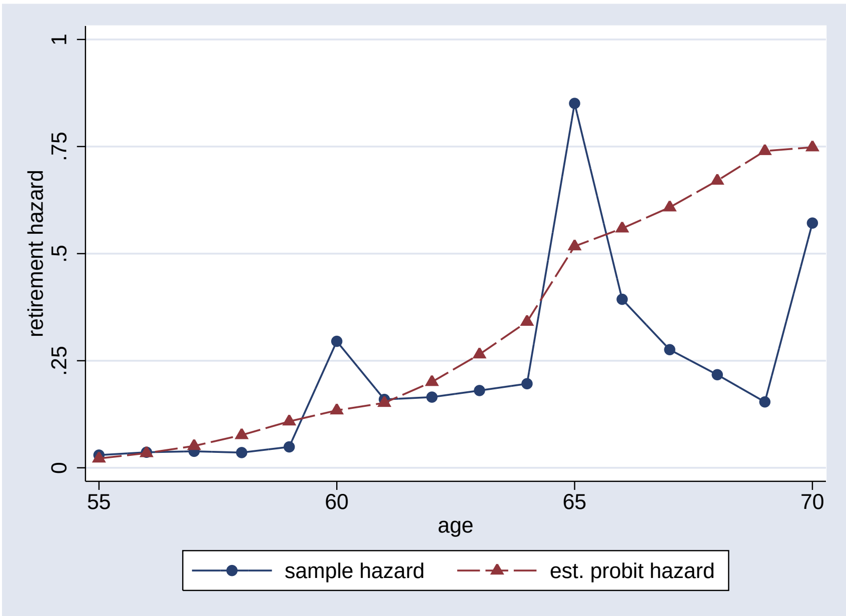

Figure 8: Hazard out of the labor force: sample vs. predictions form a probit model using the same information as our estructural model. Data: HLSS 1995.

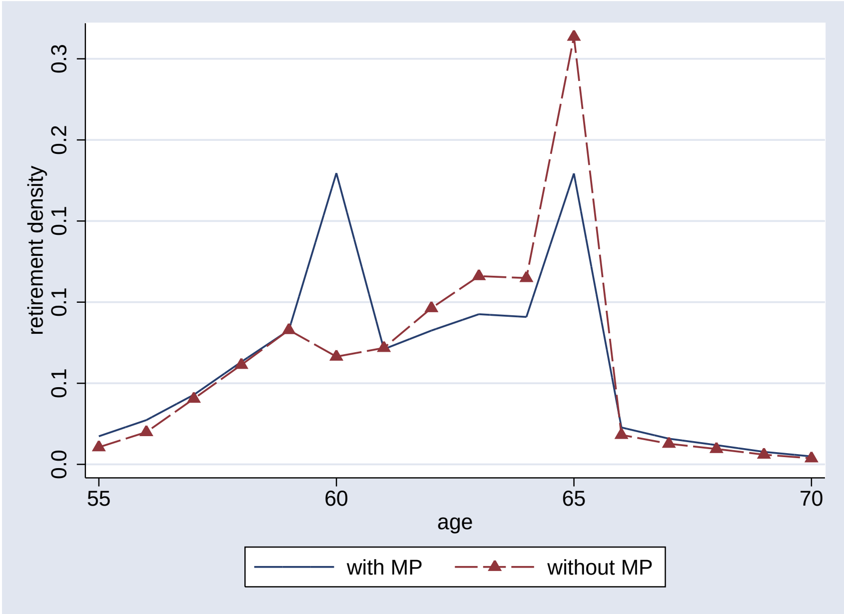

Figure 9: Simulated aggregate retirement probabilities by age in the economies with and without the minimum pension scheme. Both simulations are carried out using the preference parameters estimated for economy E3.

It is most apparent from Figure 9 that the minimum pension scheme alters the *shape* of the retirement distribution in a fundamental way, shifting substantial amounts of probability mass from 65 and the immediately preceding *early retirement* ages (between 61 and 64) to the ERA of 60. 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 a rather small increase in the incidence of *pre-retirement* (withdrawals before or at the ERA): the unconditional retirement probability with the minimum pension is higher at every age before 60. This results in a 2 % increase in the retirement probability accumulated at the age of 59.
- A remarkable spike emerges at the age of 60, as the probability of retiring exactly at the ERA almost triples (6.6% in E1 vs. 18.0 % in E3).
- Increases in the incidence of *pre-retirement* are mirrored by decreases in retirement after the ERA. *Early retirement* before 65 experiences a 15.5% reduction, while retirement at the NRA goes down by 30%. Overall, the introduction of the minimum pension implies a 10% increase in the occurrence of early and pre- retirement.

All in all, the introduction of minimum pensions (together with the other caps and ceilings included in E3) reduces the average retirement age by four months, from 63.0 to 62.66 years.

financial incentives literature. See, for example Samwick (1998).

Most changes occur at the lowest end of the income distribution, as figure 7 in the preceding section makes clear. The retirement behavior of median and high income workers is largely unaffected by the institutional change involved by shifting form E1 to E3.

5.1.1 Welfare impact of the minimum pension scheme

Low income workers, then, are the principal beneficiaries of the minimum pension scheme. Arguably this comes at the price of higher average contributions for the overall working population, emphasizing the distinctive redistributive character of this piece of the pension regulations.[17] It is clear that both effects should be accounted for by any measure of the average welfare impact of minimum pensions. In this paper we assess the welfare effect by computing a *compensated equivalent variation* that keeps constant the average generosity of the system (in terms of its implicit internal rate of return). More precisely, we proceed as follows: [18]

1. Evaluate the generosity of the current system by computing its average internal rate of return $\overline{r}$.
2. Compute the contribution rate needed to keep $\overline{r}$ constant in a system without minimum pensions (and letting individual adjust their optimal life cycle behavior to the new institutional environment).
3. Compute the equivalent variation associated with the presence of minimum pensions, but keeping the average generosity constant.

Proceeding in this way we find that the *average* welfare gain produced by minimum pensions is not very large: it amounts to approximately 0.6% of the life-cycle consumption of the median worker in the economy. This low figure is, of course, the result of the cancelation of effects of opposite sign for different individuals. The gain for a low income worker that retires at the age of 60 is a substantial 3.3% of his/her life-cycle consumption. For a worker of average earnings that stays active till 65 the losses from higher contributions amount to almost 1% of his/her life-cycle consumption. The detailed results can be checked in Table 6 of appendix F. Note that these figures are extremely sensitive to changes in the growth rate of the minimum pensions. In our benchmark simulation we assume a future growth rate of 0.5%, which is significantly smaller than the average for the 1985/2004 interval. Had we extrapolated the historical figures, we would have found a much larger welfare impact: an average equivalent variation of 3.6%, and welfare gains as large as 13% of life-cycle consumption for early retirees.

[17] In our framework, the redistributive role of minimum pensions is dominant, as the absence of health shocks eliminate the potencial *efficiency* gains of early withdrawals form the labor force and unemployment benefits.

[18] Appendix F provides formal definitions of the equivalent variation and of the compensation in generosity.

5.2 Early retirement and borrowing constraints

In this section we explore what arguably is the main drawback of the life cycle setting: the very minor role played by credit restrictions. In section 5.2.1 we show that credit constraints hardly affect optimal retirement patterns in our benchmark model (ie, when decisions are taken early in the life-cycle by agents with a homogenous discount factor). Things may be different in a population with heterogenous δ, as this would endogenously generate credit-constrained individuals who may early retire in absence of minimum pensions. This possibility is explored in section 5.2.2. We find that the quantitative bias introduced by this possibility in our main results is small.

5.2.1 The impact of the borrowing constraint in our benchmark model

Table 3: Optimal retirement with and without credit restrictions: Predicted cumulative distribution (F) in our model economy with perfect credit markets (PKM) and borrowing constraints (BC). The simulations are carried out using the parameters estimated under economy E3.

Age	F(BC)	F(PKM)	Age	F(BC)	F(PKM)
55	0.0	0.0	63	0.567	0.564
56	0.017	0.018	64	0.659	0.654
57	0.045	0.046	65	0.750	0.743
58	0.088	0.090	66	0.929	0.929
59	0.151	0.154	67	0.952	0.952
60	0.233	0.237	68	0.968	0.968
61	0.413	0.418	69	0.980	0.980
62	0.484	0.486	70	0.988	0.988

In this section we explore the role of credit constraints in our benchmark model. This is done by performing a simple experiment: comparing the optimal behavior in a model with perfect credit markets with that in our benchmark framework.[19] The results of such a comparison are displayed in Table 3 (appendix C presents some additional theoretical details). They make it clear that the presence of borrowing constraints has a very minor impact on the predicted retirement behavior. 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

[19] The optimal retirement behavior in the presence of perfect capital markets has been frequently 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 3.1, when the first binding age for the credit constraint $\bar{t}$ is the maximum length of life $\overline{T}$.

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 eg. French (2005)).

Alternatively, a life-cycle model without recursive uncertainty may produce an age-60 spike if very impatient individuals were included in it. Those individuals optimally accumulate little wealth along their working careers and are, consequently, strongly credit constrained in the years immediately before ERA. In these circumstances, they have no real option to retire until the public pension is first available. Furthermore, very impatient individuals are not much affected by the strong forces retaining workers at that particular age (stemming basically from increases in the future pension, recall section 3.2), as they discount these future gains strongly.[20] These two observations together suggest that these workers may find it optimal to retire at 60 even in absence of minimum pensions. This possibility is quantitatively evaluated in the next section.

5.2.2 Early retirement with heterogeneity in the discount factor

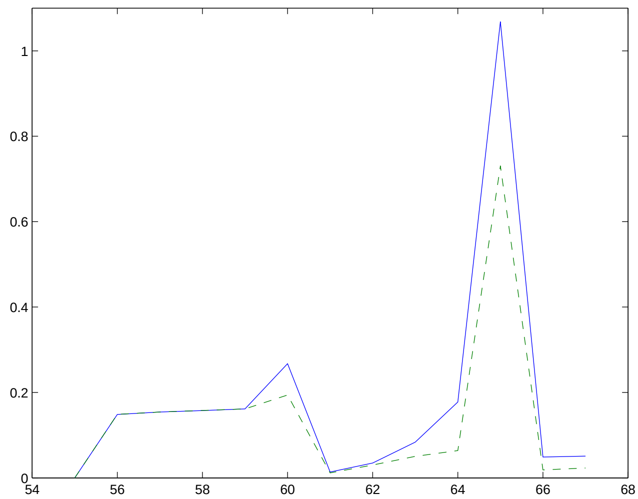

Figure 10: Aggregate retirement hazard with (-) and without (- -) minimum pensions in the economy with heterogenous discount factor.

The target is to measure the magnitude of retirement flows at ERA when there is heterogeneity in the degree of time preference. As this cannot be done within our estimation sample, we carry out a simulation exercise based on the EFF-02, the only available database including detailed information about asset holdings. The experiment involves two different calculations:

1. Evaluate the dispersion of δ in the Spanish population.

[20]This can be checked by exploring the equation (6) or, more simply, the expression in footnote 11. Take note that for these type of workers $\bar{t}$ equals the retirement age and, consequently, δ is the relevant discount factor for the valuation of changes in the pension benefit.

We undertake a *revealed preference* experiment in the tradition of Gustman and Steinmeier (2002). We infer the population distribution of δ by combining our model's predictions in terms of assets holdings and the empirical data in EFF-02. The essence of the procedure is that low levels of accumulated assets reveal a high degree of time preference. The details, including kernel estimates of the discount factor, are presented in appendix G.

2. We simulate the optimal retirement behavior in the economy with heterogeneous discount factors.[21] In particular, we measure to what extent the existence of a significant group of credit constrained individuals contributes to a spike of retirement at the age of 60 (in absence of minimum pensions).

We find a small increase in the incidence of retirement at the ERA in the economy without minimum pensions: the hazard grows from 0.16 at 59 to 0.19 at 60 (figure 10 illustrates the results). This is less than one third the increase observed with minimum pensions. This means that the incidence of credit constraints (as revealed by the data on asset holdings) is not large enough to make a big contribution to early retirement in Spain. We may conclude, then, that the quantitative bias induced by this omitted effect in our benchmark calculation is small. Thus, our basic finding about the contribution of minimum pensions to early retirement seems robust.

5.3 Reform Analysis

Our calibrated life-cycle model is a valuable tool to explore the partial equilibrium effects of policy changes. In this section we focus on changes in the pension regulations that have been recently introduced or are currently under debate in Spain. In particular, we simulate the following modifications to our base case economy [E3]:

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: We introduce two changes in the way pensions and contributions are worked out. On the one hand, we add a 2 % annual premium for extending contributive careers beyond age 65 to the pension formula in Table 4.2. The formal expression of the new age penalty after 65 changes to $1 + 0.02\,(\tau - \tau_m)$. On the other hand, workers who stay in the labor force after the "normal" retirement age (65) are exempted of paying the employee part of social contributions. (6.4 % of the covered wages). These changes were the core of the modification in pension law approved in 2002.

REFORM C: We change the elegibility conditions of the minimum benefits to make them only available at the normal retirement age of 65.

[21]To maximize the role played by credit constraints we avoid using the long term predictions of our life-cycle model. Instead, we solve the model using current information on wages and assets. This forces as to introduce some adjustments in the calibration of model. Again, the details are provided in the appendix G.

REFORM D: The combination of reforms B and C.

The changes in retirement behavior generated by the proposed policies can be appreciated in Figure 11. The change in the length of the pension averaging period in Reform A has virtually no effect on retirement patterns. In contrast, the other two 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 incentive scheme. Overall, 16 % of the population remains at work after 65 with the new regulation (7.1% in the base case), and the average retirement age goes up by more than a year and a half (from 62.66 to 64.46 years). As expected, policy C, the suppression of the minimum benefit between 60 and 64 is effective in reducing pre-retirement and early retirement. It reduces accumulated retirement at 60 by 7.1 percentage points (from 41.2% to 34.1%)and increases the average retirement age by almost 2 months. This means that roughly 50% of the total behavioral response generated by minimum pensions can be overturned by delaying its age of first entitlement. Finally, the combination of policies C and D, results in the complete removal of the peaks at the ERA and the NRA, and larger delays in the average retirement age (amounting to practically two additional years at work, in average).

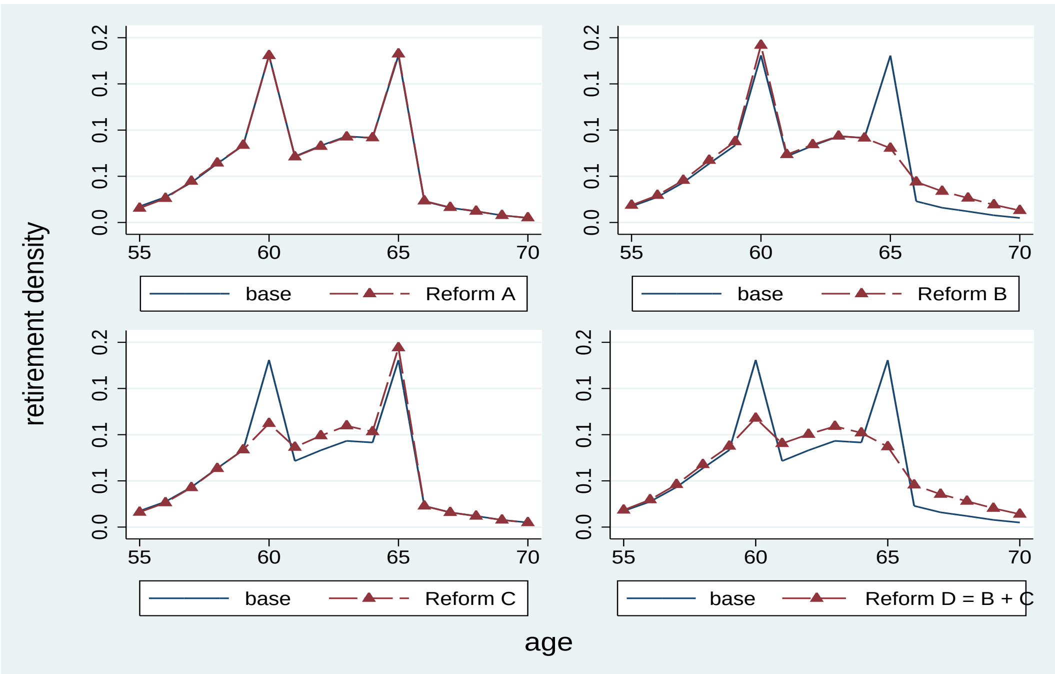

Figure 11: Effects of reforms A to D in retirement probabilities (f). The simulations are carried out using the parameters estimated under economy E3.

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 both quantify the welfare impact of minimum pensions and study the magnitude of the distortions generated by this piece of regulation on retirement behavior. 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 generating process in a structural estimation experiment, finding that our stylized model provides a rather good approximation of empirical retirement behavior, using a minimum amount of information.

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 the incidence of retirement at the age of first entitlement (60) almost triples with respect to that in the economy without minimum pensions, and total early retirement (before or at 60) is almost 50% larger with minimum pensions. We check that these findings are robust to the inclusion of heterogeneity in the discount factor (ie, in situation where the role of credit constraints is much reinforced). 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). 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.

REFERENCES

Boldrin M, Jiménez-Martín M, Peracchi F. 1999. Social security and retirement in Spain. In *Social Security and Retirement around the world*, Jonathan Gruber and David Wise (eds). University of Chicago Press for the NBER: Chicago.

Boldrin M, Jiménez-Martín M, Peracchi F. 2004. Micromodeling of social security and retirement in Spain. In *Social Security and Retirement around the world: micro-estimation*, Jonathan Gruber and David Wise (eds). University of Chicago Press for the NBER: Chicago.

Crawford VP, Lilien DM. 1981. Social security and the retirement decision. *Quarterly Journal of Economics* 96: 505-529.

Fabel O. 1994a. *The economics of Pensions and Variable Retirement Schemes*. Series in Financial Economics and Quantitative Analysis. John Wiley & Sons.

Fabel 0. 1994b. Social security, optimal retirement and savings. *European Journal of Political Economy* 10: 783-802.

French E. 2005. The effects of health, wealth, and wages on labor supply and retirement behavior. *Review of Economic Studies* 72: 395-427.

French E, Jones JB. 2001. The effects of health insurance and self-insurance on retirement behaviour.Working paper series, Research Department, wp 2001-19, Federal Reserve Bank of Chicago.

Gruber J, Wise D (eds). 1999. *Social Security and Retirement around the World*. University of Chicago Press: Chicago.

Gustman A, Steinmeier T. 1986. A structural retirement model. *Econometrica* 54: 555-584.

Gustman A, Steinmeier T. 2002. The social security early retirement age in a structural model of retirement and wealth. Working paper n. 9183, National Bureau of Economic Research.

Hurd MD. 1989. Mortality risk and bequest. *Econometrica* 57: 779-813.

Jiménez-Martín S, Sánchez-Martín AR. 2003. An evaluation of the life-cycle effects of minimum pensions on retirement behavior. Working Paper 715, Universitat Pompeu Fabra.

Jiménez-Martín S, Sánchez-Martín AR. 2004. The effects of pension rules on monetary incentives to retirement, with an application to the analysis of pension reform in Spain. *Hacienda Pública Española* 169: 35-66.

Kahn JA. 1988. Social security, liquidity and early retirement. *Journal of Public Economics* 89: 97-117.

Kalisch DW, Aman T. 1998. Retirement income systems: The reform process across OECD countries. AWP3.4. OECD: Paris.

Leung SF. 1994. Uncertain lifetime, the theory of the consumer, and the life cycle hypothesis. *Econometrica* 62: 1233-1239.

Leung SF. 2000. Why do some households save so little? a rational explanation. *Review of Economic Dynamics* 3: 771-800.

Lumsdaine RL, Stock JH, Wise DA. 1992. Three models of retirement: computational complexity versus predictive validity. In *Topics in the economics of aging.* Wise DA (ed). Chicago University Press for the NBER: Chicago.

Modigliani F, Brumberg R. 1980. Utility analysis and aggregate consumption functions: an attempt at integration. In *The Collected Papers of Franco Modigliani.* Abel A (ed). MIT: Cambridge, MA.

Rust J, Phelan C. 1997. How social security and medicare affect retirement behavior in a world of incomplete markets. *Econometrica* 65: 781-831.

Samwick A. 1998. New evidence on pensions, social security and the timing of retirement. *Journal of Public Economics* 70: 207-236.

Sánchez-Martín AR. 2002. Endogenous retirement and public pension system reform in Spain. Mimeo.

Sheshinski E. 1978. A model of social security and retirement decisions. *Journal of Public Economics* 10: 337-360.

Yaari ME. 1965. Uncertain lifetime, life insurance and the theory of the consumer. *Review of Economic Studies* 32: 137-150.

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

When both the retirement, τ, 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 $c_\tau(.\,|\bar{t})$ (ie, the solution to problem (2)). [22] Omitting the dependence on τ and $\bar{t}$ to make notation easier, the Hamiltonian of the system is:

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

Denoting a solution by $x = \{a, c, \lambda\}$, it must satisfy the following first order conditions, $\forall t \in [t_0, \bar{t}]$:

$$\frac{\partial\, H(x(t), t, \tau)}{\partial\, c(t)} \equiv e^{-\delta\, t}\,\frac{d\,u}{dc}\,(c(t)) - \lambda(t) = 0 \tag{12}$$

$$\frac{\partial\, H(x(t), t, \tau)}{\partial\, a(t)} \equiv r\,\lambda(t) = -\dot{\lambda}(t) \tag{13}$$

$$\dot{a}(t) = r\,a(t) + \tilde{w}(t) - c(t) \tag{14}$$

$$a(t_0) = a_0 \quad ; \quad a(\bar{t}) = 0 \tag{15}$$

It is easy to check that these conditions are also sufficient for our problem. To get to expression (17) we proceed as follows:

1. We integrate (13) to obtain $\lambda(t)$ as a function of $\lambda(t_0)$ (just λ in our notation). If this is particularized in (12), we obtain:

$$e^{-\tilde{\delta}(t)}\,\frac{d\,u}{dc}(c(t)) = \lambda\, e^{-r\,t} \tag{16}$$

2. If we integrate (14) we obtain the *conditional* Intertemporal Budget constraint (IBC).

[22] Our problem differs from the standard formulation (as stated in eg. **?**), pag 165, or **?**), 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 **?**), pag 87).

3. If we further restrict ourselves to the CES case, $u(c) = c^{1-\eta}/(1-\eta)$, we can express the optimal conditional consumption $c(t)$ as an explicit function of λ from (16). This, in turn, can be particularized in the *conditional* IBC. Obtaining the optimal *conditional* consumption is then straightforward:

$$c_\tau(t\,|\,\bar{t}) = \frac{[S(t)d(t)]^\gamma}{\mathcal{C}_c(\bar{t})}\,Y(\tau,\bar{t}) \quad \text{with} \quad \mathcal{C}_c(\bar{t}) = \int_{t_0}^{\bar{t}} e^{-r\,(t-t_0)}\,[S(t)\,d(t)]^\gamma\,dt \tag{17}$$

where γ stands for the intertemporal elasticity of substitution $\gamma = 1/\eta$, $d(t) = e^{(r-\delta)\,(t-t_0)}$ is the net discounted factor, $\mathcal{C}_c(\bar{t})$ 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:

$$Y(\tau,\bar{t}) = a_0 + \int_{t_0}^{\tau} e^{-r\,(t-t_0)}\,w(t)(1-\varsigma)\,dt + \int_{\hat{\tau}}^{\bar{t}} e^{-r\,(t-t_0)}\,b(t,\tau)\,dt \tag{18}$$

Expressions (17) and (18) 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 $h_\tau(.)$.

A.2 The Optimal binding age for the credit constrain

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:

$$\max_{\bar{t}\,\in\,[\hat{\tau},\overline{T}]} \quad V(\bar{t}) = \textstyle\int_{t_0}^{\bar{t}} e^{-\tilde{\delta}(t)} u(\,c_\tau(t\,|\,\bar{t})\,)\,dt + \int_{\bar{t}}^{\overline{T}} e^{-\tilde{\delta}(t)} u(b(t,\tau))\,dt$$
$$\text{Given} \quad \tau, \quad c_\tau(t\,|\,\bar{t}) : [t_0,\bar{t}] \to \mathcal{R}_+ \text{ and } \hat{\tau} = max\{\tau_m,\tau\} \tag{19}$$

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 $h_\tau(.)$

$$t^* \equiv h_\tau(\bar{t}) = \bar{t} \tag{20}$$

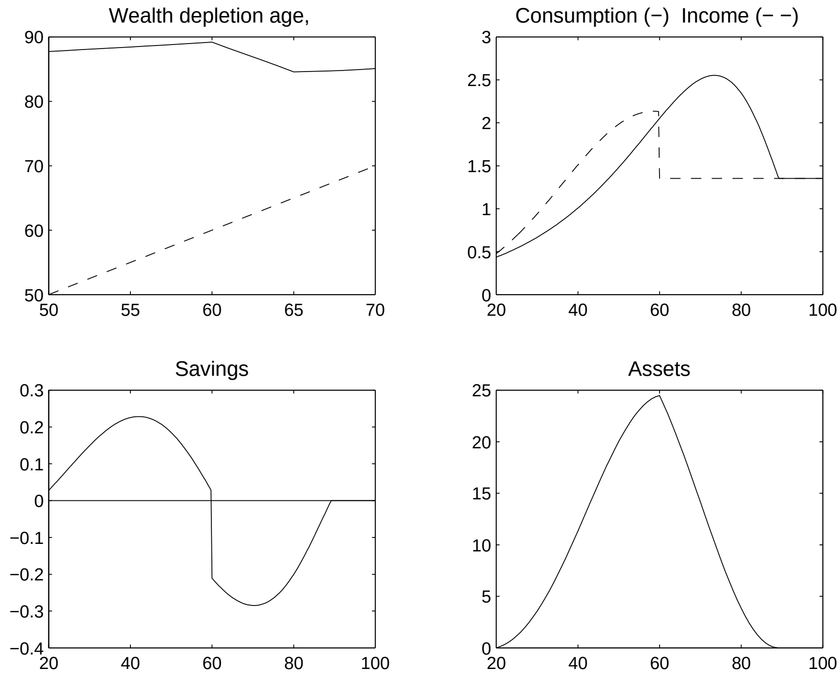

Figure 12: Optimal wealth depletion age $\bar{t}$, and optimal life cycle behavior (consumption, savings and accumulated assets) for the Spanish economy's median worker in case of retirement at the age of 60.

This is easily established from the first order condition of the problem:

$$(d\,V\,/\,d\,\bar{t})(\bar{t}^*) \equiv e^{-\tilde{\delta}(\bar{t}^*)}\psi(\bar{t}^*) = 0$$

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

Under concavity of the utility function, the only root to this equation is obtained from condition (20). This result was established in **?**). 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 $\psi(\bar{t}) < 0 \quad \forall \bar{t} \in [\tau, \overline{T}])$. In practice, we obtained the optimal $\bar{t}$ by applying a root finding routine to the equation $t - h_\tau(t)$ in the interval $[\hat{\tau}, \overline{T})$.[23]

Figure 12 displays the basic **qualitative properties** of the optimal $\bar{t}$ (as a function of retirement age) and the life-cycle profiles of consumption and savings for a Representative Agent (RA) of the Spanish economy.[24] 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

[23] There can be corner solutions ($\bar{t} = \hat{\tau}$) to the problem if $c_\tau(\hat{\tau}\,|\,\hat{\tau}) < b(\hat{\tau})$.

[24] 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

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.

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 τ is as follows:

1. Differentiate the expression of $E[V]$ in (1) with respect to both τ and consumption.
2. Particularize the first order condition of the optimal consumption problem (16) and group all terms containing $d\,c_\tau/d\,\tau$.
3. Differentiate the conditional intertemporal budget constraint with respect to τ and gather all the terms containing $d\,c_\tau/d\,\tau$.
4. Particularize the expression in step 3 into the general equation obtained in step 2. In this way we disposed of the term containing the consumption derivative, and we are left with a general analytical expression for optimal retirement.

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

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

where $\bar{t} = \bar{t}(\tau)$, $b = b(\tau)$; $b' = b'(\tau)$, $\bar{c}(.) = c_\tau(.|\bar{t})$, $d(t) = e^{(r-\delta)\,(t-t_0)}$, $\mathcal{A}(\hat{\tau},\bar{t}) = \int_{\hat{\tau}}^{\bar{t}} e^{-r\,t}\,dt$ and $\mathcal{A}_\delta(\bar{t},\overline{T}) = \int_{\bar{t}}^{\overline{T}} e^{-\tilde{\delta}(t)}\,dt$. When the pension system includes a guarantee minimum the expression becomes a bit more complicated:

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

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

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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.

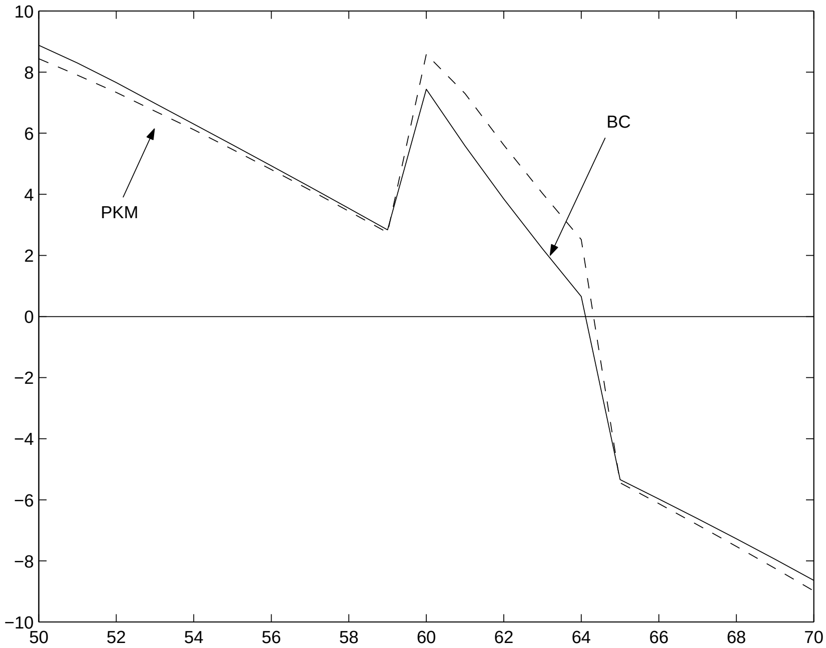

Figure 13: Marginal utility of working with (-) and without (- -) credit constraint. Representative (median) agent.

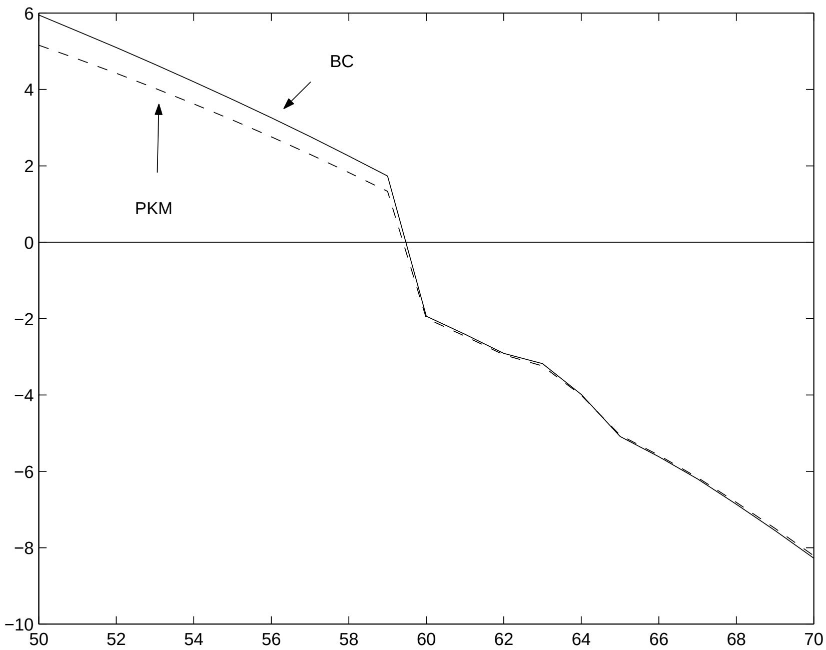

Figure 14: Marginal utility of working with (-) and without (- -) credit constraint. Agent in the 10% quantile of the income distribution.

C Optimal retirement with and without credit constraints

Figures 13 and 14 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 λ 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).

D 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*). 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 all the Special regimes but excludes Central Government employees.

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 from 1986 to 1995. The third file ("Benefits file") contains information on the SS benefits received by the individuals in the sample.

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 are not covered, that is, they do not generate any future right and, as such, are not reported in the CE file.

For each employment spell in the H file, we know the age, sex and marital status of the person (not reliable), the duration of the spell (in days), the type of contract (either part-time or 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 restrict our empirical analysis to the sample of male workers enroled in the General Regime in 1995, that have been working continuously from 1986 to 1994. Descriptive statistics of the variables employed are presented in table D. We refer to Boldrin et al. (2004) for a more detailed description of the variables in the HLSS files.

Table 4: Descriptive statistics

by education	Total		Edu high		Edu low	
# observations:	16359		1472		14887	
	mean	s.e.	mean	s.e.	mean	s.e.
%retiring	.122	.328	.0822	.274	.1268	.332
High education	.0899	.286	—	—	—	—
Age	58.90	2.96	59.28	3.33	58.86	2.92
Receipt temporary benefits	.3272	.469	.1637	.370	.343	.474
Years of contribution	31.4	5.72	31.76	5.53	31.44	5.73
Wage[a]	2.420	1.56	4.502	2.25	2.215	1.31
Benefit base[a]	2.17	1.02	3.553	1.17	2.030	.897
Theoretical Benefit[a]	1.33	.728	2.246	.947	1.244	.635
Effective benefit[a]	.627	.930	1.17	1.49	.5730	.835
by age group	55–59		60–64		65+	
# observations:	9970		5716		673	
	mean	s.e.	mean	s.e.	mean	s.e.
%retiring	.0342	.181	.206	.405	.7221	.448
High education	.0818	.270	.0970	.296	.1500	.357
Age	56.91	1.48	61.58	1.39	65.53	1.16
Receipt temporary benefits	.3118	.463	.3497	.476	.3655	.481
Years of contribution	29.85	5.25	33.90	5.40	34.69	6.27
Wage[a]	2.471	1.61	2.362	1.47	2.165	1.50
Benefit base[a]	2.169	1.03	2.192	.995	2.092	1.11
Theoretical Benefit[a]	1.178	.601	1.528	.770	2.007	1.12
Effective benefit[a]	—	—	1.558	.741	2.018	1.11

a: (in 10^6 1995 pta)

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 (log) 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 1986 and year 1995 $= T$ we impute the individual profile of "true" real earnings (w_t, $t = 1986, \ldots, 1995$). Given this information, we "smoothly" project earnings forward and backward in the following way:

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

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 β 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.

E Impact of minimum pensions on retirement

Table 5 provides detailed results of our main experiment: the comparison of the aggregate retirement distribution with and without the minimum pension scheme.

Table 5: Probability of retirement between ages t and t+1, f(t); cumulative probability, F(t); and retirement hazard, h(t), in two institutional environments: E1 (without minimum pensions) and E3 (with minimum pension). P3 denotes parameters estimated under economy E3.

age	f(E1,P3)	f(E3,P3)	F(E1,P3)	F(E3,P3)	h(E1,P3)	h(E3,P3)
55	0.011	0.017	0.0	0.0	0.011	0.017
56	0.020	0.027	0.011	0.017	0.020	0.028
57	0.040	0.043	0.030	0.045	0.042	0.045
58	0.061	0.063	0.071	0.088	0.066	0.069
59	0.083	0.083	0.132	0.151	0.095	0.097
60	0.066	0.180	0.215	0.233	0.085	0.234
61	0.072	0.071	0.282	0.413	0.100	0.121
62	0.096	0.082	0.353	0.484	0.149	0.160
63	0.116	0.093	0.450	0.567	0.211	0.214
64	0.115	0.091	0.566	0.659	0.265	0.267
65	0.264	0.179	0.681	0.750	0.825	0.717
66	0.018	0.023	0.944	0.929	0.326	0.322
67	0.013	0.016	0.962	0.952	0.338	0.331
68	0.009	0.012	0.975	0.968	0.381	0.371
69	0.006	0.008	0.985	0.980	0.390	0.383
70	0.015	0.020	0.991	0.988	1.0	1.0

F Welfare impact of minimum pensions

Definitions

Individual i-equivalent variation, θ_i, is the size of a parallel shift in his/her optimal consumption profile under the current system, c_i^{mp}, that makes him/her indifferent to the simultaneous (1) elimination of the minimum pension and (2) reduction in the contribution rate that keeps the average generosity constant. Formally:

$$V_i^{mp}(c_i^{mp}(1+\theta_i), \tau_i^{mp} \mid \varsigma^{mp}) = V_i^*(c_i^*, \tau_i^* \mid \varsigma^*)$$

where V_i^j, c_i^j, τ_i^j and ς^j stand for life-cycle utility, consumption, optimal retirement and contribution rate under system j. The current system ($j = mp$) includes real-world contribution rates and minimum pensions. In the alternative system $j = *$ minimum pensions are absent and contributions are reduced to ς^* (a rate that guarantees the same average generosity in absence of minimum pensions. We measure the average generosity under system j by the average internal rate of return: $\overline{r}^j = \int_i r(i)^j \, dP(i)$, with $P(i)$ denoting agent i measure. The $r(i)$ are defined in a standard way (the rates that match the expected discounted value of life cycle pension benefits and contributions).

Detailed calculations

The welfare calculation involves three steps:

1. To compute the current system's average internal rate of return $\overline{r}$ we partition the sample (active individuals aged 55 or older) according to the wage and educational levels. Each individual is then assigned a "type" i of the I possible observable groups. The empirical measure (weight) of each group is denoted μ_i. Recall than, on top of this observable heterogeneity, individuals differ in their unobservable relative value of leisure (implying different consumption paths and retirement ages for otherwise identical households). $\overline{r}_{mp}$ is then computed as follows:

   (a) We calculate $r_i^{mp}(\tau)$ $\forall i \in I$ and for each possible retirement age. This implies solving the following nonlinear equation:

   $$\sum_{a=20}^{\tau-1} S_a \frac{cot_a^i}{(1+r_i^{mp}(\tau))^a} = \sum_{a=\tau}^{\overline{T}} S_a \frac{b_a^i(\tau)}{(1+r_i^{mp}(\tau))^a}$$

   where cot_a^i stands for age-a contributions, $b_a^i(\tau)$ for pension income in case of retirement at τ and S_a is the probability of surviving to age a (conditional on surviving till age-20).

   (b) For each $i \in I$, we compute the retirement probabilities predicted at every age by our theoretical model, $P_i(\tau)$.

   We use them to find an internal rate of return that accounts for both observable and unobservable heterogeneity:

   $$\overline{r}_{mp} = \sum_{i=1}^{I} \mu_i \sum_{\tau=56}^{70} P_i(\tau)\, r_i^{mp}(\tau)$$

2. We work out the contribution rate (ς^*) that results in the same implicit average rate of return in absence of minimum pensions. We allow individuals to change their optimal consumption and retirement behavior during the process.

3. Finally, we compute the Equivalent Variation ($\overline{\theta}$) associated with the elimination of the minimum pension scheme, while keeping constant the average generosity of the pension system.

Table 6 presents the results obtained assuming the same parameter values implemented in the paper.[25] Table 7 shows that the results are very sensitive to the projected growth rate of the minimum pensions. If their historical growth rates (roughly in line with average wages) were to stay unchanged, their welfare impact would be much larger.

age	High Education			Average Education		
	Q 1/3	Q 2/3	Q 3/3	Q1/3	Q 2/3	Q 3/3
57.0000	2.5831	-0.1015	-0.1015	3.4899	-0.1017	-0.1017
58.0000	2.5387	-0.1021	-0.1021	3.4280	-0.1024	-0.1024
59.0000	2.4966	-0.1027	-0.1027	3.3692	-0.1030	-0.1030
60.0000	2.4568	-0.1032	-0.1032	3.3133	-0.1035	-0.1035
61.0000	-0.1016	-0.1016	-0.1016	-0.0923	-0.1020	-0.1020
62.0000	-0.1009	-0.1009	-0.1009	-0.1013	-0.1013	-0.1013
63.0000	-0.0999	-0.0999	-0.0999	-0.1003	-0.1003	-0.1003
64.0000	-0.0997	-0.0997	-0.0997	-0.1001	-0.1001	-0.1001
65.0000	-0.0990	-0.0990	-0.0990	-0.0995	-0.0995	-0.0995

Table 6: Compensated equivalent variation by age of retirement, education and wage level (positive signs indicates welfare gains)

age	High Education			Average Education		
	Q 1/3	Q 2/3	Q 3/3	Q1/3	Q 2/3	Q 3/3
58.0000	13.5220	-0.2308	-0.2308	13.9952	-0.2314	-0.2314
59.0000	13.4186	-0.2321	-0.2321	13.7802	-0.2328	-0.2328
60.0000	13.2362	-0.2334	-0.2334	13.6807	-0.2341	-0.2341
61.0000	7.7155	-0.2298	-0.2298	8.8084	-0.2306	-0.2306
62.0000	3.3081	-0.2281	-0.2281	4.1861	-0.2289	-0.2289
63.0000	0.2378	-0.2258	-0.2258	0.9270	-0.2267	-0.2267
64.0000	-0.2222	-0.2254	-0.2254	-0.2142	-0.2263	-0.2263
65.0000	-0.2239	-0.2239	-0.2239	-0.2249	-0.2249	-0.2249

Table 7: Compensated equivalent variation projecting historical growth rates of minimum pensions

[25] We consider 2 educational types and 3 labor earnings-quantiles.

G Heterogenous discount factor

To calibrate the empirical dispersion of the discount factor we proceed as follows:

(i) We summarize the empirical evidence about assets (financial and real) and labor earnings by age in the EFF-02 data via a set of parametric models. In particular, we estimate quantile regressions of the value of accumulated assets on labor income, a logit model of the probability of having no wealth as a function of labor earnings and quantile regressions of labor earnings on age.

(ii) We obtain from our life-cycle model a theoretical prediction of the value of accumulated assets and labor earnings at any particular age, conditional on an underlying discount factor δ: $a = a(\delta|\, i, w)$.

(iii) We make a *revealed preference* exercise: by inverting the function above we can always find a value of the discount factor that rationalizes any pair of observed assets holdings and wages at any particular age. Proceeding in this way we transform the empirical information in (i) into an estimation of the quantiles of the population distribution of the unobserved degree of time preference. The resulting kernel density estimates (by wage level) are illustrated in figure 15

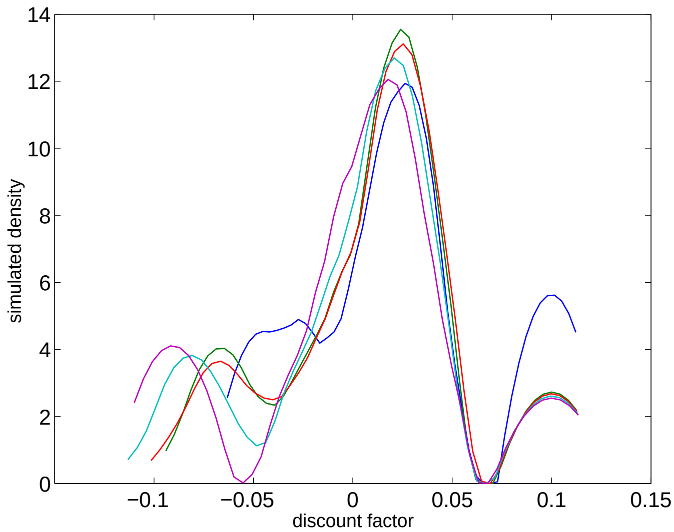

Figure 15: Estimated distribution of the discount factor: Kernel estimation from *revealed* discount factors in EFF-02 for labor income quantiles (5, 25, 50, 75 and 95).

Once equipped with a distribution of δ we can proceed to simulate the incidence of early retirement in presence of credit constraints. To undertake this experiment in a context where the role of borrowing restrictions is enhanced in as much as the life-cycle framework makes possible, we avoid using the long term predictions of the model. Instead, we predict aggregate retirement in the cross section of the EFF-02 by solving a "*current*" version of the model: we solve the model from the age each individual is observed onwards, taking into account the available information on current wages and assets. This, and the use of data from 2002, force us to introduce some changes with respect to the calibration of the benchmark model: (1) Social Security parameters are those in effect in 2002, (2) we account for observable heterogeneity in wages and accumulated assets as described in point (i), but abstract from differences in education, (3) unobservable heterogeneity in leisure preference is Normally distributed, with variance calibrated to reproduce the incidence of early retirement in the data, and (4) a value of the unobservable δ is assigned to each pair of wages an assets considered by using the *revealed preference* procedure.

The retirement probability at age i for an individual with observables characteristics (w, a) is $P_i(a, w) = \Phi[\phi(i, a, w|\, \delta(a, w))\, |\sigma] - \Phi[\phi(i+1, a, w)|\, \delta(a, w)\, |\sigma]$, where $\phi(i, a, w|\delta)$ is the marginal utility of staying active at age i for an individual with accumulated assets a, labor income w and discount factor δ, and $\Phi(.\, |\sigma)$ is the Normal CDF with standard deviation σ. The aggregate incidence of retirement at age i is then $P_i = \int_{w,a} P_i(w, a)\, dF(w, a)$, with F the calibrated joint distribution of wages and assets. Table

Age	With MP	Without MP	With MP	Without MP
56	0.1484	0.1486	0.0347	0.0301
57	0.1541	0.1542	0.0837	0.0503
58	0.1577	0.1578	0.1775	0.0639
59	0.1614	0.1614	1.0682	0.7307
60	0.2673	0.194	0.0488	0.0185
61	0.0136	0.0116	0.0508	0.0231

Table 8: Simulated retirement hazard in the economy with heterogeneous discount factor. Model predictions with and without minimum pensions.