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ARTICLE

Heterogeneity in longevity, redistribution, and pension reform

Julián Díaz-Saavedra

Department of Economic Theory and History, Universidad de Granada, Granada, Spain
Corresponding author. Email: julianalbertodiaz@ugr.es

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Abstract
The gap in the life expectancy of the elderly across educational groups is high, and this will probably increase over the coming decades. In this article, we use a computable overlapping generations model economy to show that the long-term link between heterogeneity in longevity and education could translate into an implicit tax/subsidy on the expected lifetime benefits to lifetime payroll taxes ratio, with rates around 10%, and that such rates pervert redistributive objectives of pension systems. We then analyze some parametric changes aimed at restoring the progressiveness of these systems in the long run, and find that a higher minimum pension or changes in the pension benefit formula go a long way as tools to restore the system's long-term progressivity.

Key words: Computable general equilibrium; redistribution; social security reform

JEL classification: C68; H55; H23

1. Introduction

There is significant heterogeneity in the life expectancy of the elderly, as more-educated people enjoy longer life expectancies than their less-educated counterparts.[1] Moreover, and according to Bound *et al.* (2015), this gap in the life expectancy of the elderly has been increasing over recent decades. This situation could prove problematic, since this increasing gap in life expectancy can undermine the progressiveness of some tax and transfer programs, as first suggested by Breyer (1997). Then, and in order to avoid this, it has been suggested several pension policies that differentiate between socioeconomic groups.[2] However, the use of explicit socioeconomic indicators is problematic because of within-group differentials, as suggested by Sheehan *et al.* (2018), Chetty *et al.* (2016), and Pestieau and Racionero (2016), among others.

Against this background, this paper analyzes to what extent parametric pension reforms that do not differentiate between socioeconomic groups may restore pension income redistribution in the long run. We assume a projected long-term demographic scenario characterized by longer lifespans and an increased education mortality gradient, and we evaluate pension policies through key dimensions – efficiency, inequality, and welfare – in order to shed light on whether or not there is a trade-off between them. We do this by comparing a steady-state benchmark allocation with steady-state allocations of economies that differ in pension rules. We study these reforms one at a time to explore which reform is quantitatively more important.

[1]See, for example, Kitagawa and Hauser (1973), and Murtin *et al.* (2017).

[2]See Ayuso *et al.* (2016).

To do this, we use a life-cycle general equilibrium model of labor supply and retirement, where *ex ante* educationally heterogeneous workers face idiosyncratic labor income risk. Our model economy is an enhanced version of the general equilibrium, multi-period, overlapping generations model economy populated by heterogeneous households, described in Díaz-Saavedra (2020), which differ in age, education and employment status, and, consequently, in income, wealth, pension rights, and pensions, and they decide optimally how much to work, consume, and save and when to retire. However, the model economy that we study here differs from the one used in that article in certain important features. First, mortality risk depends on age and education. This is a crucial assumption if we intend to quantify both how much the long-term progressiveness of pension systems is undermined when there are gaps in life expectancy of the elderly across educational groups, and how parametric changes can restore that progressiveness. Second, unemployment risk also depends on age and education. This is important because, as low-educated workers face a greater unemployment risk, particularly late in their working lives, their earnings-based pension entitlements at the moment of retirement may be significantly affected. Third, and related to this, unemployed households receive unemployment benefits temporarily. It is important to include limited unemployment insurance in the model, since restricting access to unemployment benefits may also have an unintended consequence on the probability of not fulfilling vesting period conditions.

Our quantitative experiments rely on the Spanish social security system since Spain is a fairly extreme case of the aforementioned demographic tendencies, because even though the gains in longevity over past decades have benefited the entire population, some groups have benefited more than others. For instance, according to Permanyer *et al.* (2018), the average life expectancy at age 35 increased 6.9 years for less-educated individuals, from 39.9 years in 1960 to 46.8 years in 2012. However, for highly educated individuals, the increase was larger: 9.0 years, from 41.2 to 50.2 years, over that same period. Consequently, the gap in life expectancy at age 35 between university graduates and school dropouts increased by more than 2 years over the period examined, since this difference rose from 1.3 to 3.4 years. Moreover, if this trend continues over the coming decades, life expectancy at age 35 in 2060 will be 52.2 years for dropouts, and 58.4 years for university graduates. Thus, the gap in life expectancy by educational type would continue to increase steadily, and the difference in this variable between university graduates and dropouts could increase to 6.2 years over the next four decades.

Our simulation results, summarized in Section 6, show that: (i) the current gap in life expectancy utterly reverses the progressiveness of the Spanish retirement pension program. Our results show that the expected lifetime-benefits-to-lifetime-payroll-taxes ratios of high school and college workers are 2% and 6% higher than that same ratio for the case of dropouts. Moreover, if the growing trend in lifetime gaps continues over the coming decades, these numbers will be 4% and 9% by 2060; (ii) a direct way to recover the progressiveness of Spanish social security is by increasing the minimum pension, since this parametric change increases the lifetime benefits of low-educated households, which is precisely the socioeconomic group that proportionally receives this type of guaranteed minimum the most. However, concerns about the long-term pension system's sustainability and the possible reduced ability of governments to increase public revenues may make this choice non-viable; (iii) eliminating the cap on the payroll tax as a tool to improve progressiveness may have rather limited effects. Moreover, it would not solve social security's financial shortfalls, besides imposing economically damaging marginal tax rates on upper-income earners. As in the case of increasing the guaranteed minimum retirement pension, this parametric reform ends up with reduced output and welfare losses for different socioeconomic groups; (iv) changes in the penalties and/or bonuses related with early and late retirement may not induce a significant change in the progressiveness of the pension system, as these changes could encourage an earlier exit from the labor market, which on the other hand increase lifetime benefits across different socioeconomic groups; and (v) increasing the number of periods of labor income used to compute the pension may have several positive aggregate effects, besides somehow increasing pension progressiveness, such as improving the pension system's sustainability, and increasing work hours, saving rates, and output. However, more importantly, a reform that combines this policy change with an increase in the minimum pension would fully restore the system's long-term progressivity in pensions, in addition to reducing the long-term financial imbalance of the system, and delivering welfare gains.

Two final comments are reported, both of which are related to the link between employment risk and education. First, as with previous research papers, we continue to find that an increase in the probability of losing a job reduces pension entitlements at retirement (see, e.g., Bravo and Herce, 2020). On the other hand, we also find that payroll taxes paid throughout working lifetime also decrease, since the number of periods where there is no obligation to contribute to social security increases. Consequently, our results show that the fact that employment risk varies across educational groups does not have a significant effect on pension income redistribution. Second, social security policies have a mitigating effect on losses in pension entitlements brought about, for instance, from spells of unemployment. In the case of Spain, these unlisted periods are integrated with fictitious estimates, so that an increase in the amount of these estimates should, *ex ante*, benefit those who face higher unemployment rates, e.g., less-educated workers. Our results confirm this conjecture but we also find that the effect of increasing these fictitious quotes on pension redistribution is somewhat limited.

Much of the literature uses life cycle models to study the aggregate effects of parametric reforms on social security systems, which we build on (see, e.g., Conesa and Krueger, 1999; De Nardi *et al.* 1999; Imrohoroglu and Kitao, 2012). In contrast, Gustman and Steinmeier (2001) and Coronado *et al.* (2002) are two of the relatively few studies that focus on the redistributionary consequences of alternative social security reforms, although these studies do not analyze how redistribution might change as the gap in life expectancy increases. However, the papers most similar to ours are Fehr *et al.* (2012, 2013) and Laun *et al.* (2019). Fehr *et al.* (2012) study the macroeconomic and welfare consequences of different pension reforms on the German public pension. To do so, they use a life-cycle general equilibrium model of labor supply and retirement, populated by *ex ante* educationally heterogeneous households with different life expectancies, to study, first, a pension reform in Germany that increases the normal retirement age by two years. Despite finding that this reform delays the effective retirement by about one year, they also find that a more effective way to delay retirement may be achieved by raising the actuarial adjustment of pension benefits.

Subsequently, Fehr *et al.* (2013), in a setup which is very similar to the present paper, study the consequences of rising pension progressivity in Germany. At this point, their model economy introduces idiosyncratic earnings risk, and also disability risk. Starting from the current German public pension system, which is purely earnings related, they increase the degree of progressivity and compute the optimal mix between flat and earnings-related pensions, and they find that a flat-rate pension share of 30% maximizes aggregate economic efficiency, as defined by Auerbach and Kotlikoff (1987). In our paper, however, we take the implicit redistribution of the Spanish system as an objective to be maintained, in a qualitative way, over the coming decades, despite the increase in the lifetime gap. Finally, another difference between our work and the paper by Fehr *et al.* (2013) is that our quantitative experiments involve comparing a steady-state benchmark allocation with steady-state allocations of economies that differ in pension rules, while Fehr *et al.* (2013) compute a full transition path of the economy up to a new long-run equilibrium.

Finally, Laun *et al.* (2019) study how the Norwegian pension system could be reformed to achieve fiscal stability in the face of increasing longevity, with a focus on how redistribution might change as the gap in life expectancy and health increases. Specifically, Laun *et al.* (2019) use a dynamic, structural life-cycle model of heterogeneous agents who face health, mortality, and income risk, to analyze four pension reforms designed to achieve fiscal sustainability for the Norwegian pension system: increasing the early retirement age, raising income tax rates, reducing pensions, and reducing pension and disability benefits. They find that this last pension reform results in the highest average welfare and the lowest degree of inequality.[3] We emphasize the importance of including heterogeneous employment risk in the analyses of pension progressiveness, in order to estimate the impact of

[3]Related papers are those of Liebman (2002) and Goda *et al.* (2011), who use microsimulation models to show that differential mortality reduces the progressiveness of the US Social Security System.

unemployment spells on pension benefits. Thus our paper is also related to a recent branch of the literature that quantifies how employment breaks influence pension benefits. See Peinado and Serrano (2017), and Bravo and Herce (2020).

The paper is organized as follows: Section 2 presents some stylized facts between education and longevity; Section 3 describes our benchmark model economy; Section 4 shows the calibration results; Section 5 describes in detail the policy experiments; Section 6 presents the results; and, lastly, Section 7 concludes.

2. Stylized facts

One of the key factors that generate lifetime differences across socioeconomic groups is educational attainment. Specifically, less-educated individuals tend to live shorter lives than their highly educated counterparts (see, e.g., Cutler *et al*., 2011; Pijoan-Mas and Rios-Rull, 2014). Table 1 presents estimates of life expectancy (LE) at age 65, and shows that the higher the educational level the greater the LE. The difference in the average LE for men between the middle and low levels of education is 1.3 years, while it is 2.9 years between the highly educated and less educated groups.[4] This table also shows significant differences between countries, since Finland has much lower differences between groups in comparison to, for instance, Austria.

Moreover, there is growing evidence that the LE gap as measured by education or other socioeconomic characteristics has been widening in recent decades. For instance, Meara *et al.* (2008) compare remaining LE at age 25 for US college men to that of men who have attained high school or less in 2000. They find that for white men the difference was 7.4 years, and that this difference had increased by 2 years since 1990. Other studies also reported diverging trends in LE across socioeconomic groups, with the socially advantaged benefiting more than the rest. Thus is the case for Norway, according to Steingrímsdóttir *et al.* (2012), and for Belgium as reported by Deboosere *et al.* (2009). Finally, Bronnum-Hansen and Baadsgaard (2012) and Tarkiainen *et al.* (2012) find similar patterns for Denmark and Finland.

Furthermore, in the case of Spain, Permanyer *et al.* (2018) report LE differences according to educational attainment that are both strikingly wide and increasing, and this is shown in Figure 1.[5] This figure shows how average LE at age 35 for three educational categories have evolved over time. LE at age 35 increased 6.9 years for less-educated individuals, from 39.9 years during the period 1960–1969, to 46.8 years for the period 2012–2015. However, for highly educated individuals the increase was larger: 9.0 years, from 41.2 to 50.2 years, during that same period. Consequently, the gap in LE at age 35 between college graduates and school dropouts increased more than 2 years over the period examined, since this difference rose from 1.3 to 3.4 years. Thus, these numbers also show that in Spain LE has been increasing for all educational groups but particularly among the highly educated.

What will those differences would be like in the coming decades, if continuing this growing trend in lifetime gaps? This is shown in panel A in Figure 2, where we have extrapolated current tendencies on life expectancies at age 35 by educational type over the coming decades. Panel A shows that, under this assumption, LE at age 35 in 2060 will be 52.2 years for dropouts, 56.1 years for high-school graduates, and 58.4 years for college graduates. Consequently, panel B shows that the gap in LE by educational type would continue to increase steadily, and that the difference in this variable between high-school graduates and dropouts would increase from 2.1 years in 2012 to 3.9 years in 2060, and from 3.43 to 6.19 years during the same period for the case of college graduates and dropouts.

[4]Majer *et al.* (2011) also report that the average differences in LE were smaller in the case of women. Specifically, these numbers were 1.3 and 1.9 respectively.

[5]Permanyer *et al.* (2018) compute life expectancies at age 35 by gender and educational attainment for four periods: 1960–69, 1970–79, 1980–89, and 2012–15. They also classify educational attainment in four categories: individuals with less than primary education, and those with primary, secondary, and university education. In our case, we include the first two groups within dropouts, secondary education within high school, and university education within college.

Table 1. Life expectancy at age 65 by educational type (men)

	High	Middle	Low	ΔH-L[a]	ΔM-L[b]
Finland	15.7	14.6	14.2	1.5	0.3
Denmark	15.8	14.5	13.8	2.1	0.7
Ireland	17.8	16.0	14.1	3.7	1.9
Austria	17.5	16.3	13.6	3.8	2.7
Belgium	16.2	15.2	13.4	2.8	1.8
Greece	19.2	17.2	15.8	3.4	1.4
Italy	19.0	15.3	16.7	2.3	−1.3
France	19.4	18.5	16.4	3.0	2.1
Spain	19.4	18.4	16.4	2.9	2.0
Portugal	18.7	16.7	14.8	3.8	1.9
Average	17.9	16.7	14.9	2.9	1.3

[a]Difference between high and low (years).
[b]Difference between middle and low (years).
Source: Majer *et al*. (2011).

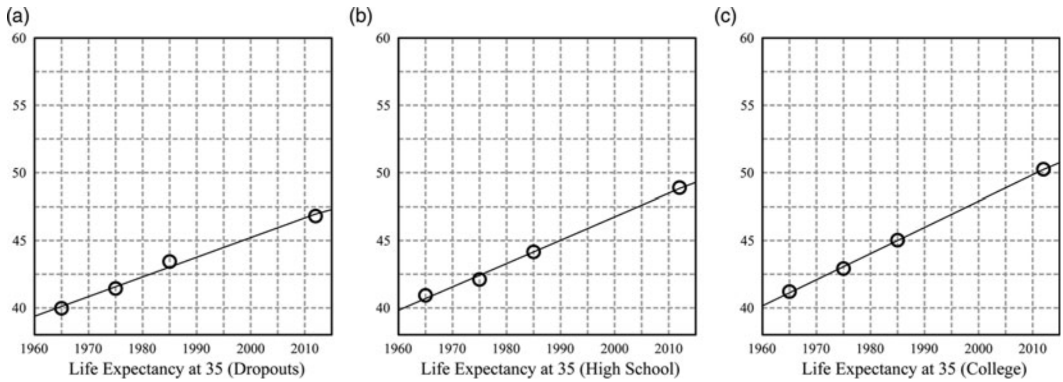

Figure 1. Life expectancy at age 35 in Spain (years, average for men and women).
Source: Own elaboration based on Permanyer *et al*. (2018).

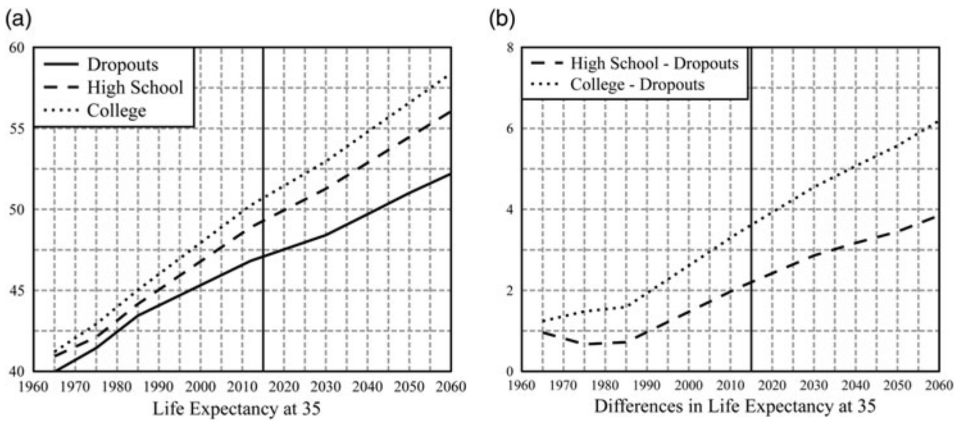

Figure 2. Projected life expectancy at age 35 in Spain (years, average for men and women).
Source: Own elaboration based on Permanyer *et al*. (2018).

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3. The model economy

This section presents the baseline model economy. We study an overlapping generations model economy with heterogeneous households, a representative firm, and a government, which we describe in turn.

3.1 The households

Households in our baseline economy are heterogeneous and differ in their age, $j \in J$; in their education, $h \in H$; in their labor market status, $e \in \mathcal{E}$; in their pension rights, $b \in B$; in their pension, $p \in P$; and in their assets, $a \in A$. Sets J, H, $\mathcal{E}$, B, P, and A are all finite sets and we use $\mu_{j,h,e,b,p,a}$ to denote the measure of households of type (j, h, e, b, p, a). We think of a household in our model as a single individual, even though we use the two terms interchangeably. To calibrate the model, we use individual data of persons older than 20 in the Spanish economy.

Age. Individuals enter the economy at age 20, the duration of their lifetimes is random, and they exit the economy at age 100 at the latest. Therefore $J = \{20, 21, \dots, 100\}$. The parameter ψ_{jh} denotes the conditional probability of surviving from age j to age $j+1$, for those households with educational level h.

Education. Households can either be high school dropouts with $h = 1$, high school graduates who have not completed college $h = 2$, or college graduates denoted $h = 3$. Therefore $H = \{1, 2, 3\}$. A household's education level is exogenous and determined forever at the age of 20.

Labor market status. Households in our economy are either employed, unemployed eligible for benefits, unemployed non-eligible, or retired. We denote workers by ω, eligible unemployed by ϖ, non-eligible unemployed by υ, and retirees by ρ. Consequently, $\mathcal{E} = \{\omega, \varpi, \upsilon, \rho\}$. Upon entering the economy, individuals draw a job opportunity. In subsequent years, the labor market status evolves according to exogenous job separation and job finding rates, and also to the optimal retirement decision.

Workers. A worker provides labor services and receives a salary that depends on his endowment of efficiency labor units and his hours worked. This endowment has two components: a deterministic component, which we denote by ϵ_{jh}, and a stochastic component, which we denote by s.

The deterministic component depends on the household age and education, and we use it to characterize the life-cycle profiles of earnings. We model these profiles using the following quadratic functions:[6]

$$\epsilon_{jh} = a_{1h} + a_{2h}j + a_{3h}j^2. \tag{1}$$

We choose this functional form because it allows us to represent the life-cycle profiles of the productivity of workers in a very parsimonious way.

The stochastic component is independently and identically distributed across the households, and we calibrate it to match moments of the Spanish earnings and wealth distribution, following Castañeda *et al.* (2003). This component does not depend on the age or the education of the households, and we assume that it follows a first order, finite state, Markov chain, with invariant distribution given by $\pi(s)$, and with conditional transition probabilities given by Γ:

$$\Gamma[s'|s] = \Pr\{s_{t+1} = s'|s_t = s\}, \text{ with} s, s' \in S. \tag{2}$$

We assume that the process on s takes three values and, consequently, that $s \in S = s_1, s_2, s_3$. We make this assumption because it turns our that three states are sufficient to account for the Lorenz curves of the Spanish distributions of income and labor earnings in enough detail, and because we want to keep this process as simple as possible.

[6]In the expressions that follow the letters a denote parameters.

Every period agents receive a new realization of s. His labor productivity is then given by $\epsilon_{jh}s$. A worker with education h and age j who supplies l hours of labor has gross labor earnings y^l given by:

$$y^l = w\epsilon_{jh}sl, \tag{3}$$

where the economy-wide wage rate w.

Workers face a probability of losing their job at the end of the period, denoted φ_{jh}. This probability is education and age dependent, and we use it to generate the observed labor market flows between employment and non-employment states within age cohorts. We model these profiles using the following functions:

$$\varphi_{jh} = a_{4h} + a_{5h}j + a_{6h}j^2 + a_{7h}j^3. \tag{4}$$

Unemployed. Eligibility for unemployment benefits is conditional on having lost a job during the previous 2 years and not having started a new job yet. Eligibility expires when one of the conditions is not met. An eligible agent with education h receives unemployment benefits given $y^u = \vartheta y_h^{\bar{l}}$, where $y_h^{\bar{l}}$ is the average labor earnings of those workers with education h, and where $\vartheta < 1$ is a replacement rate.

At the end of each period, an unemployed receives a job offer with probability ξ_{jh}. This probability is also education and age dependent, and we use it to generate the observed labor market flows between unemployment and employment. The offer is the productivity shocks. Therefore, its amount is either s_1, s_2, or s_3. Conditional on receiving an offer, the probability of receiving each one of the productivity shocks is the unconditional probability of each realization of that shock. Once a household is re-employed, the future values of s are determined by the process on s.

We model the probabilities to receive a job offer as:

$$\xi_{jh} = a_{8h} + a_{9h}j + a_{10h}j^2 + a_{11h}j^3. \tag{5}$$

Retirees. Workers who are R_0 years old or older decide whether to retire and collect the retirement pension. They take this decision after observing their current labor productivity. If they decide to retire, they lose the endowment of labor efficiency units forever and exit the labor market. Unemployed households who are R_0 years or older are forced to retire.

Pension rights. Workers and unemployed also differ in the pension rights. These rights are used to determine the value of their pensions when they retire. The rules of the pension system, which we describe below, include the rules that govern the accumulation of pension rights, and the rules that determine the mapping from pension rights into pensions. In our model economy households take this mapping into account when they decide how much to work and when to retire. We assume that pension rights belong to the discrete set $B = \{b_0, b_1, \ldots, b_m\}$, that $m = 9$, and that the spacing between points in set B is increasing. We also assume that $b_0 = 0$, and that $b_m = a_{12}y$, where $a_{12} > 1$, y is the model economy per capita output, measured at market prices, and $a_{12}y$ is the maximum covered earnings, following the Spanish public pension system.

Pensions. Retirees differ in their retirement pensions. We assume that retirement pensions belong to the set $P = \{p_0, p_1, \ldots, p_m\}$. Since this mapping is single valued, and the cardinality of the set of pension rights, B, is 10, we let $m = 9$ also for P. We also assume that $p_0 = a_{13}y$, and that $p_m = a_{14}y$, where p_0 and p_m are the minimum and maximum retirement pensions, in accordance with the Spanish public pension system. Finally, we also assume that the distances between any two consecutive points in P are increasing. We make this assumption because minimum pensions play a large role in the Spanish system and this suggests that we should have a tight grid in the low end of P.

Assets. Households in our model economy differ in their asset holdings, which are constrained to being non-negative. The absence of insurance markets gives the households a precautionary motive to save. They do so by accumulating real assets which take the form of productive capital, denoted $a \in A$.[7]

[7]An important feature of the model is that there are no insurance markets for the stochastic component of the endowment shock nor for unemployment risk.

Preferences. Households derive utility from consumption, c, and disutility from labor effort, l, where labor is decided both at the extensive and intensive margins. The period utility is described by a utility flow from consumption and leisure, $u(c, 1-l)$. Unemployed and retired agents dedicate all the time endowment to leisure consumption. Accordingly, lifetime utility is given by

$$\mathbb{E}\sum_{j=20}^{100}\beta^{j-20}\psi_{jh}[\log(c)+\chi\frac{(1-l)^{1-\gamma}}{1-\gamma}], \tag{6}$$

where β is a time discount factor, c is consumption, χ is the relative utility weight on leisure, and γ is the labor elasticity.

3.2 The representative firm

In our model economy there is a representative firm. Aggregate output, Y, is obtained combining aggregate capital, K, with the aggregate labor input, L, through a Cobb–Douglas, aggregate production function which we denote by $Y = K^{\theta}L_t^{1-\theta}$. We assume that factor and product markets are perfectly competitive and that the capital stock depreciates geometrically at a constant rate, which we denote by δ.

3.3 The government

The government in our model economy taxes capital income, household income, and consumption, and it confiscates unintentional bequests. It uses its revenues to consume, and to make transfers to households other than pensions. In addition, the government runs a pay-as-you-go pension system. The consolidated government and pension system budget constraint is

$$G+Z+P+U = T_k + T_y + T_c + T_s + E. \tag{7}$$

On the expenditure side, G denotes government consumption, Z denotes government transfers other than pensions, P denotes pensions, and U denotes unemployment benefits, and, in the revenue side, T_k, T_y, and T_c, denote the revenues collected by the capital income tax, the household income tax, and the consumption tax, T_s denotes the revenues collected by the payroll tax, and E denotes unintentional bequests. Finally, we assume that the government uses the consumption tax rate to clear the government budget.[8]

3.3.1 The fiscal policy

Expenditures. We assume that the amount of government consumption is given by $G = a_{15}Y^*$, where Y^* is the model economy output at market prices. Transfers other than pensions are delivered to those households whose income is below a minimum income level, $\underline{y} = a_{16}y$. In this case, these households receive a transfer from the government, denoted by $t_r = \underline{y}$. We already defined unemployment benefits, and we describe pension expenditures in the next section.

Revenues. We assume that the proportional capital income and consumption tax rates are given by τ_k, and τ_c. Moreover, we assume that the assets that belong to the households that exit the economy are confiscated by the government. To model the household income tax, we use the following function:

$$\tau_y(y_t^b) = a_{17}\{y_t^b - [a_{18} + (y_t^b)^{-a_{19}}]^{-1/a_{19}}\}, \tag{8}$$

where y_t^b is the income tax base. This expression, where a_{17}, a_{18}, and a_{19} are parameters, is the function

[8]We also assume that there is no Pension Reserve Fund. This is because the stock of assets of this fund only represented 0.4% of GDP at the end of 2018, which is our calibration target year.

chosen by Gouveia and Strauss (1994) to model effective personal income taxes in the United States, and it is also the functional form chosen by Calonge and Conesa (2003) to model effective personal income taxes in Spain.[9] Finally, we describe payroll taxes in the next section.

3.3.2 The pension system

In our benchmark model economy we choose the payroll tax and the pension system rules so that they replicate as closely as possible the *Régimen General de la Seguridad Social* of the Spanish pay-as-you-go pension system in 2018, which is our calibration target year. See Díaz-Saavedra (2020) for a description of the Spanish public pension system.

Payroll taxes. In our model economy, as in Spain, the payroll tax is capped and workers older than the full entitlement retirement age, which we denote by R_1, are exempt from paying payroll taxes. Specifically, the payroll tax function is the following:

$$t_s(y^l) = \begin{cases} 0 & \text{if } j > R_1 \\ \text{otherwise} & \begin{cases} \tau_{ss} y^l & \text{if } y^l < \bar{y}^l \\ \tau_{ss} \bar{y}^l & \text{otherwise} \end{cases} \end{cases}, \tag{9}$$

where parameter τ_{ss} is the payroll tax rate and $\bar{y}^l = b_m = a_{12} y$ is the maximum covered earnings. Finally, we also assume that eligible unemployed also pay social security contributions, so that the payroll tax function becomes $t_s(y^u) = \tau_{ss} y^u$.

Retirement ages. In our model economy the early retirement age is R_0. Workers who choose to retire early pay a penalty, λ_j, which is determined by the following function

$$\lambda_j = \begin{cases} a_{20} - a_{21}(j - R_0) & \text{if } j < R_1 \\ 0 & \text{if } j \geq R_1 \end{cases}, \tag{10}$$

where a_{20} and a_{21} are parameters which we choose to replicate the Spanish early retirement penalties.

Retirement pensions. A household of age $j \geq R_0$, that chooses to retire, receives a retirement pension, $p(b)$, which we compute following the Spanish pension system rules. The main component of the retirement pension is its *regulatory base*, *RB*, which averages labor earnings up to the maximum covered earnings, during the last $N_b = 21$ years prior retirement. If a household has not reached the full entitlement retirement age, its pension is subject to an early retirement penalty. If the household is older than R_1, its pension claims are increased by 3% for each year worked after this age. The regulatory base is multiplied by a pension replacement rate, ϕ, which we use to replicate the pension expenditures to output ratio. Finally, retirement pensions are bounded by a minimum and a maximum pension.

Note that the regulatory base takes into account a long period of time. Consequently, it can be relatively frequent that contribution gaps occur; that is, periods to be taken into account to determine the amount of the pension in which the household does not credit any contribution. This is the case, for instance, of non-eligible unemployed. In order to mitigate the negative effects of these gaps, the Spanish pension rules established that these unlisted periods will be integrated with fictitious quotes. In our model economy, we assume that these fictitious quotes are $y^{fq} = a_{22} y$.

[9]Additionally, Guner *et al.* (2014) conclude that this functional form generates a better statistical fit for average tax rates, in comparisons to other alternatives.

In our benchmark model economy we calculate the retirement pensions using the following formula:

$$p(b) = \phi(1.03)^{v}(1-\lambda_j)RB, \tag{11}$$

where ϕ denotes the replacement rate, and v denotes the number of years that the worker remains in the labor force after reaching the full entitlement retirement age. The regulatory base, RB, is exactly equal to the pension rights at the time of retirement. Consequently, it is defined as:

$$RB = \frac{1}{N_b}\sum_{s=j-N_b}^{j-1}\min\{y_s^l, \bar{y}^l\}. \tag{12}$$

Note that labor earnings, y_s^l, is replaced by y_s^u or y_s^{fq} in the case of eligible or non-eligible unemployed households (see below). Expressions (11) and (12) replicate most of the features of Spanish retirement pensions. The main difference is that in our model economy the pension replacement rate is independent of the number of years of contributions. We abstract from this feature of Spanish pensions because it requires an additional state variable. Finally, we require that $p_0 \leq p(b) \leq p_m$.

3.4 The households' decision problem

Individuals with education h are heterogeneous in five dimensions $x = \{j, e, b, p, a\}$, where j is age, e is employment status, b is pension rights, p is pensions, and a is private savings. The households' problem is described recursively. Let $V_h(x)$ be the value function of an individual with education h in state x.[10]

Workers. We start with employed individuals that are younger than the minimum retirement age, specifically $j < R_0$. In this way we can abstract, for now, from the retirement decision. An individual of education level h, with age j, stochastic productivity s, pension rights b, and private savings a, faces the following optimization problem:

$$\begin{aligned} V_h(j, s, b, a) = \; & \max_{(c,l,a')}\{u(c, 1-l) + \beta E[(1-\varphi_{jh})\textstyle\sum_{s'\in S}\Gamma(s'|s)V_h(j+1, s', b', a') \\ & +\varphi_{jh}V_h(j+1, \varpi, b', a')]\} \end{aligned} \tag{13}$$

subject to

$$(1+\tau_c)c + a' = y^l + (1 + r(1-\tau_k))a - t_s(y^l) - \tau_y y^b + I_{t_r},$$

where $y^b = (1-\tau_k)ra + y^l - t_s(y^l)$ is the income base of the personal income tax, and I_{t_r} is an indicator function that takes value 1 if households are eligible for public transfers other than pensions. In addition, the law of motion of pension rights is:

$$b' = \begin{cases} 0 & \text{if} \quad j < R_0 - N_b \\ b + (\min\{y^l, \bar{y}^l\}/N_b) & \text{if} \quad R_0 - N_b \leq j < R_0, \\ [b(N_b - 1) + \min\{y^l, y^{\bar{l}}\}]/N_b & \text{if} \quad j \geq R_0. \end{cases} \tag{14}$$

[10]When the household is not a retiree, we drop the variable describing retirement pensions, p. Conversely, when the household is a retiree, with drop the variable describing pension rights, b.

Eligible unemployed. A household currently unemployed and eligible for unemployment benefits, aged $j < R_0$, solves the following problem:

$$V_h(j, \varpi, b, a) = \max_{(c,a')} \{u(c, 1)\beta E[\xi_{jh} \textstyle\sum_{s\in S} \pi(s) V_h(j+1, s, b', a') + (1-\xi_{jh}) V_h(j+1, u', b', a')]\} \quad (15)$$

subject to

$$(1+\tau_c)c + a' = y^u + (1 + r(1-\tau_k))a - \tau_s(y^u) - \tau_y y^b,$$

where $y^b = (1-\tau_k)ra$ and u' is ϖ if the current period is the first period that the unemployed collects unemployment benefits, and u' is υ if it is the second period. Note that eligible unemployed households do not receive public transfers other than pensions, since we assume that unemployment benefits are well above the minimum income level $\underline{y}$, which entitles families to receive these public transfers.

The law of motion for pension rights is in this case:

$$b' = \begin{cases} 0 & \text{if} \quad j < R_0 - N_b \\ b + (y^u/N_b) & \text{if} \quad R_0 - N_b \le j < R_0. \end{cases} \quad (16)$$

Non-eligible unemployed. A household currently unemployed and non-eligible for unemployment benefits, aged $j < R_0$, solves the following problem:

$$V_h(j, \varpi, b, a) = \max_{(c,a')} \{u(c, 1)\beta E[\xi_{jh} \sum_{s\in S} \pi(s) V_h(j+1, s, b', a') + (1-\xi_{jh}) V_h(j+1, u', b', a')]\} \quad (17)$$

subject to

$$(1+\tau_c)c + a' = (1 + r(1-\tau_k))a - \tau_y y^b + I_{t_r},$$

where $y^b = (1-\tau_k)ra$ and the law of motion for pension rights is:

$$b' = \begin{cases} 0 & \text{if} \quad j < R_0 - N_b \\ b + (y^{fq}/N_b) & \text{if} \quad R_0 - N_b \le j < R_0. \end{cases} \quad (18)$$

Retired. Retired individuals do not receive labor income. They finance consumption with past private savings and pension payments. The problem is a standard consumption-savings decision, with survival risk and a certain maximum attainable age, assumed to be $J = 100$. At age $j = 99$, the continuation value is zero because the agent exists the economy next period with probability one. Before that, the retired household solves:

$$V_h(j, \rho, p, a) = \max_{(c,a')} \{u(c, 1) + \beta\psi_j[V_h(j+1, \rho, p, a')]\} \quad (19)$$

subject to

$$(1+\tau_c)c + a' = p + (1 + r(1-\tau_k))a - \tau_y y^b,$$

where $y^b = p + (1 - \tau_k)ra$. Retired households, similarly to eligible unemployed, are not eligible in any case to receive public transfers other than pensions, since we assume that the minimum retirement pension is well above the minimum income level.

Retirement decision. Recall that we assume that unemployed households who are R_0 years or older are forced to retire. On the other hand, a worker aged $j \geq R_0$ must decide if to retire or not from the labor market. In this case, she chooses the optimal plan after solving problems 13 and 19.

3.5. Equilibrium

A detailed description of the equilibrium process of this model economy can be found in Appendix 1.

4. Calibration

To calibrate our model economy, we choose 2018 as our calibration year. Then we choose the initial conditions and the parameter values that allow our model economy to replicate as closely as possible selected macroeconomic aggregates and ratios, distributional statistics, and institutional details of Spain in 2018.

4.1. The initial distribution of households

Individuals are assumed to be born at the age of 20 and they can live a maximum of $J = 100$ years. After age 100, death is certain. The sequence of conditional average survival probabilities $\{\psi_j\}_{j=1}^{J}$ is taken directly from the Spanish Institute of Statistics (INE) at 2018. The initial share of age groups in the population, μ_j, is then calculated from the relation:

$$\mu_{j+1} = \frac{\psi_j}{(1+n)}\mu_j, \tag{20}$$

where n is the growth rate of the population, which has averaged 0.67% per year in Spain over the last 50 years. Finally, we also take from INE the distribution by education across cohorts, μ_{jh}, at 2018.[11]

4.2. Parameters and targets

To characterize our model economy fully, we must choose the values of a total of 70 parameters. Of these 70 parameters, 20 describe the government policy, 21 describe the endowment of efficiency labor units profiles, 24 describe the employment and unemployment risk functions, two describe the production technology, and the remaining three describe the household preferences. To choose the values of these 70 parameters, we need 70 equations which formalize our calibration targets.

4.3. Equations

To determine the values of the 70 parameters that identify our model economy, we do the following. First, we assign values to 51 parameters that can be estimated directly using equations that involve either one parameter only, or one parameter and our guesses for (K, L). These include, for instance, the deterministic productivity profiles and the probabilities governing employment transitions. Second, we use the model and a system of 19 non-linear equations to calibrate the 19 remaining parameters. Most of these equations require various statistics in our model economy to replicate the values of the corresponding Spanish statistics in 2018. We describe the determination of both sets of parameters in the subsections below.

[11]Data can be found at the Encuesta de Población Activa.

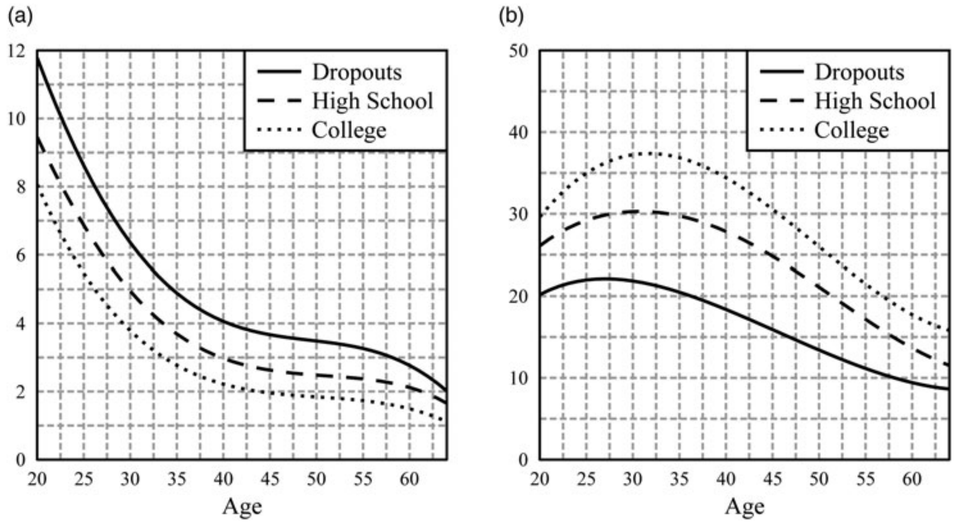

Figure 3. The probabilities for find/lose a job (%).

4.3.1 First stage of calibration

The life-cycle profile of earnings. We measure the deterministic component of the process on the endowment of efficiency labor units independently of the rest of the model. We estimate the values of the parameters of the three quadratic functions that we describe in expression (1), using the age and educational distributions of hourly wages reported by the *Instituto Nacional de Estadística* (INE) in the *Encuesta de Estructura Salarial* (2010) for Spain.[12] This procedure allows us to identify the values of nine parameters directly.

The employment risk. We also measure the exogenous probability to find/lose a job independently of the rest of the model. We estimate the values of the parameters of the functions that we describe in expressions (4) and (15), using the age and educational distributions of employment flows reported by the INE in the *Encuesta de Población Activa* (2018) for Spain, and the implied exogenous probabilities to fin/lose a job are shown in Figure 3.[13] This procedure allows us to identify the values of 24 parameters directly.

The pension system. In 2018 in Spain, the payroll tax rate paid by households was 28.3% and it was levied only on the first 45,014 euros of annual gross labor income, which corresponds to 141.06% of per GDP per person aged 20+. Consequently, we set $a_{12} = 1.4106$, so that the maximum covered earnings is $b_m = 1.4106y$.[14] We also assume that the payroll tax rate is $\tau_{ss} = 0.235$. The rationale for our choice is because the part of the payroll tax that would finance the expenditure of retirement and widowhood pensions is limited to 23.5% of earnings.

Our choice for the number of years used to compute the retirement pensions in our benchmark model economy is $N_b = 21$. This is because in 2018 the Spanish *Régimen General de la Seguridad Social* took into account the last 21 years of contributions prior to retirement to compute the pension. Our choice for the first and normal retirement ages are $R_0 = 62$ and $R_1 = 66$, so that to identify the early retirement penalty function, we choose $a_{20} = 0.28$ and $a_{21} = 0.07$. This is because we have chosen $R_0 = 62$.

[12]Since we only have data until age 64, we estimate the quadratic functions for workers in the 20–64 age cohort and we project the resulting functions from age 65 onwards.

[13]We assume that these probabilities remain constant from age 65 onwards.

[14]In Spain in 2018, the GDP per person who was 20 or older was 31,910.46 euros.

Table 2. First stage of calibration (life-cycle profiles)

		Deterministic earnings life-cycle		
	$i=1$	$i=2$	$i=3$	–
$h=1$	0.9189	0.0419	0.0006	
$h=2$	0.8826	0.0674	0.0008	
$h=3$	0.5064	0.1648	0.0021	
		Probability to find a job		
	$i=4$	$i=5$	$i=6$	$i=7$
$h=1$	0.1991	546.4×10^{-5}	-39.5×10^{-5}	0.5×10^{-5}
$h=2$	0.2499	$1{,}008\times10^{-5}$	-52.8×10^{-5}	0.5×10^{-5}
$h=3$	0.2785	$1{,}671\times10^{-5}$	-83.8×10^{-5}	0.9×10^{-5}
		Probability to lose a job		
	$i=8$	$i=9$	$i=10$	$i=11$
$h=1$	0.1267	-827.8×10^{-5}	25.9×10^{-5}	-0.3×10^{-5}
$h=2$	0.1020	-678.1×10^{-5}	20.4×10^{-5}	-0.2×10^{-5}
$h=3$	0.0859	-627.9×10^{-5}	19.9×10^{-5}	-0.2×10^{-5}

We assume that the minimum and the maximum pension are also directly proportional to per capita income. Our targets for the proportionality coefficients are $a_{13}=0.2362$ and $a_{14}=1.1390$. These numbers correspond to their values in 2018.[15] Finally, we assume that the fictitious quotes are also a proportion $a_{22}=0.24$ of per capita output, so that we set $y^{fq}=0.24y$.

Government policy. To specify part of the government policy, we must choose the values of government consumption, G, of the parameters of the income tax function, of the tax rate on capital income, τ_k, and of the tax rate on consumption, τ_c. We target the output shares of G and T_k, so that they replicate the GDP shares of government consumption and capital income taxes. According to the INE, in 2018, government consumption was 236,342 million euros, and the corporate profit tax collected 29,711 million euros. Consequently, we set $a_{16}=0.1961$ and $\tau_k=0.0964$.

To identify the income tax function, we must choose the values of parameters a_{17}, a_{18}, and a_{19}. Since a_{17} and a_{19} are unit-independent, we use the values reported by Calonge and Conesa (2003) for these parameters, namely, $a_{17}=0.45$ and $a_{19}=1.071$. Finally, the government budget is an additional equation that allows us to obtain residually the consumption tax rate.

Preferences. Of the three parameters in the utility function, we choose the value of γ directly. Specifically, we choose $\sigma=4.0$.

Technology. According to the Spanish National Institute of Statistics (INE) data, the capital income share in Spanish GDP was 0.4846 in 2018. Consequently, we choose $\theta=0.4846$.

Adding up. So far we have determined the values of 51 parameters either directly or as functions of our guesses for (K, L) only. We report their values in Tables 2 and 3.

4.3.2 Second stage of calibration

We still have to determine the values of 19 parameters. To find the values of those 19 parameters we need 19 equations. Of those equations, 15 require that model economy statistics replicate the value of the corresponding statistics for the Spanish economy in 2018, and four are normalization conditions (Table 4).

Aggregate targets. According to the BBVA database, in 2016 the value of the Spanish capital stock was 3,281,631 million euros.[16] According to the INE in 2016 the Spanish gross domestic product at market prices was 1,113,840 million euros. Dividing these two numbers, we obtain $K/Y=2.94$, which is our target value for the model economy capital to output ratio.

[15]Specifically, in 2018 the minimum retirement pension in Spain was 7,537.1 euros, and the maximum pension was 36,121.8 euros. All these data are yearly.

[16]This number can be found at http://www.fbbva.es/TLFU/microsites/stock09/fbbva_stock08_index.html.

Table 3. First stage of calibration (single parameters)

	Parameter	Value
Parameters obtained directly		
Preferences		
Curvature	γ	4.0000
Technology		
Capital share	θ	0.4846
Public pension system		
Number of years of contributions	N_b	21
First retirement age	R_0	62
Normal retirement age	R_1	66
Payroll tax rate	τ_{ss}	0.2350
Years in the RB	N_b	21
Fictitious quote	a_{22}	0.2400
Maximum penalty	a_{20}	0.2800
Year penalty	a_{21}	0.0700
Fiscal policy		
Income tax function	a_{17}	0.4500
Income tax function	a_{19}	1.0710
Parameters determined by the guess for (K, L)		
Public pension system		
Maximum covered earnings	a_{12}	1.4106
Minimum pension	a_{13}	0.2362
Maximum pension	a_{14}	1.1390
Fiscal policy		
Government consumption	a_{16}	0.1961
Capital income tax rate	τ_k	0.0964
Consumption tax rate	τ_c	0.2161

Table 4. Macroeconomic aggregates and ratios in 2018 (%)[a]

	h[b]	K/Y^*	DSS/Y^*[c]	U/Y^*	Tr/Y^*	T_y/Y^*	C/Y^*
Spain	34.59	2.94	1.75	1.32	0.13	7.05	54.35

[a]Variable Y^* is GDP at market prices.
[b]Variable h denotes the average share of disposable time allocated to the market.
[c]Variable DSS denotes the social security deficit.

According to the INE, private consumption plus indirect taxes was 654,574 million euros in 2018, and unemployment benefits amounted 17,469 million. That same year, and according to the Spanish Instituto Nacional de la Seguridad Social, pension deficit was 21,038 million euros. Consequently, the ratios of these variables to GDP at market prices are 54.35%, 1.32%, and 1.75%. Finally, and according to the Spanish Ministerio de Inclusión, Seguridad Social y Migraciones, the sum of minimum income transfers delivered by the central government amounted 0.13% of Spanish GDP in 2019.

Finally, and according to the Encuesta de Población Activa (INE), in Spain in 2018 an average worker devoted 33.9 hours per week to labor market activities. If we assume that the total endowment per week is 98 hours ($=14 \times 7$), it means that an average worker devoted 34.59% of his disposable time to labor market activities.

Distributional targets. We target the three Gini indexes and five points of the Lorenz curves of the Spanish distributions of earnings, income, and wealth. We have taken these statistics from the INE, the OECD, and Budría and Díaz-Giménez (2007), and we report them in bold face in Table 5. As we said before, Castañeda *et al.* (2003) argue in favor of this calibration procedure to replicate the inequality reported in the data. These targets give us a total of eight additional equations.

Normalization conditions. In our model economy there are four normalization conditions. The transition probability matrix on the stochastic component of the endowment of efficiency labor units process is a Markov matrix and therefore its rows must add up to one. This gives us three

Table 5. The distributions of earnings, income, and wealth[a]

	Gini	Bottom 10	Quintiles 1st	2nd	3rd	4th	5th	Top 10
The earnings distributions (%)								
Spain	**0.34**	NA	NA	NA	NA	NA	NA	NA
The income distributions (%)								
Spain	**0.33**	2.1	**6.3**	**12.1**	17.2	23.7	**40.7**	25.0
The wealth distributions (%)								
Spain	**0.57**	0.0	0.9	**6.6**	12.5	**20.6**	59.5	42.5

[a]The source for the Spanish data of earnings and income are the Spanish National Institute of Statistics (INE) and the OECD. The source for the Spanish data of wealth is the 2004 *Encuesta Financiera de las Familias Españolas* as reported in Budría and Díaz-Giménez (2006).

Table 6. Second stage of calibration (the stochastic component of the endowment process)

	Values	Transition probabilities $s' = s_1$	$s' = s_2$	$s' = s_3$	$\pi^*(s)$[a]
$s = s_1$	1.0000	0.9821	0.0177	0.0002	59.39
$s = s_2$	2.3490	0.0291	0.9708	0.0000	36.29
$s = s_3$	4.9042	0.0000	0.0004	0.9995	4.32

[a]$\pi^*(s)$% denotes the invariant distribution of s.

Table 7. Second stage of calibration (preferences, technology, and public policies)

	Parameter	Value
Preferences		
Time preference	β	0.9751
Leisure weight	χ	0.7001
Technology		
Depreciation rate	δ	0.0685
Public pension system		
Replacement rate	ϕ	0.7955
Fiscal policy		
Minimum income	a_{16}	0.0500
Income tax function	a_{18}	0.1181
Replacement rate	ϑ	0.4251

normalization conditions, and finally, we also normalize the first realization of this process to be $s(1) = 1$ (Tables 6 and 7).

In the Technical Appendix of Díaz-Saavedra (2020), we describe in detail how we solve the system of 15 non-linear equations needed to find the value of these parameters.

4.4 Calibration results

In this section we show that our calibrated, benchmark model economy replicates reasonably well both most of the Spanish statistics that we target, and also untargeted moments in our calibration procedure. To differentiate targeted from untargeted moments, we present the first group of Spanish statistics in bold face.

Macroeconomic aggregates and ratios. In Table 8 we report the macroeconomic aggregates and ratios in Spain and in the benchmark model economy for 2018. We find that the benchmark model economy does a good job in replicating most of the main Spanish macroeconomic aggregates and ratios. The only exceptions are the inheritance tax revenues and the consumption tax collections. This is not surprising because the assets that belong to the households that exit our model economy

Table 8. Macroeconomic aggregates and ratios in 2018 (%)[a]

	K/Y^*	h^b	G/Y^*	DSS/Y^{*c}	U/Y^*	Tr/Y^*	T_y/Y^*	T_k/Y^*	T_c/Y^*	E/Y^*
Spain	**2.94**	**34.59**	**19.61**	**1.75**	**1.32**	**0.13**	**7.05**	**2.24**	9.07	0.20
Model	2.94	33.82	19.61	1.41	1.17	0.21	7.20	2.24	10.19	2.77

[a]In this table, variable Y^* is GDP at market prices.
[b]Variable h denotes the average share of disposable time allocated to the market.
[c]Variable DSS denotes the social security deficit.

Table 9. The Spanish pension system in 2018[a]

	$\underline{p}^b$	$\bar{p}^c$	IRR^d
Spain	34.8	3.2	2.1/5.4
Model	35.9	4.1	2.1

[a]The source of Spanish data for the shares of minimum and maximum pensions is the Spanish Social Security Statistics and the Ministry of Inclusion, Social Security and Migration.
[b]Share of minimum pensions.
[c]Share of maximum pensions.
[d]Average internal rate of return of pensions.

are confiscated by the government, and because the consumption tax rate is determined residually to satisfy the government budget.

The pension system. Some of the more important features of the Spanish economy that our model economy should approximate are those related to public pension system, e.g., the shares of retirees collecting minimum and maximum pensions, and the internal rate of return of the Spanish public pension system. This is so since the Spanish pension system redistributes pension income mainly through a minimum pension, and also a cap of the payroll tax that is well above the maximum pension. We find that the 35.9% of all retirees in our model economy receive the minimum pension, and only 4.1% of retirees receive the maximum pension. In Spain, these same numbers are 34.8% and 3.2% (see Table 9).

There are several studies that analyze the internal rate of return of the Spanish pension system. For instance, Barea (1996) find that the average internal rate of return of the Régimen General de la Seguridad Social is 2.1%. On the other hand, Jimeno and Licandro (1999) find that this same number may reach 5.4%. Finally, and in a recent study, Moraga and Ramos (2020) find that this number is 3.5%. In our case, the model economy predicts an average internal rate of return of 2.1%. The main reason why Jimeno and Licandro (1999) and Moraga and Ramos (2020) obtain higher internal rates of return is due to the fact that these authors assume that the payroll tax rate is only 15% and 18% of gross earnings respectively, while our model economy assumes that this same rate is 23.5%. The rationale for our choice is because the part of the payroll tax that would finance the expenditure of retirement and widowhood pensions is limited to 23.5% of earnings.[17] Overall, we find these results very encouraging since we did not target explicitly any of these statistics in our calibration procedure.

Retirement behavior. Another salient feature of the Spanish economy that our model economy should approximate, if we are to take its results seriously, is the retirement behavior of Spanish households. In Figure 4, we report the probabilities of exiting the labor force due to retirement.[18] Two features stand out from this comparison. Qualitatively, our model economy does a good job in replicating the general shape of the retirement hazards observed in Spain, including the peaks observed at ages 62 and 65.[19]

[17]That is, the expenditure on retirement and widowhood pensions represents around 89% of total pension expenditure. Moraga and Ramos (2020), and Jimeno and Licandro (1999) only consider retirement pensions.

[18]The Spanish data are reported by the Spanish *Instituto de la Seguridad Social* and they correspond to 2018.

[19]In Spain in 2018, the first peak in the probability of retirement occurred at the age of 61, given that there were still people who fulfilled the requirements for not waiting until the age of 62.

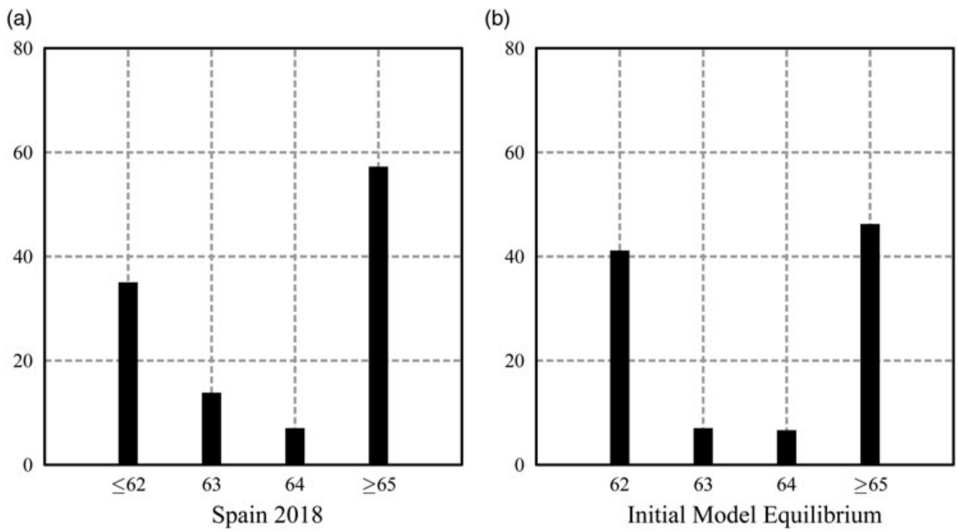

Figure 4. The retirement hazards in Spain and the model economy (%)*.
*The Spanish data are reported by the Spanish *Instituto de la Seguridad Social* and they correspond to 2018.

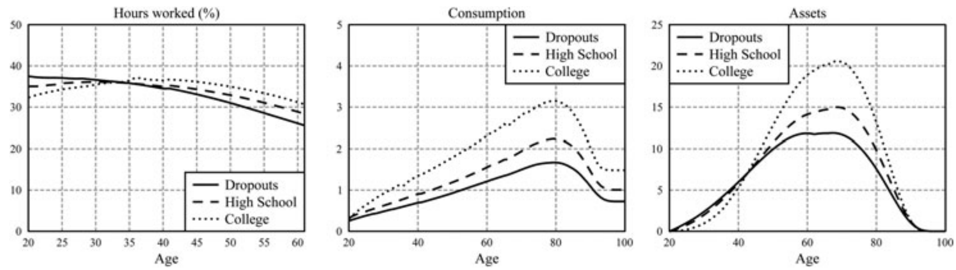

Figure 5. Life-cycle profiles of hours worked, consumption, and assets in the model economy.

Quantitatively, the peak at age 62 is higher in our model economy. For instance, at that same age the hazard in our model economy is 40.9% while in Spain it is only 34.8%. One of the main reasons for this is that our replacement rate is independent of the number of years of contributions to the pension system, while in Spain the pension replacement rate is an increasing function of this number.

We also analyze the composition of acquired wealth between the legal retirement ages. We find that those households that choose to retire between the ages of 62 and 66, and are located in the 30th percentile of the wealth distribution, have a social-security-wealth-to-liquid-assets ratio of 2.1. We also find that this number is 1.0 for those located in the 90th percentile. Unfortunately, we could not find these data for Spain, but we think that this decreasing relationship is very plausible. For instance, Poterba *et al.* (2011) find that these figures are 2.9 and 0.9 in the United States for individuals aged 65–69 years old. Finally, and once again, these results can be interpreted as an overidentification condition, since we did not use them as a calibration target.

Life-cycle profiles. Figure 5 shows life-cycle profiles of average hours worked as a percentage of disposable time, average consumption, and average assets. We find that hours are mainly in the range of 30–40%, which decline gradually as individuals age. The overall patterns of the hour profiles are consistent with the data, for example, as reported by Díaz-Saavedra (2017) for Spain (Figure 5), and French (2005) for the case of the United States.

Table 10. The distributions of earnings, income, and wealth[a]

	Gini	Bottom 10	Quintiles 1st	2nd	3rd	4th	5th	Top 10
The earnings distributions (%)								
Spain	**0.34**	NA	NA	NA	NA	NA	NA	NA
Model	0.35	3.3	7.5	11.0	15.5	23.9	42.1	26.6
The income distributions (%)								
Spain	**0.33**	2.1	**6.3**	**12.1**	17.2	23.7	**40.7**	25.0
Model	0.34	0.8	5.1	13.0	17.8	24.2	39.9	23.6
The wealth distributions (%)								
Spain	**0.57**	0.0	0.9	**6.6**	12.5	**20.6**	59.5	42.5
Model	0.56	0.0	0.4	4.7	13.3	26.1	55.4	34.3

[a]The source for the Spanish data of earnings and income are the Spanish National Institute of Statistics (INE) and the OECD. The source for the Spanish data of wealth is the 2004 *Encuesta Financiera de las Familias Españolas* as reported in Budría and Díaz-Giménez (2007).

Figure 5 also displays the usual patterns of average asset holdings over the life cycle. That is, individuals accumulate wealth during their working lifetime for two main reasons. First, in order to accumulate stock savings against uncertainty about earnings and longevity, and second, to build the stock of savings for old-age consumption. However, since households are not altruistic in our model economy, consumption grows continuously until age 80, as they deplete their assets after leaving the labor market at a higher rate than they would if they were to leave inheritances. For instance, at the age range of 45–54 years, the median net wealth in Spain in 2017 was 3.6 times GDP per person aged 20+, and in our model economy it is 3.4. However, at the age range of 65–74 years, these figures are 5.6 in Spain, but only 4.6 in our model economy.[20]

Inequality. In Table 10 we report the Gini indexes and selected points of the Lorenz curves for earnings, income, and wealth in Spain and in our benchmark model economy. The statistics reported in bold face are our eight calibration targets. The source for the Spanish data of earnings and income are the INE and the OECD. The source for the Spanish data of wealth is the 2004 *Encuesta Financiera de las Familias Españolas* as reported in Budría and Díaz-Giménez (2006).The model economy statistics correspond to 2018.

We find that our model economy replicates the Spanish Gini indexes of earnings, income, and wealth reasonably well – the largest difference is only 0.01. When we look at the top tail of the distributions we find that the share of wealth owned by the top 10% of the wealth distribution is 8.2 percentage points higher in Spain. This disparity was to be expected, because it is a well-known result that overlapping generation model economies that abstract from bequests fail to account for the large shares of wealth owned by the very richest households in the data.[21]

Moreover, our model economy also comes close to replicating the Gini index of pensions. According to Conde-Ruiz and Profeta (2007), in 2000 this number was 0.32 in Spain and in our model economy it is 0.29 in our calibration year.

The labor market. Figure 6 shows the profiles of employee and unemployed households by age and education. When carrying out this comparison we must keep in mind that there are some fundamental differences between Spain and our model economy. In Spain, working-age people fall into one of five categories: employed, unemployed, retired, inactive, and other non-participants. In our model economy we only have three of these categories: employed, unemployed, and retired. Since these differences necessarily would distort our comparisons, we opted for excluding inactive and other non-participants people from the Spanish data.

We find that the model economy replicates these profiles well. If we look at the fine print, we find that the largest difference is observed in the case of dropouts households between 30 and 32 years old,

[20]The data for Spain are taken from the *Encuesta sobre las condiciones materiales de vida* of the Spanish Instituto Nacional de Estadística.

[21]See Castañeda *et al.* (2003) for an elaboration of this argument.

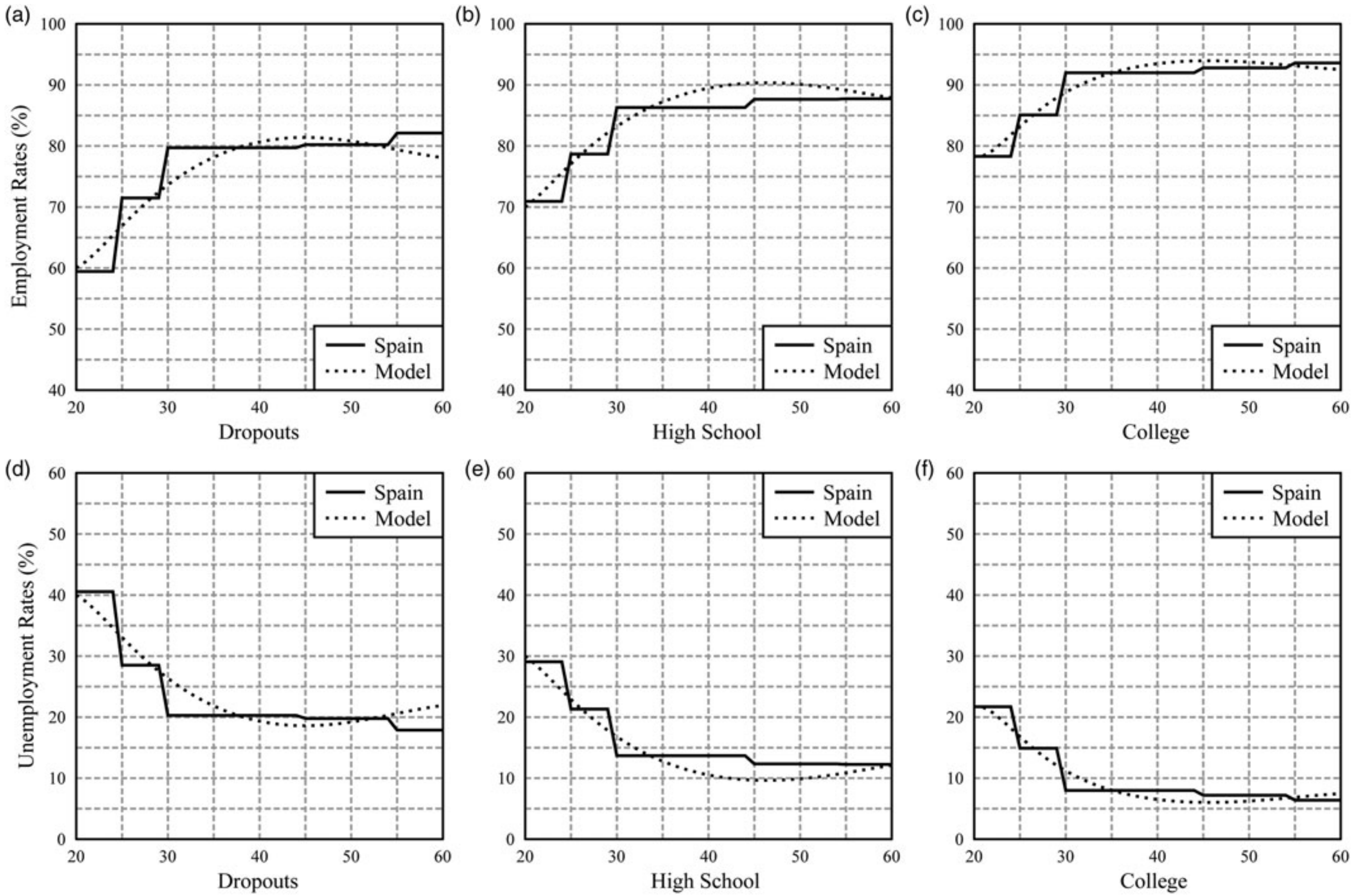

Figure 6. The share of workers and unemployed in Spain and the model economy (%)*.
*The shares of workers are the shares of workers in the sum of workers and unemployed. We compute this share for Spain from the *Encuesta de Población Activa (2018)*, reported by the INE.

Table 11. The model economies: mortality risk and pension reform

	Parametric pension reform	Heterogeneity in mortality risk	Year of the simulation
Benchmark	None	Age	2018
Experiment 0	None	Age and education	2060
Experiment 1	Minimum pension	Age and education	2060
Experiment 2	Regulatory base	Age and education	2060
Experiment 3	Exp. 1 + Exp. 2	Age and education	2060

since the model predicts that their employment rates are around 5 percentage points lower than those observed in Spain.

5. Policy experiments

In the next section, we will study the effects of some policy experiments aimed to increase the progressiveness of the Spanish social security, under the projected Spanish demographics for 2060. In this section we describe the policy experiments, the concept we apply to quantify the welfare effects of these experiments, and the demographic, educational, employment, and government policy scenarios that we use in our simulations.

5.1 The experiments

We compare a steady-state benchmark allocation with different steady-state allocations of economies that differ in the mortality risk and in their pension rules. We describe below all simulations in turn (Table 11).

The benchmark economy. Our benchmark economy is the economy that we modelled and calibrated to approximate the Spanish economy in 2018, but with the counterfactual assumption that survival risk only differs across ages, and it is given by the average age-dependent survival probabilities estimated by the INE in 2018. The rationale for this choice is because it allows us to quantify the degree of progressiveness embodied in the Spanish pension system. Additionally, we report the results of this same economy but assuming that these probabilities also differ by educational type, in order to analyze the loss of progressivity due to the current gap in life expectancy. In other words, what we expect from these exercises is to understand how much lifetime benefits and taxes change when we assume that less-educated workers have less longevity, whereas more-educated individuals live longer.

Alternative economies. The next simulations assume that mortality risk depends on both age and education, but with the projected long-term demographic and educational distributions. First, we simulated an economy called *experiment 0*. Essentially it is a *do-nothing* policy, where the pension rules follow the 2011 and 2013 pension reforms in Spain. Consequently, in this economy the first retirement age is 63 and the full entitlement retirement age is 67. The number of years of labor income used to compute the pension is the last 25 before retirement.[22] We simulate this economy, because from its comparison with our previous results, we can obtain a measure of how much progressiveness of the pension system is lost in the long-run because of the expected increase in lifetime gaps (Figure 7).

The next simulations are counterfactual experiments that allow us to evaluate how parametric pension reforms that do not differentiate between socioeconomic groups may restore pension income redistribution in the long run. Thus, at this point it is crucial first to identify which are the elements of this system that generate an income redistribution from the earnings poor to the earnings rich.

[22]We assume that both the Pension Revaluation Index and the Sustainability Factor, introduced by the 2013 Reform of the Spanish pension system, are ultimately not implemented. This is because the Spanish Government has recently replaced the Pension Revaluation Index by the Consumer Price Index, and also because it delayed the incorporation of the Sustainability Factor.

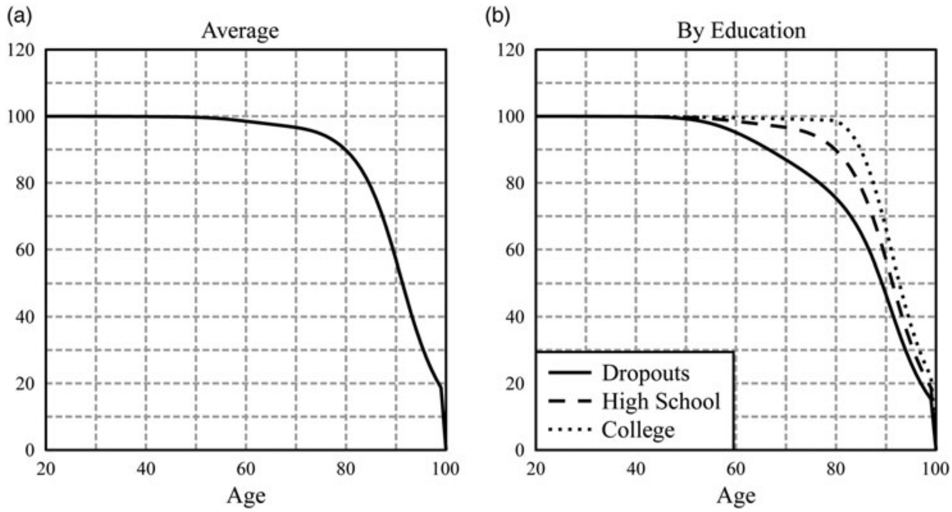

Figure 7. The unconditional survival probabilities in 2060 (%).

Conde-Ruiz and González (2018) show that in many cases this is mainly achieved through the existence of a minimum pension. Consequently, in *experiment 1* we assume that the minimum pension, as a share of per capita GDP, is increased by 50%.[23]

Additionally, one can explore the consequences of changes in the regulatory base, which is the main component of the Spanish retirement pension, for the progressiveness of the pension system. At this point, two main potential changes emerge. First, in Spain, from 2022 the regulatory base will be computed using labor earnings from the last 25 years before retirement, but contributions are broadly on the basis of the working lifetime. Furthermore, as Jimeno (2003) points out, because the distribution of labor income is much more unequal in the later periods of working life, the resulting pension distribution is more unequal under the current system than it would be under a system that takes into account the contribution bases or the contributions actually made during longer periods of working life, as occurs in other European countries with defined benefit pension systems.[24] Consequently, if a person's salary doubles in their final years, their pension will double. Thus, there is a subsidy from people whose earnings grow more slowly to those whose earnings grow rapidly later in their working lifetime. The former group tends to be low earners, and the latter the high earners. Thus, on average, final-earnings schemes redistribute from low to high earners. Therefore, extending the averaging period of the regulatory base should reduce retirement pensions especially for the more educated workers, thus increasing the progressiveness of the pension system. In *experiment 2* we explore this hypothesis by assuming that the regulatory base computes the average labor earnings for the entire working lifetime.

Lastly, we carry out a final simulation, *experiment 3*, in which we assume that there is both an increase in the minimum pension and in the number of years used to calculate the pension. In other words, we are applying the reforms of experiments 1 and 2 jointly. The rationale for doing this is given in the next section.

[23]Conde-Ruiz and González (2018) also point out that pension system's progressiveness is also due to the case of a maximum pension that is below the cap of the payroll tax rate.

[24]In Europe, similar to Spain, pension schemes in Austria, France, Portugal, and Slovenia are based on a comparatively small fraction of career earnings to calculate benefits.

5.2 Welfare effects

We follow Conesa and Krueger (1999) and compute the consumption equivalent variation measure (CEV) for newborns before and after the reforms in 2060. Specifically, we compute the welfare change of a reform for a newborn with education h and labor status e, by asking by how much this newborn's consumption has to be increased, holding leisure constant, in the old steady state, so that her expected utility equals that under the specific reform. Consequently, and given the form of the utility function, we compute

$$CEV_h(e) = e^{(V_h^*(e) - V_h(e))/\kappa} - 1, \tag{21}$$

where $V_h(e)$ and $V_h^*(e)$ are the value functions of a newborn with education h and labor status e under the current and the reformed pension system, respectively, and $\kappa = \sum_{j=20}^{J-1} \beta^{j-20} \psi_{jh}$. For example, a $CEV_h(e)$ of 0.01 implies that a newborn with education h and labor status e will enjoy an increase in welfare equivalent to receive 1% higher consumption under the current pension system.[25]

Finally, we also compute a weighted average consumption equivalent variation. That is, the model implicitly defines some social welfare weights under which a distributional outcome arises. Thus, the weighted average consumption equivalent variation, ($\overline{CEV}$), is given by

$$\overline{CEV} = \iint CEV_h(e) d\mu_e d\mu_h. \tag{22}$$

In fact, we use a weighted social welfare function where the weights are given by the projected long-term measure of newborns by education and labor status.

5.3 The environments

All the model economies described in experiments 0–3 share the demographic, educational, employment, and government policy scenarios that we now describe.

The demographic scenario. The long-term demographic scenario replicates the demographic projection for Spain in the year 2060 estimated by the INE in 2018. In panel A of Figure 8 we plot the projected distribution by age of Spanish population in 2060. According to this projection, the old-age dependency ratio is 52.76 (=[34.54/65.45] × 100) percent that same year.[26]

However, a problem we have faced when carrying out our simulations is the lack of data regarding the mortality risk across the different educational groups. Therefore, to solve this lack of data, we have had to estimate it, for which we have carried out a process that consisted of several stages. First, from the data reported by Permanyer *et al.* (2018) we extrapolate current tendencies on life expectancies at age 35 by educational type to the year 2060. Second, as input we use the average probabilities calculated by the INE in 2018 and 2060. Third, we assume that the differences in these probabilities across educational groups appear after age 40, and that this difference reaches a maximum at age 70, and then decreases. Finally, using iterative methods we generate profiles of survival probabilities by age and educational type that produce a life expectancy at the age of 35 consistent with the estimates for the period 2012–2015 provided by Permanyer *et al.* (2018) or our extrapolation for 2060 of each educational group.

The educational scenario. In panel B of Figure 8 we plot the assumed distribution of education in 2060, and this panel shows that high school households is the most numerous educational group

[25]Alternatively, one could follow the approach of Fehr *et al.* (2013), who compute the optimal degree of progressiveness for the German Public Pension System, using a metric based on efficiency effects. This involves making use of the concept of Lump-Sum Redistribution Authority (LSRA), in the spirit of Auerbach and Kotlikoff (1987). However, our research question is simpler, since we are interested in evaluating the effects, e.g., on welfare, of the different alternatives available to governments to maintain the degree of progressivity of their pension systems, despite the increase in the lifetime gap.

[26]This ratio is computed as those aged 67+ years over people aged 20–66 years.

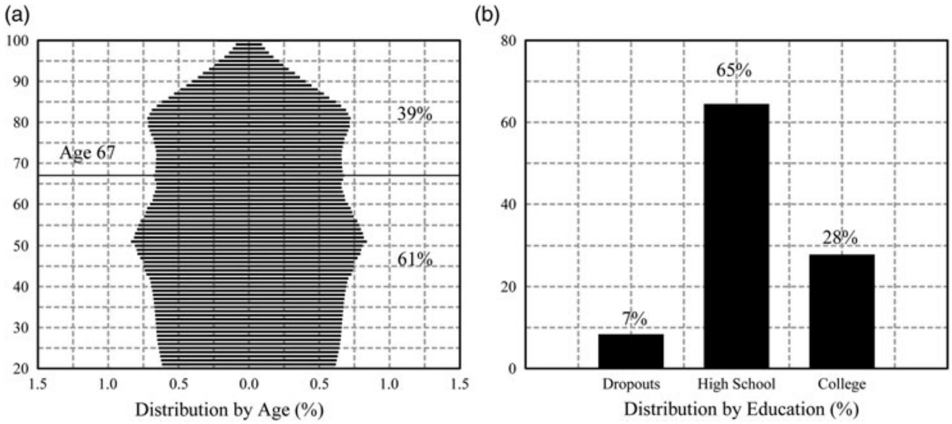

Figure 8. The age and educational distribution in 2060.

within the population. See Díaz-Saavedra (2020) for an explanation of how we obtain this educational distribution for the Spanish population in 2060.

The employment scenario. We assume that employment risk continues to be characterized by the age-dependent probabilities in/out of employment that we estimated for Spain in 2018.

The government policy scenario. Recall that the consolidated government and pension system budget constraint in our model economy is

$$G + P + U + Z = T_k + T_s + T_y + T_c + E. \tag{23}$$

In this expression G is exogenous and the remaining variables are endogenous. In all model economies the income, capital income, and payroll tax rates are identical and they remain unchanged at their calibrated values. The consumption tax rates differ across economies because we change it to clear the government budget. Every other variable in expression (23) varies and differs across both economies because they are all endogenous.

Finally, all of pension parameters that characterize the pension policy are already set because both, our assumption that all model economies introduce the main pension rules following the 2011 and 2013 pension reforms in Spain, and also because the aforesaid described pension policy experiments.

6. Results

In Section 6.1, we quantify how the heterogeneity in lifespan reduces the redistributive objectives of the Spanish pension system both in the calibrated target year and in the long run. The remaining sections deal with parametric pension reforms aimed at recovering the loss in progressiveness due to educational differences in mortality risk. In this way, Section 6.2 analyzes the consequences of increasing the minimum pension, and Section 6.3 considers changes in the regulatory base. Finally, Section 6.4 studies a joint parametric change in the minimum pension and the regulatory base. All our results are shown in Figures 9 and 10, and Tables 12–14.

6.1 Heterogeneity in lifespan and progressiveness

We start our analysis with the study of the effect of differential mortality on the degree of progressiveness of Spanish social security in 2018. The metric used here is the ratio of the expected lifetime retirement benefits that individuals receive, *LB*, to the expected lifetime payroll taxes that they pay during their working lifetime, *LT*. This ratio is then normalized to one for the case of school dropouts, and we

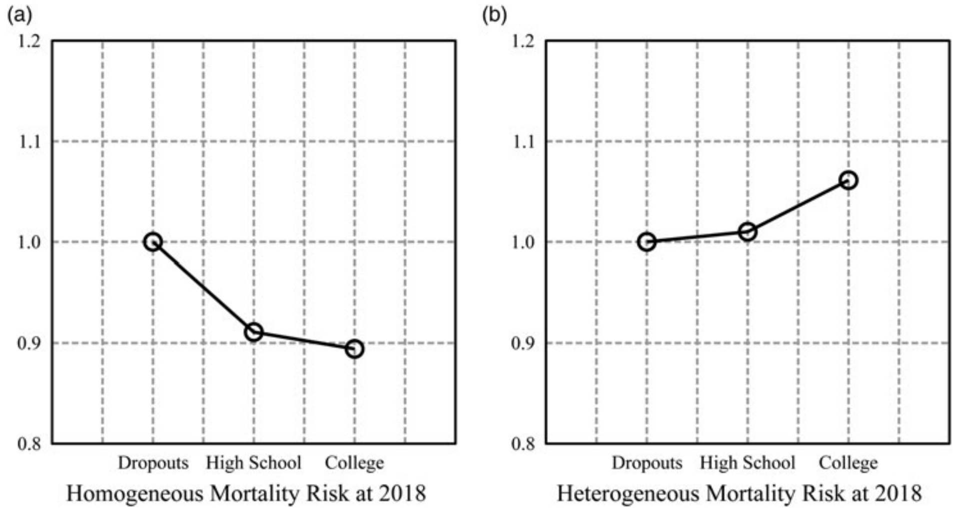

Figure 9. The expected lifetime benefits to lifetime payroll taxes ratio in 2018*.
*This ratio is normalized to one for the case of dropouts, and we express the ratio of the remaining educational groups as a proportion of that number.

express the ratio of the remaining educational groups as a proportion of that number. Specifically, we compute expected lifetime benefits and taxes for an average household with educational level h as:

$$LB_h = \int_{jh}^{\psi} p(b) d\mu \tag{24}$$

and

$$LT_h = \int_{jh}^{\psi} \tau_s(y^l) d\mu, \tag{25}$$

where all the integrals are defined over the state space $J \times \mathcal{E} \times B \times P \times A$.[27]

In panel A of Figure 9, the green line represents this ratio in the benchmark model economy, where we assume that individuals within the same cohort have identical survival risk, and where the survival probabilities are the average for men and women estimated by the INE for the year 2018. In this economy, the line is downward-sloping, meaning that the pension system redistributes income from high- to low-educated households, since this ratio would be 1.00, 0.91, and 0.89 for school dropouts, secondary-school graduates, and university graduates, respectively. According to Conde-Ruiz and González (2018), this is mainly achieved through the existence of a minimum pension.

In panel B of Figure 9, we represent that same ratio considering the effects of differential mortality by education. This line now becomes upward-sloping, showing that the benefit-to-tax ratio increases as the number of years of education also increases, and our results show that this ratio would be 1.00, 1.01, and 1.06 for average school dropouts, secondary-school, and university graduates. Less-educated workers would now have less longevity, thereby reducing their lifetime benefits, whereas more educated individuals would now live longer, and therefore collect their pension benefits for longer.

Consequently, we find that the gap in life expectancy reverses the progressiveness of the Spanish public retirement pension program. Our results also show that an average less-educated household

[27]Whenever we integrate the measure of households over some dimension, we drop the corresponding subscript.

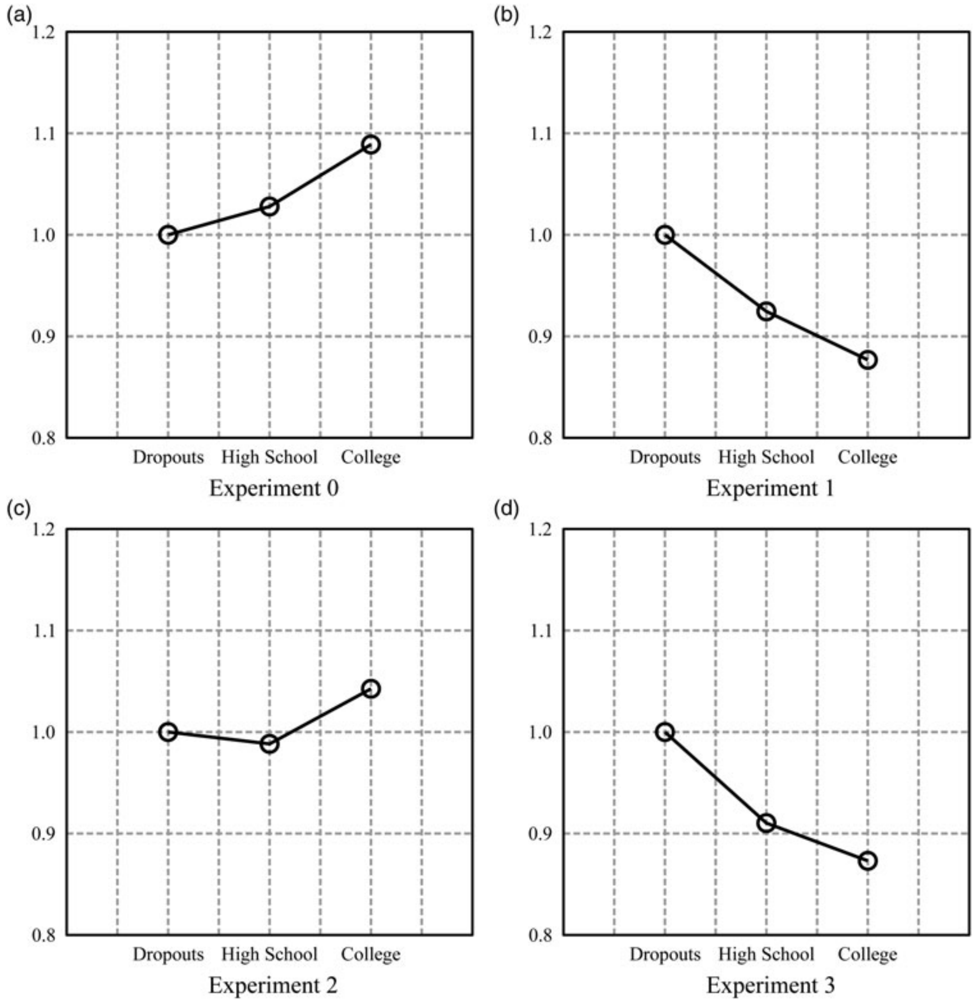

Figure 10. The expected lifetime benefits to lifetime payroll taxes ratio in 2060*.
*This ratio is normalized to one for the case of dropouts, and we express the ratio of the remaining educational groups as a proportion of that number.

Table 12. Output, physical capital, and effective labor

	Output	Capital	Labor	Δ Output (%)	Δ Capital (%)	Δ Labor (%)
Experiment 0	2.4443	8.4840	0.7592	–	–	–
Experiment 1	2.3794	8.2124	0.7417	−2.7159	−3.2778	−2.3471
Experiment 2	2.5037	8.7497	0.7731	2.3656	3.0501	1.7871
Experiment 3	2.4504	8.5537	0.7574	0.1885	0.7421	−0.2777

Table 13. The pension system and the consumption tax rate[a]

	Payments	Taxes	Deficit	Cons. tax rate (%)
Experiment 0	18.5273	9.0564	9.4709	42.34
Experiment 1	20.0730	8.9254	11.1476	48.62
Experiment 2	16.5101	9.1515	7.3586	36.14
Experiment 3	17.6467	9.0435	8.6032	40.57

[a]Pension payments, tax collections, and pension deficit are expressed as a percentage of output.

Table 14. Gini indexes: income, earnings, wealth, and pensions

	Income	Earnings	Wealth	Pensions
Experiment 0	0.3192	0.3525	0.5419	0.2913
Experiment 1	0.3166	0.3555	0.5530	0.2410
Experiment 2	0.3253	0.3539	0.5335	0.2825
Experiment 3	0.3254	0.3556	0.5427	0.2445

would face tax equivalent to 4% in the benefit-to-tax ratio, but at the same time an average university-graduate household would receive an implicit subsidy of almost 13% of this same ratio. Our results are consistent with those found by Ayuso *et al.* (2016), who report that the link between heterogeneity in longevity and lifetime income across countries translates into an implicit tax/subsidy, with some rates reaching above 10%, and higher in some countries, for example Australia, Canada, and Germany.

In panel A of Figure 10, we continue to represent that same ratio, but considering the effects of the differential mortality by education in the long run, i.e., in 2060. This line now becomes steeper, showing that the growing trend in lifetime gaps increases further the regressivity of the Spanish public pension system in the long run. Specifically, our results show that this ratio would be 4% and 9% higher for secondary-school and university graduates. Notice also that our results show that the future financial situation of the pension system in Spain is dramatic, since we find that the system's long-term deficit exceeds 9% of output, which requires considerable increases in tax rates (see Table 13). This is because the Spanish government has recently eliminated the pension revaluation index, the most effective measure for containing the future increase in pension spending over the coming decades. Thus, the substantial expected increases in tax rates and the high welfare costs that this could bring about lead us to conjecture that further reforms lurk in the future of Spanish pensions.

6.2 The minimum pension

We begin our analysis with some of the alternatives available to the government to restore in the long term, the implicit progressivity of the pension system in 2018.

A direct way to recover all or part of the progressiveness of Spanish social security is through changes in the minimum pension, since this parametric change increases the lifetime benefits of low-educated households, which is precisely the socioeconomic group that proportionally receives this type of guaranteed minimum the most. Thus, in experiment 1 we assume that the minimum pension, as a share of per capita GDP, is increased by 50%, and the results show that this pension reform goes a long way as a tool to restoring pension progressiveness. Specifically, the benefit-to-payroll taxes ratio becomes 1.00, 0.92, and 0.87 (see panel B of Figure 10). This is because lifetime benefits increase by 22% in the case of an average school-dropout household, while this number is 10% in the case of secondary-school graduate households, while there is no significant variation in lifetime benefits for the average university-graduate worker. Note also that changes in lifetime benefits are not only due to a higher minimum pension, but also due to a longer retirement period, since a higher minimum pension encourages early retirement, especially for low-educated workers. In addition, earlier retirement reduces lifetime payroll taxes, this decrease being 3% in the case of school dropouts and 2% for secondary-school graduate workers.

The distributional consequences of this increase in the minimum pension are mixed. A higher minimum pension reduces the range of variability of pensions, thereby reducing pension inequality (see last column of Table 14). Thus, the pension Gini index decreases by up to 5 percentage points, from 0.29 to 0.24. Yet due to the lower saving rates, especially in those less-educated households, there is an increase in wealth inequality, as the wealth Gini index goes from 0.54 to 0.55. These two effects, however, tend to offset each other, so that the final effect of this pension reform on income inequality is almost null.

On the negative side, however, we find an increase in pension deficit due to both higher pension payments and lower payroll tax collections (see Table 13), so that the government would be forced to increase its revenues. In our case, where the model economy assumes that the consumption tax rate would adjust to clear the consolidated government budget, we find that this tax rate should be increased by a significant 6 percentage points, from 42.3% to 48.6%. Hence, it turns out that increasing pension generosity may be not convenient at all, given the reduced long-term potential ability of the Spanish government to increase taxes to finance pensions.

This reform also reduces the output (see Table 12). This is mainly because of the lower saving rates, which turns into a lower amount of physical capital and also a reduction in work hours due to the incidence of early retirement. Finally, we also compute the consumption equivalent measure (CEV) brought about by these pension reforms by asking by how much a newborn household's consumption has to be increased in all future periods and contingencies in experiment 0 (do-nothing pension policy with the long-term heterogeneous mortality risk), so that its expected future utility equals that under this reform. We find increasing the minimum pension brings about welfare losses for all newborns, so that the weighted average CEV is −2.8, and this is mainly due to the higher consumption tax rates needed to finance higher pension payments.[28]

6.3 Changes in the regulatory base

Experiment 2 assumes an increase in the number of years used to compute the regulatory base, from the last 25 years to the entire working lifetime. Our quantitative findings show that increasing the number of years used to compute the regulatory base is successful in reducing the regressivity of the system, since the lifetime-benefits-to-lifetime-taxes ratio becomes 1.00, 0.98, and 1.04, respectively (see panel C of Figure 10). This is achieved mainly through a reduction in pensions, since the average pension of school dropout, secondary-school, and university-graduate households decreases by 5.4%, 8.3%, and 9.3% respectively. In other words, the more educated the household the greater the drop in their pension, and the reason for this is that inequality in labor income increases in the later periods of working life. This same reason is behind the results of Jimeno (2003), who shows that the defined benefit Spanish retirement pension system with a short calculation period of the pension regulatory base produces higher pension inequality. That is, pension systems that only take into account labor income during the later years of working life for calculating the pension are less egalitarian than systems that take into account longer calculation periods or than pension systems based on the principle of defined contribution. Our results confirm this point, since the Gini index of pensions decreases from 0.29 to 0.28, so that pension benefits become more equally distributed (see Table 14).

There is another channel through which, although to a lesser extent, this reform affects the lifetime-benefits-to-lifetime-taxes ratio. This is the prolongation of the working lifetime of the more-educated households, which is due to the drop in the opportunity cost to keep working, which is precisely the retirement pension. Our results show that secondary-school and university-graduate workers delay retirement by 6 and 12 months, respectively. Consequently, these educational groups pay more payroll taxes during their working lifetime, which also helps to improve the redistribution of the pension system.

Finally, we also find that this reform increases output by more than 2% (see Table 12), mainly due to both the higher saving rates and the longer working career of more educated workers. More importantly, we find that this reform reduces the pension deficit by 2 percentage points of output and,

[28]We also simulated removing the cap on the payroll tax rate, and we find that it increases somewhat the progressiveness of the system, as more-educated workers increase their lifetime taxes, and it also reduces earnings inequality because of the lower net earnings of those workers located at the top of the earnings distribution. However, the budgetary implications for the pension system are rather limited, since this parametric change increases payroll tax collections by 0.5 percentage points of output at most. Moreover, as in the case of increasing the guaranteed minimum retirement pension, this parametric reform ends up with reduced output and welfare losses, particularly for highly educated and highly productive workers, where these losses may reach more than 4% in terms of the consumption equivalent variation.

consequently, the tax needed to balance the government budget, as the consumption tax rate decreases by more than 8 percentage points, or 15% (see Table 13). Therefore, despite the reduced retirement pensions, we also find that this reform produces an average welfare gain of 3.1% of lifetime consumption.[29]

6.4 Combining parametric changes

Our previous results show that an effective measure to restore progressiveness in the pension system is to increase the minimum retirement pension. This is because it increases pension benefits, especially for low-educated households. However, the aggregate and welfare effects of this parametric change mean that it may not be easily implemented. Conversely, an increase in the number of years used to compute the pension also increases the progressiveness of this system, although to a lesser extent, mainly by reducing the pension benefits of people with more education. However, unlike the increase in the minimum pension, this reform of the pension system reduces the long-term deficit of the system, and increases output and welfare.

Therefore, in view of the results we have obtained, a natural step is to evaluate both reforms jointly. Specifically, experiment 3 assumes that the minimum pension, as a share of per capita output, increases by 40%, and that the regulatory base is computed as the average labor earnings during the entire working lifetime.

The results show that these reforms, applied together, manage to fully restore the progressivity of the pension system (see panel D of Figure 10). Furthermore, the results also show that this reform does not produce a significant variation in the product, but does reduce the long-term pension deficit. Consequently, the consumption tax rate needed to finance this deficit is reduced, and the consumption equivalent variation is 1.1%.[30]

6.5 Sensitivity analysis

So far, we have assumed in our quantitative exercises that the growing trend in lifetime gaps would continue over the coming decades. We also simulated the aforesaid experiments under the assumption that the life expectancy differentials across groups in terms of remaining life-year gaps are held constant.

As expected, when we simulate experiment 0, we now find that the expected lifetime-benefits-to-lifetime-payroll-taxes ratio has a lower positive slope (see Figure 11), since this ratio is 1.0, 1.02, and 1.06 for average school dropouts, secondary-school, and university graduates, respectively. Put differently, the regressivity of the pension system hardly varies in relation to that observed in 2018. This then implies that the necessary changes in the pension system to reverse its regressivity are now minor. For example, in the case of the rise in the minimum retirement pension, we find that this increment, as a share of per capita GDP, should be around 40%, rather than the 50% of our previous simulations. Moreover, if such a parametric change is combined with an increase in the number of years used to compute the pension, we find that the rise in the minimum guaranteed pension should not exceed 20%.

[29]We also simulated the effects of doubling the amount of the fictitious estimates integrated into the Regulatory Base, where the rationale of this parametric change is based on the fact that low-educated workers are those who face a greater risk of being unemployed, so that this policy change should benefit this educational group more in comparison to its counterparts. Our results confirm this conjecture, since we find that lifetime benefits increase by 3.5% in the case of school-dropout households, but only by 1.5 and 0.5% in the case of secondary-school and university graduate workers, respectively. Yet the effect on progressiveness is rather slight.

[30]We also simulated reductions in the penalties or awards related to the moment of retirement from the labor force, aimed at increasing the progressiveness of the pension system, and we find that these parametric changes may not induce a significant change in the progressiveness of the pension system, since the changes in retirement behavior can partially or totally offset the changes entailed by these reforms.

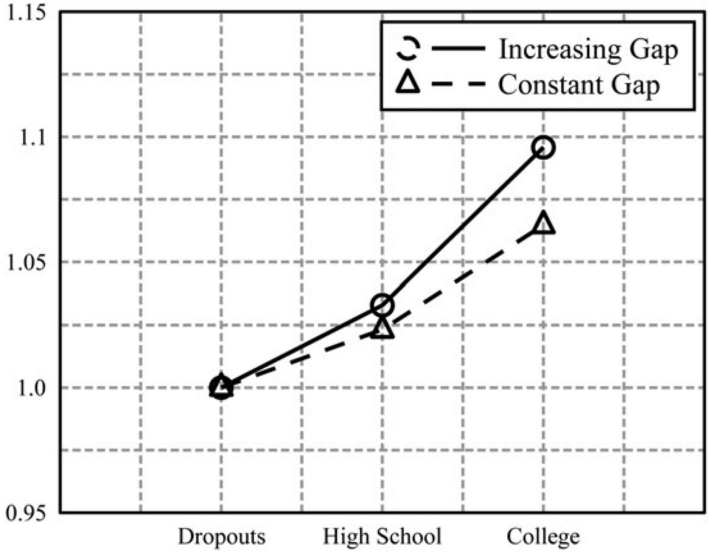

Figure 11. Expected lifetime benefits to lifetime payroll taxes in 2060 (experiment 0).

7. Conclusions

The gains in longevity over the last few decades have been unequal across the population, since it is the highly educated who have benefited more from these improvements than those individuals who have received less education. This situation could be problematic, since this increasing gap in life expectancy can undermine the progressiveness of some tax and transfer programs, such as public pension systems. In other words, life expectancy gains for more-educated people entail further additional years of pension benefits in comparison to those individuals not facing similar increases. In the specific case of Spain, we find that the gap in life expectancy totally reverse the progressiveness of the Spanish retirement pension program, and that an average low-educated household would face a tax equivalent to 4% of the benefit-to-payroll tax ratio, but at the same time an average university-graduate household would receive an implicit subsidy of almost 13% of this same ratio. Moreover, and if the trend of a growing gap in life expectancy continues, these taxes and subsidies will also continue to grow.

In order to avoid or mitigate the fact that income redistribution may be reversed by mortality differentials, it has been suggested that individuals should have several pension policies during their lifetime. For instance, two options could be the linkage of legal retirement ages with socioeconomic group-specific life expectancy or the use of differential pension indexation rules by socioeconomic group. At this point, however, it is essential to construct suitable indicators for capturing the difference in life expectancy, but the use of these socioeconomic indicators is controversial and is not exempt from design problems.

Alternatively, policymakers could implement parametric changes in the public pension system so that the degree of progressiveness of social security is preserved over time as the differences in life expectancy across education levels increase. These parametric changes involve modifying those elements that bring about the progressiveness of the system or pose some regressive features. At this juncture, a simple way to boost lifetime benefits for those low-educated households is through increases in the minimum retirement pension. However, concerns about pension systems' sustainability and the possible reduced ability of governments to increase public revenues may make this choice non-viable.

Also, the cap on the payroll tax could be eliminated, as this should help to increase both the progressiveness of retirement systems and payroll tax collections. However, the effect of this action as a tool for improving progressiveness may be rather limited. Moreover, eliminating the payroll tax cap would not solve social security's financial shortfalls, besides imposing economically damaging marginal tax rates on upper-income earners, and finally, as in the case of increasing the guaranteed minimum retirement pension, this parametric reform ends up with reduced output and welfare losses.

Lastly, those retirement pension systems, such as in France and Spain that are based on the principle of defined benefit and in which pension amounts are determined based on the contribution bases during a short period of working life, produce a greater degree of inequality than other systems that either take into account longer periods of individuals' working lives for the calculation of pensions or were based on the principle of defined contribution. Moreover, these systems involve taxes and subsidies on the labor supply that are not equally distributed throughout the working life of individuals, distorting individual lifecycle labor supply and savings decisions. Thus, increasing the number of periods used to compute the pension may have several positive aggregate effects, besides increasing pension progressiveness, for example, improving the pension system's sustainability, and increasing work hours, saving rates, and output. However, for the specific case of Spain, we find that a reform of the pension system that combines an increase in the minimum pension together with an increase in the calculation period of average labor income would fully restore the system's long-term progressivity of pensions, in addition to reducing the financial imbalance of the system, and simultaneously generating welfare gains. However, this option could only be a short- and medium-term solution in Spain if the gap in life expectancy continues to increase.

Of course, our quantitative conclusions could be affected in part by the assumed model structure. For example, we omit the fact that low-educated households enter the labor market earlier in comparison to their more-educated counterparts, so that our model economy could possibly underestimate lifetime payroll taxes for this educational group. Our quantitative exercises also present some limitations, since they rely on comparing a do-nothing steady-state allocation with steady-state allocations of economies that differ in pension rules. However, this strategy entails some limitations that could be avoided if one were to implement such an analysis throughout the transition. For instance, an increase in the number of years used to compute the pension, even if this increase were to occur gradually, could harm the well-being of older workers, since they are the ones with the least time remaining in the labor market to readjust their optimal decisions of hours worked and consumption before retirement. That is, unlike their younger colleagues, they would not have time to adjust to the new retirement rules and they would be forced to accept reductions both in their consumption and in their leisure. It could also be the case that the aggregate consequences initially appear in labor hours, and would then be reflected in the capital, as shown in Díaz-Giménez and Díaz-Saavedra (2009), so that the short-term variation in output differs from that same variation in the long run. Finally, because of the steady-state comparisons, the metric used to compute the progressivity of the pension system is based on periodic life tables – that is, the probability of surviving just depending on age and educational level and not on time. This could somehow affect the expected lifetime pension benefits received during the retirement period in particular, and consequently the regressivity obtained in our computations.

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Appendix

Appendix 1: Stationary equilibrium and calibration

In this appendix, we present in detail the equilibrium process of our model economy, and we also describe both all parameters and targets used to calibrate it.

Definition of a stationary equilibrium

Let $j \in J$, $h \in H$, $e \in \mathcal{E}$, $b \in B$, $p \in P$, and $a \in A$, and let $\mu_{j,h,e,b,p,a}$ be a probability measure defined on $\Re = J \times H \times \mathcal{E} \times B \times P \times A$.[31] Then, a stationary competitive equilibrium for this economy is a government policy, $\{G, P, Z, U, T_k, T_y, T_c, T_s, E\}$, a household policy, $\{c(j, h, e, b, p, a), l(j, h, e, b, p, a), a'(j, h, z, l, a)\}$, a measure, μ, factor prices, $\{r, w\}$, macroeconomic aggregates, $\{C, K, L\}$, and a function, Q, such that:

(i) The government policy satisfies the consolidated government described in expression (7).
(ii) Firms behave as competitive maximizers. That is, their decisions imply that factor prices are factor marginal productivities $r = f_1(K, L) - \delta$ and $w = f_2(K, L)$.
(iii) Given the government policy, and factor prices, the household policy solves the households' decision problem defined in expressions (13), through (19).
(iv) The stock of capital, consumption, the aggregate labor input, pension payments, unemployment benefit payments, lump-sum transfers, tax revenues, and accidental bequests are obtained aggregating over the model economy

[31]For convenience, whenever we integrate the measure of households over some dimension, we drop the corresponding subscript.

households as follows:

$$K = \int a \, d\mu$$

$$C = \int c \, d\mu$$

$$L = \int \epsilon_{jh} z e_j \, d\mu$$

$$P = \int p_h \, d\mu$$

$$U = \int ub \, d\mu$$

$$Z = \int t_r \, d\mu$$

$$T_c = \int \tau_c c \, d\mu$$

$$T_k = \int \tau_k y_k \, d\mu\%$$

$$T_s = \int \tau_p y^l \, d\mu\%$$

$$T_y = \int \tau_y \hat{y} \, d\mu\%$$

$$E = \int (1 - \psi_j)(1 + r)a' \, d\mu$$

where all the integrals are defined over the state space $\aleph$.

(v) The goods market clears:

$$C + \int (a' - (1 - \delta)a) d\mu + G = F(K, L). \quad (26)$$

(vi) The law of motion for μ_j is:

$$\mu_{j+1} = \int_{\aleph} Q d\mu_j. \quad (27)$$

Describing function Q formally is complicated because it specifies the transitions of the measure of households along its six dimensions: age, education level, employment status, pension rights, pensions, and assets holdings. An informal description of this function is the following: We assume that new-entrants, who are 20 years old, enter to the economy as workers, or unemployed, following the shares of these groups for the 20–24 cohort in the Spanish economy in 2018, and that they own zero pension rights and assets. Moreover, workers enter the economy with a stochastic productivity that they draw from the stochastic component of their endowment of efficiency labor units from its invariant distribution. Their educational shares are exogenous. The evolution of μ_{jh} is exogenous, it replicates the distribution by age and education of the Spanish population in our calibration target year, 2018. The evolution of μ_{je} is governed by the conditional transition probability matrix of its stochastic component, the exogenous probabilities to find or lose a job, and the optimal decision to retire. The evolution of μ_{jb} is determined by the rules of the Spanish public pension system, and for the optimal decision to how much to work. The evolution of μ_{jp} is determined by the rules of the Spanish public pension system, and for the optimal decision to retire. The evolution of μ_{ja} is determined by the optimal savings decision.

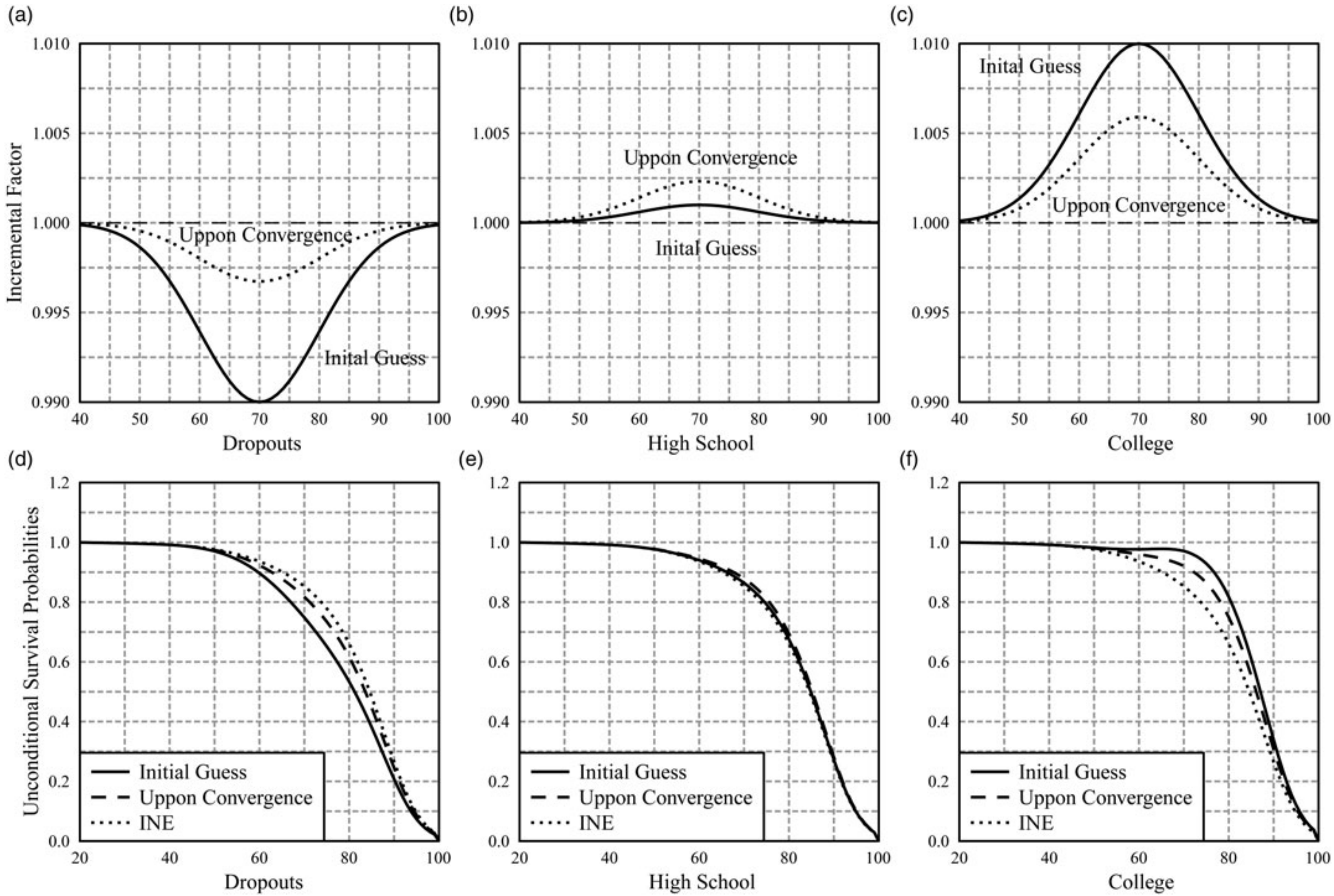

Figure 12. The unconditional survival probabilities by education at 2060.

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Appendix 2: Mortality risk across educational groups

A problem we have faced when carrying out our quantitative exercises is the lack of data regarding the mortality risk across the different educational groups. Therefore, and to solve this lack of data, we have had to estimate it, for which we have carried out a process that consisted of two stages. First, and from the data reported by Permanyer *et al.* (2018), we extrapolate current tendencies on life expectancies at age 35 by educational type over the coming decades. The result is shown in panels A and B of Figure 2. Panel A of this figure shows that LE at age 35 in 2060 will be 52.2 years for dropouts, 56.1 years for high-school graduates, and 58.4 years for college graduates. Consequently, panel B shows that the gap in LE by educational type would continue to increase steadily, and that the difference in this variable between high-school graduates and dropouts would increases from 2.1 years in 2012 to 3.9 years in 2060, and from 3.43 to 6.19 years during the same period for the case of college graduates and dropouts.

Then, and with these numbers and the future average age-dependent survival probabilities projected by the Spanish National Institute of Statistics (INE), we use iterative methods to estimate the survival probabilities according to age and educational type for future cohorts. To do so, we introduce two assumptions, which are backed by empirical evidence related to survival risk by socio-economic groups. The first assumption states that the probabilities of survival conditioned by age differ across the educational types from the age of 40. The second assumption states that the difference in these probabilities between educational groups grows until around the age of 70, and then decays. Note that these assumptions are consistent with the evidence found for various countries, such as Denmark, Sweden, and Spain.[32] Consequently, we assume that up to 39 years of age all educational groups have a probability of survival conditioned by age equal to those reported by the INE. Then, and for each educational group, we use the survival probabilities calculated by the INE together with a guess for an incremental factor on these probabilities between the ages of 40 and 100. The top panel of Figure 12 shows this incremental factor for each educational group.

With these guesses, we then use these initial survival probabilities (see the bottom panel of Figure 12) to compute the life expectancy at 35 years of age and compare it with the value reported by Permanyer *et al.* (2018). If the number obtained in life expectancy differs from the numbers estimated by Permanyer *et al.* (2018), we adjust this factor for each of the ages, and we recalculate the life expectancy implied by the new probabilities of survival. We continue with this process until the probabilities obtained with this method coincide with those reported by Permanyer *et al.* (2018). Finally, to obtain the probabilities of survival by educational type in 2060, we proceed in an analogous way, with the difference that the life expectancy at 35 years of age that we set as an objective, is that which we previously projected.

[32]See Brønnum-Hansen (2017), Van Raalte *et al.* (2012), and Permanyer *et al.* (2018).

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