A WORKER'S BACKPACK AS AN ALTERNATIVE TO PAYG PENSION SYSTEMS

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Abstract
Facing an ageing population and historical trends of low employment rates, pay-as-you-go (PAYG) pension systems, currently in place in several European countries, imply very large economic and welfare costs in the coming decades. In an overlapping generations economy with incomplete insurance markets and frictional labour markets, an employment fund, which can be used while unemployed or retired, can enhance production efficiency and social welfare. With an appropriate design, the sustainable Backpack employment fund (BP) can greatly outperform (measured by average social welfare in the economy) existing PAYG systems and also Pareto dominate a full privatization of the pension system, as well as a standard fully funded defined contribution pension system. We show this in a calibrated model of the Spanish economy, by comparing the effect of its ageing transition under these different pension systems and by showing how a front-loaded transition from the PAYG to the BP system can be Pareto improving, while minimizing the cost of the reform. (JEL: C68, H55, J26)

Teaching Slides
A set of Teaching Slides to accompany this article is available online as Supplementary Data.

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1. Introduction

Advanced economies in the 21st century are characterized by their ageing population and relatively low employment rates, are threatened by automation, and in some cases have prevailing rigidities in labour markets. For most countries, ageing means a persistent change of the dependency ratio between retired and working age groups, which we call the ageing transition.[1] Furthermore, the financial and euro debt crisis, the COVID pandemic crisis, and now the war in the Ukraine, with its trade, energy market, and inflationary distortions, have put the fiscal capacity of most European countries under stress, especially those with unfunded social insurance systems such as pay-as-you-go (PAYG) retirement pensions. For these economies, unfunded can only mean bankrupt—that is, partial default in pension entitlements—or disruptively high and greatly distorting payroll taxes to finance those promises. Governments in these countries can either face this latter choice or change their PAYG system. Other so-called social security reforms that do not face these choices are bound to face a major social security crisis.

Since the pioneering work of Auerbach and Kotlikoff (1987a, b), there has been an extensive, theoretical, quantitative, and empirical literature comparing social security systems. Early examples of studies on the economic and welfare implications of Social Security reform, in particular transitions from unfunded to private savings (PS) or fully funded (FF) retirement finance systems are Kotlikoff, Smetters, and Walliser (1998, 1999) and De Nardi, İmrohoroğlu, and Sargent (1999). Our paper contributes to this literature in five dimensions. First, we build and calibrate a quantitative framework—an overlapping generations model with rich intra- and inter-generational heterogeneity and labour market frictions—suited for quantitative evaluation of social and labour market policies (pension systems, as in this paper, and unemployment insurance, minimum income programs, etc.). The framework allows us to study the interaction between optimal life-cycle consumption, savings, labour market and retirement decisions, and government tax and transfer programs, in particular retirement pension systems.[2] Second, we integrate in the framework the foreseen ageing transition, which reveals that the problem with unfunded PAYG systems is not only their financial sustainability through the reform-transition but, more importantly, that it is a very inefficient system in an aged society. Third, we focus on a worker's "Backpack" (BP), an employment fund that can be used during unemployment and after retirement, which has not been studied as an alternative to the PAYG, and show not only that the BP outperforms it, but also that it dominates—in allocation efficiency and welfare—alternative systems often studied in the literature, such as FF defined contribution pension systems, or pure

1. This persistent change of the dependency ratio is the result of the transformation of the population pyramid from the the existing one at the beginning of the 21st Century to one with a stable aged distribution (Spain from 2018 to 2068 in our simulations). The "ageing transition" is an aftermath (or last stage) of the "demographic transition" or shift from high birth and death rates to low birth and death rates.

2. We use the same framework in the related work Brogueira de Sousa, Díaz-Saavedra, and Marimon (2022), where we study "steady-state" comparisons of different social security system for Spain in 2018.

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PS systems. Fourth, by showing that, given the large long-run steady-state welfare gains of having a funded system, it is possible to finance with debt a Pareto improving transition (i.e. without losers) between the current PAYG and these funded systems—as long as interest rates on the PAYG "entitlement debt" are not too high—in particular, a transition to the dominant BP system. Finally, accounting for the ageing transition, we show that a front-loaded fast transition minimizes the costs of implementing a Pareto improving reform from the PAYG to a BP system.

The basic features of a BP employment fund that we study are: It is a fund contract with the employee, which accumulates the individual savings of a basic payroll tax (BP tax), while working; it is transferable across jobs and can be used during periods of unemployment and finally as a pension fund; and it earns a market interest rate, but there are restrictions in its use (e.g. additional individual contributions are restricted and the worker may only be able to use it if he or she is unemployed or retired). While different forms of private employment funds are not a novelty in some countries, such funds are not common as part of the public insurance policy.[3] Austria in 2003 is an example in which a (small) BP-type employment fund was introduced during a reform of the tenure based severance pay system to improve flexibility in the labour market.[4] One of the main features that distinguishes the BP system from a standard defined contribution public pension system is its additional flexibility in allowing for withdrawals during unemployment spells. While some retirement plans and individual retirement accounts in some countries allow for early withdrawals, these often come with penalties or unfavourable tax treatment. Recently, in the wake of the coronavirus pandemic, several countries have implemented temporary measures in order to make mandatory retirement savings more flexible, by expanding withdrawal options with favourable tax treatment and increasing borrowing possibilities for workers facing pandemic related financial consequences.[5]

Our work builds directly on two models: the model of Díaz-Giménez and Díaz-Saavedra (2009) and Díaz-Giménez and Díaz-Saavedra (2017), developed to study pension system reforms in Spain using overlapping generations general equilibrium models, and the model with job creation and destruction with search frictions and three employment states (employed, unemployed, and inactive) of Krusell et al. (2011), further developed in Ábrahám et al. (2022) to study unemployment insurance reforms in Europe. Our benchmark model economy allows for a detailed description of the Social Security system: There are transfers for low-income households, a

3. One example of a private funding scheme is the TIAA-CREF (Teachers Insurance and Annuity Association-College Retirement Equities Fund, which is a non-profit employment fund founded by Andrew Carnegie in 1918 and today serving over 5 million active and retired employees; it has played, and plays, an important role in enhancing mobility among university professors across US universities. However, it is a retirement fund not designed to provide unemployment insurance, while the BP provides both forms of insurance.

4. See Kettemann, Kramarz, and Zweimüller (2017) for the details of the reform.

5. Two examples are the CARES Act in the United States and the legislative package by the Australian government, both enacted in March 2020.

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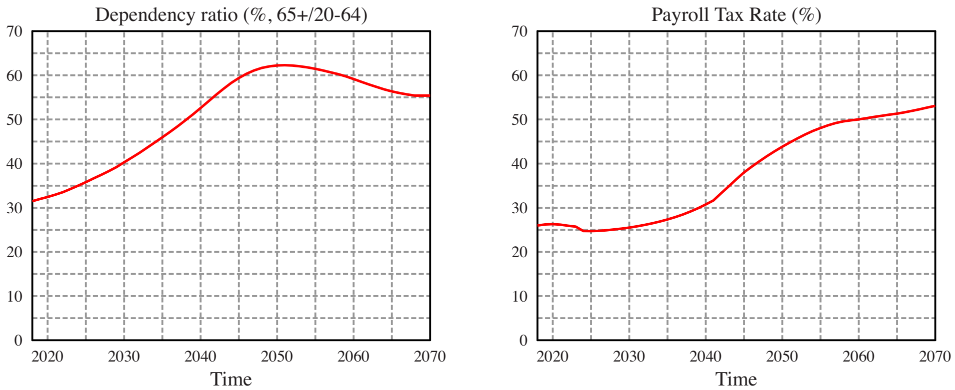

FIGURE 1. The expected evolution of the dependency ratio and payroll tax rate in Spain.

public unemployment insurance, and a PAYG pension system, financed with payroll taxes. Agents find jobs in a stochastic search environment and, while working, face idiosyncratic productivity shocks, as well as layoff shocks. After a certain age, a worker can choose to retire. These exogenous factors and their optimal work and search decisions generate a labour market distribution of households into employed, unemployed, inactive, and retired. In addition to payroll taxes, there are income, consumption, and capital taxes. An aggregate production function and a government that must balance the budget complete the model. The model is calibrated to the Spanish economy with its public policies in 2018, as an initial steady state. We simulate the economy in the following decades, accounting for the projected demographic changes in the age and education distributions.[6]

Spain is a particularly interesting economy to study. Unemployment is high and highly volatile, population is ageing, and the PAYG system, which had a separate budget and fund, has seen its social security fund being depleted in the aftermath of the euro-debt crisis. If one assumes that the current system prevails in the next decades, given the expected fall of the employees/retired ratio, fulfilling the unemployment insurance and pensions promises will be extremely costly and distorting, as Figure 1 obtained with our calibrated model shows: Doubling the dependency ratio implies that to fulfil unemployment benefits and pension promises the distorting payroll tax also needs to be doubled.[7]

6. Unfortunately, the most recent and reliable long-term demographic forecasts do not incorporate the effect of the COVID-19 crisis. Nevertheless, this may not substantially change our results since there has been a reduction in the number of retired, but also of employed and, looking further ahead, births.

7. Some reforms, or more appropriately, parametric changes to the PAYG system have had a positive, but almost negligible, effect in reducing social security liabilities. The small reduction of the payroll tax in the 2020s captures the effect of two reforms in 2011: increasing the number of years of labour income used to compute the pension, from the last 15 to the last 25, and increasing the legal retirement ages in one more year (see Online Appendix G for a description of the Spanish PAYG).

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Figure 1 is also behind the results of other studies of the Spanish pension system, namely that with the ongoing ageing process of the population, its sustainability is under immense pressure.[8] Many advanced economies are, or will be, going through similar ageing transitions and the concern about the sustainability of the unfunded PAYG system with ageing populations and the difficulties to replace it with a funded system are neither unique nor new.[9] In a 21st century perspective, the main problem is not the efficiency or sustainability of the PAYG system in itself, but the large and perverse effect of the system with an ageing population: It deters late retirements when life expectancy is high and its financing, with distortionary taxes, may further depress labour supply (see Erosa, Fuster, and Kambourov 2012 and Cooley, Henriksen, and Nusbaum 2020).

We assume that after the ageing transition the economy reaches a new steady state. We then compare the PAYG steady state with three alternative steady states for the same economy with the same policies and institutions, except for the PAYG system, which is replaced by a: (i) private savings (PS), an economy without public pensions in which households' retirement is fully financed by the proceeds of their PS at the risk-less interest rate; (ii) a fully funded pension fund (FF), financed with a defined contribution rate (a payroll tax), and, upon retirement, an actuarially fair annuity, and (iii) the BP fund, as already described. In the latter two economies, households can complement the retirement (forced) savings with PS, and to determine the retirement fund savings rate, we search for the welfare maximizing contribution, which is 16% for the FF fund and 22% for the BP fund.

Both the aggregate and individual level effects of eliminating (PS) or replacing the PAYG system (with the FF & BP alternatives) are very large. There are differences amongst the three alternatives but in relation to the benchmark PAYG economy they are very similar. Overall these alternative economies are more productive (working hours per worker are lower but aggregate labour supply is higher) and agents benefit from higher consumption. As a result, the average welfare increase—measured as consumption equivalent variation (CEV)—of replacing PAYG by PS is 26.5%, replacing it by FF 30.9%, and by BP 36.1% in the long-run. Furthermore, all households gain from these reforms of the PAYG system. Behind these huge welfare gains, there is a factor that partially explains them: while the steady-state effective labour tax[10] is 65.6% in the benchmark PAYG economy, in the alternative economies is: 37.8% PS, 43.9% FF, and 47.9 BP. Even in the alternative system with the largest social

8. The already mentioned Díaz-Giménez and Díaz-Saavedra (2009) and Díaz-Giménez and Díaz-Saavedra (2017), as well as Rojas (2005), De la Fuente, García Díaz, and Sánchez (2019), de Cos, Jimeno, and Ramos (2017), and García-Gómez et al. (2020).

9. Early warnings, stressing the general dynamic equilibrium effects, are Conesa and Krueger (1999) and De Nardi, İmrohoroğlu, and Sargent (1999); see Aubuchon, Conesa, and Garriga (2011) for an introduction to the replacement problem.

10. The effective labour tax, τ_e, is given by $(1-\tau_e) = (1-\tau_y)(1-(\tau_p+\tau_x))/(1+\tau_c)$, where τ_y is the income tax, τ_p the payroll tax, τ_c the consumption tax, and τ_x is the fund tax; that is, $x = f, b$ in FF and BP, respectively, and $\tau_x = 0$ in PAYG and PS.

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insurance coverage (the Backpack), the effective labour tax is substantially lower. In fact, the reduction of labour supply distortions is a feature of optimal reform designs (see Conesa and Garriga 2008).

Our work also helps to elucidate the non-obvious welfare differences amongst the three alternatives to PAYG. The economies with an employees' fund dominate the *laissez-faire* PS economy in aggregate welfare mainly for two reasons. First, as it is common practice with social security funds, (forced) savings into the fund are not part of taxable income, but if there are capital gains these are taxed as other capital gains. Second, when a worker decides to retire, the accumulated assets in the fund account can be used as PS or, as we have seen, converted into an actuarially fair annuity. As existing employees' funds, FF and BP funds can be managed privately (with proper regulations). Therefore, one can argue that the possibility to transform assets into actuarially fair annuities could also exist in the PS economy, which would increase its estimated welfare gains. However, while these contracts exist in advanced economies, these markets are thin and having them as part of a large public pension program can change their relevance and fairness; in particular, guaranteeing that the reform preserves a valued feature of a sustainable PAYG system (i.e., that a worker upon retirement can have a stable source of income).[11]

The BP is the winner of the race amongst the four social insurance systems because, in contrast with the other three systems, it provides additional unemployment insurance. As we show, with the BP households can better manage the loss of income during periods of unemployment, as well as their lifetime consumption profile. This individual gain translates into better employment choices, which in turn aggregate into the general equilibrium effects that make the BP economy the most (constrained) efficient amongst the four we analyse. In making welfare comparisons, (e.g. to compute optimal BP contributions or to compare different pension systems) our reference is the welfare of the entering cohort, at the age of 20, in the final steady state, when the "aged population" dependency ratio is constant and all PAYG claims have already been covered by the "entitlement debt".

Importantly, we provide an analysis of a Pareto improving transition from the PAYG to the BP social insurance system. In an economy that will go through an ageing transition in the coming decades, the well known problem of how to design a transition without losers is aggravated (e.g. Aubuchon, Conesa, and Garriga 2011). Our transition relies on the large long-term welfare gains of having the BP (or FF or PS) instead of the PAYG, which provides fiscal space to compensate the initial cohorts who are entitled to PAYG entitlements. Uncovered PAYG liabilities, due to workers moving from the PAYG to the BP, are funded with public debt. We take as a benchmark a low interest rate environment, in line with recent conditions in the Euro area and globally. The fast ageing process (see Figure 1) dictates the need to anticipate the social security reform, before the ageing transition takes place. We show that this is possible,

11. In well designed credible funds, such as in the Swedish social security system, the retirement entitlements are conditional on the fund's returns; in our simulated economies, there is no aggregate uncertainty at the steady state and, therefore annuities are constant.

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in the case of Spain, with a front-loaded transition, in which BP asset transfers make the BP system (weakly) preferred to the PAYG by the working age population, from the first year of the reform, limiting PAYG claims to those of the retirees that year. Public debt finances the BP asset transfers and these PAYG liabilities. In our calibrated Spanish economy, this level of debt is relatively high: 203% of GDP in the first year, 2019, increasing to 340% at the end of the transition (late 2050s) when there are no more PAYG liabilities. To put this figure in perspective, Conesa and Garriga (2008) calculate the implicit debt in the US Social Security system in 2005 to be 2.2 times GDP, in a steady state without accounting for the demographic evolution.[12]

We study Spain as a relatively small open economy in which interest rates and wages that households face are taken as given. In Online Appendix A, we provide an abridged account of the parallel analysis of Spain as a closed economy. In both, the open and the closed economy, the interest rate on sovereign debt is the "global economy" safe rate (in our baseline simulations, 1%). In the closed economy, the general equilibrium effects of reforming the Spanish unfunded PAYG system for a funded system are much larger than in the open economy (due to a reduction of interest rates and increase in wages). Similarly, the closed economy exacerbates the differences across alternative pension systems, while amongst them the BP system still dominates.

Our paper is closely related to the literature on the sustainability of Social Security systems in economies with ageing populations. Kitao (2014) considers four options to make the U.S. Social Security system sustainable taking into account the ongoing ageing process that increases the dependency ratio in the population. These options involve increasing taxes or decreasing benefits (by increasing the minimum retirement age, decreasing the pensions replacement rate, or making the system means-tested and letting benefits fall with income). Despite all options making the system sustainable, the paper finds significant differences amongst alternatives in the aggregate and individual level responses, as well as heterogeneous distribution of welfare costs during the transition. As in Kitao (2014), individuals in our model make decisions on consumption, savings, labour force participation, and hours of work over a life cycle. In contrast, our analysis considers the replacement of an unfunded PAYG system with alternative funded systems (by construction, sustainable regardless of the demographic structure) and constructs Pareto improving transitions in which no generation is worse off with the reform.

McGrattan and Prescott (2017) engineer a Pareto improving transition for the U.S. economy, whereby the dependency ratio increases from 25% to 41% (i.e. from 4 workers per retiree to 2.4) without debt financing. Aside from the fact that the U.S. is a milder ageing transition from a better initial position than the Spanish one, there are important differences in their work with the transition we analyse. Their main

12. Note that to know the "entitlement debt", we need to compute the transition, which—in the case of BP or FF—requires to know the corresponding optimal contribution and, to find the latter, we need to know the interest rate cost of the "entitlement debt"; a complex fixed-point problem that we solve computationally.

transition is not from a PAYG to a Fund (in our case, the BP), but from transfers to the retirees paid by current payroll taxes to a system in which the transfers are paid from the general federal budget, which is subject to a timely overhaul of the tax system. We compare different social security systems without resorting to a major overhaul of the tax system and, in contrast with them, the transition of the PAYG to the BP system is financed with public debt, taking advantage of the long-term gains of the reform and the existing low interest rates. In this dimension, our work is closer to Conesa and Garriga (2008), who study optimal reform of Social Security as a Ramsey problem. In their baseline policy exercise, the planner is constrained to a single tax instrument (labour income tax), individual asset transfers, and government debt. We follow this approach and study the transition into a BP system with debt issuance and initial BP asset transfers to the young cohorts. Other related papers in the quantitative literature on Social Security reform are Imrohoroğlu and Kitao (2012), Díaz-Giménez and Díaz-Saavedra (2009), and Díaz-Giménez and Díaz-Saavedra (2017). In addition to the labour supply decision (intensive and extensive margins), our model includes job search effort over the life-cycle, which produces three possible labour market states: employment, unemployment, or inactive. Our analysis shows how labour supply and job search, especially at older ages, respond significantly to changes in taxes and retirement pension rules.[13]

The related finance literature focuses on the portfolio choice over the life cycle within a partial equilibrium framework (Cocco, Gomes, and Maenhout 2005) and how accounting for this choice can help the design of social security systems. Agents in our model make a limited portfolio choice in private assets and BP assets during unemployment and at retirement taking into account the annuity value of BP asset after retirement (Larsen and Munk 2023). Similarly, recent work emphasizes the possible gains of having age-dependent taxes or flexible defined contributions plans (Schlafmann, Setty, and Vestman 2020). These are improvements that could be added to the BP design that we consider, but on this we also have followed a parsimonious approach.

The next section presents our model economy, Section 3 describes our calibration, Sections 4 and 5 the steady-state results, Section 6 the transition from the PAYG to the BP security system, and Section 7 concludes.

2. The Model Economy

This section presents the model economy at a steady state. We study an overlapping generations (OLG) economy with heterogeneous households, a representative firm,

13. In related work, de la Croix, Pierrard, and Sneessens (2013) study the consequences of ageing and pension system reform in a model with search and matching frictions, and show that changes in participation rates of older workers is an important margin of adjustment. The paper compares predictions about pension system reforms in a model with labour market frictions to the competitive economy benchmark, and concludes that labour market frictions are important. In our model, labour market frictions also help to explain participation over the life cycle, and use it to study alternative reform scenarios and their fiscal and welfare implications.

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and a government. The OLG framework is based on Díaz-Giménez and Díaz-Saavedra (2009), with job creation and destruction and dynamic work and search decisions as in Ábrahám et al. (2022). Readers familiar with these economies, or mostly interested in our results, may prefer to skip this section.

Time is discrete and runs forever, and each time period represents one calendar year. During transitional dynamics, out of a steady state, all variables depend on calendar time t, but in this section, we omit this dependence and use a recursive formulation in the description of the decision problems given below.[14] In the main text, we maintain the assumption that Spain is a small open economy. The risk-free interest rate is taken as given. We present our results under a closed economy setting in Online Appendix A. We begin with a description of household heterogeneity.

2.1. *The Households*

Households in our economy are heterogeneous and differ in their age, $j \in J$; in their education, $h \in H$; in their productivity level $z \in \mathcal{Z}$; in their labour market status $s \in S$; in their private assets, $a \in A$; and in their BP savings, $b \in B$. Sets J, H, $\mathcal{Z}$, S, A, and B are all finite sets and we use $\mu_{j,h,z,s,a,b}$ to denote the measure of households of type (j, h, z, s, a, b). They also differ in their claims to different social insurance systems: unemployment benefits UB, retirement pensions P, and government transfers TR. 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 $T = 100$ at the latest. Therefore, $J = \{20, 21, \ldots, 100\}$. The parameter ψ_j denotes the conditional probability of surviving from age j to age $j + 1$. The notation makes explicit that the exogenous probabilities depend on age j, but not on education or other factors.

Education. Households can 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.

Labour Market Productivity. Individuals receive an endowment of efficiency labour units every period. This endowment has two components: a deterministic component, denoted $\varepsilon_{h,j}$ and a stochastic component, denoted by z. The deterministic component

14. In a steady state, as defined below, all aggregate variables are constant and the exogenous age-education distribution is also constant. During transitional dynamics, the dependence on t comes from the ageing transition that is modelled as a change, over time, of the age-specific survival probabilities, and the share of age groups and education levels as new cohorts enter the economy, as well as from any changes to policy variables such as taxes or parameters governing the retirement pension system.

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depends on the household's age and education, and we use it to characterize the life-cycle profiles of earnings. The stochastic component is independently and identically distributed across the households, and we use it to generate earnings and income dispersion in the economy. 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 conditional transition probabilities given by Γ

$$\Gamma[z'|z] = \Pr\{z_{j+1} = z'|z_j = z\}, \text{ with } z, z' \in Z. \tag{1}$$

Every period agents receive a new realization of z. Total labour productivity is then given by $\varepsilon_{h,j}z$. A worker who supplies l hours of labour, when the economy-wide wage rate is ω, has gross labour earnings y given by

$$y = \omega \varepsilon_{h,j} z l. \tag{2}$$

Labour Market Status. In the model, an agent is employed, unemployed, non-active, or retired. Among the unemployed, there are individuals who are eligible to receive unemployment benefits and access their BP savings (workers who have recently been laid off), and others who are not eligible (either because eligibility expired, or because they quit work). Workers decide when to retire, leaving the labour force permanently once they do. Upon entering the economy, individuals randomly draw a job opportunity and then decide to work or not during the first period. Similarly, in subsequent years the labour market status evolves according to both optimal work and job search decisions (described below), and exogenous job separation and job finding probabilities.

Employed. An individual with a job at hand in the beginning of the period, and who decides to work, is employed in that period and his labour market status is denoted by $s = e$. An employed worker provides labour services and receives a salary that depends on his efficiency labour units and hours worked. Workers face a probability of losing their job at the end of the period, denoted σ_j. This probability is age dependent, and we use it to generate the observed labour market flows between employment and non-employment states within age cohorts.

Unemployed. An agent may not have a job opportunity at the beginning of a period, because he lost his job last period, because he quit his job, or because he was unemployed last period and did not find (or did not accept) a new job offer. Without a job, agents may actively search for a job offer next period. If they do actively search, we label them as unemployed. Unemployed agents who have lost a job are eligible for unemployment benefits (we refer to them as *unemployed eligible*, with $s = ue$). A formal description of eligibility criteria is given below. Agents who have quit work are not eligible for unemployment compensation (we often refer to this group as *unemployed non-eligible*, $s = un$). Active job searchers receive a job offer at the end of the period with probability $\lambda_j^{\mathbf{u}}$. This probability is again age dependent, and we use it to generate the observed labour market flows between unemployment and employment.

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Non-Active. Agents without a job and who do not actively search for a new one are labeled non-active, with $s = n$. Those agents are not eligible for unemployment benefits, and receive a job offer for next period with a lower probability than an unemployed agent, $\lambda_j^{\mathbf{n}} < \lambda_j^{\mathbf{u}}$. This probability is also age dependent, and we use it to generate the observed labour market flows between non-activity and employment.

Retirees. In our model, workers optimally decide whether to retire and leave the labour force. They take this decision after observing their current labour productivity. If they decide to retire, $s = r$, they lose the endowment of labour efficiency units for ever and exit the labour market. Depending on the pension system in place, they may receive retirement pension payments after retirement.

Private Assets. Households in our model economy endogenously differ in their asset holdings, that 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 $a \in A$. Different retirement pension systems affect the agents' PS decisions.

Backpack Assets. Workers accumulate BP savings while they work. These savings result from a mandatory contribution out of workers' salaries, and are invested in productive capital and earn the real rate of return in the international capital market. When workers loose a job and search for a job, they can access their accumulated savings and decide how much to keep in their individual accounts or how much to use to finance consumption while unemployed. At retirement, BP assets are converted into retirement pension payments (an actuarially fair life annuity).

Households derive utility from consumption, and disutility from labour and the search effort. Labour is decided at both the extensive and intensive margins, while search is a discrete choice. Non-active and retired agents dedicate all the time endowment to leisure consumption. Accordingly, lifetime utility is given by

$$\mathbb{E} \sum_{j=20}^{100} \beta^{j-20} \psi_j [u(c, l) - \gamma e], \tag{3}$$

where β is a time discount factor, u satisfies standard assumptions, c is consumption, and l is labour supply, and γ represents a job search utility cost. l can take values between 0 and 1, while e equals 1 in periods of active job search and is zero otherwise. Survival probabilities ψ_j determine average life expectancy in the economy, a central object in our analysis.[15]

At this point, it is useful to clarify the timing of events within a period. At the beginning of each period, z, households' stochastic productivity component, is realized. When entering the economy (at age 20), agents additionally learn their education level

15. Fertility and immigration flows are exogenous. Note that preferences for leisure are not age-dependent, while labour productivity is.

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and draw a job opportunity, which they can either accept or reject. For older households, if they start a period with a job opportunity, they decide whether to work and if so, by how much. If they lost a job or decided not to work in the previous period, they choose whether to search for a new job or not. Depending on these decisions, individuals then spend the period working, unemployed, or inactive. Wages and unemployment benefits are received, and decisions on consumption and savings are taken. At the end of the period, workers observe the job separation shock, and unemployed or inactive learn if they have found a job for next period. Households can choose to retire at the beginning of the period, and once they do they leave the labour market permanently.

2.2. *The Firm*

In our model economy, there is a representative firm. Aggregate output depends on aggregate capital, K, and on the aggregate labour input, L, through a constant returns to scale, Cobb–Douglas, aggregate production function:

$$Y = K^{\theta}(L)^{1-\theta}. \tag{4}$$

Factor and product markets are perfectly competitive and the capital stock depreciates geometrically at a constant rate, δ. The firm rents capital in the international capital market at an interest rate r, and hires workers in the domestic market at a wage rate ω per efficiency unit of labour. Under these assumptions, the international interest rate r pins down the wage rate ω.

2.3. *Backpack System*

The BP economy features a FF pension system, funded by individual worker contributions. Workers may choose to use all or a fraction of the BP savings during periods of involuntary unemployment. Every individual enters the economy without BP claims. For every period of employment, a worker sees a fraction τ_b of his gross labour earnings deducted and invested into a personal employment-linked savings account, which is remunerated at the capital market rate of return, r. If b is the level of BP assets at the beginning of an employment period, then next period's BP b' evolves according to

$$b' = \tau_b y + (1 + r(1 - \tau_k))b, \tag{5}$$

with τ_k being the capital income tax rate. When a worker loses his job, his BP assets can be allocated to finance consumption (present or future, as he can choose to save the BP assets). How much to reduce his BP assets becomes a choice variable for the involuntary unemployed. In contrast, if a worker chooses to quit his job, while still in the labour force, he keeps the BP but cannot withdraw. In that period, the BP evolves according to

$$b' = (1 + r(1 - \tau_k))b. \tag{6}$$

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Upon retirement, BP assets can be used to buy a lifetime annuity or added to PS. If the worker decides to retire at age R and allocate b amount of BP savings to the purchase of the annuity contract, he receives in return

$$p^B(b) = \frac{(1+r)^{R-T}}{\sum_{j=R}^{T} \psi_j} b. \tag{7}$$

The aggregate amount of BP assets is invested in the capital market and adds to the stock of productive capital available in the economy. Since this is an individual, FF system, the aggregate amount of BP assets used to purchase annuity contracts equals the total amount of annuity payments received by retirees.

2.4. *The Government*

Before we specify the government budget constraint, we describe the government programs other than retirement pensions discussed above.

Unemployment Benefits. The government taxes workers and provides unemployment benefits to the unemployed. Eligibility for unemployment benefits—denoted $\mathbb{1}_{UB} = 1$, below—is conditional on: (i) having lost a job (i.e. a job separation) and not having started a new job yet, (ii) on actively searching for a job, and (iii) having been unemployed for fewer than a given number of periods, $\bar{d}$. Eligibility expires when one of the conditions is not met, and non-eligibility is an absorbing state. Eligible agents receive unemployment benefits given by $u_b = b_0 \bar{y}_{h,j}$, where $b_0 \in (0, 1)$ is a replacement rate and $\bar{y}_{h,j}$ is the average labour earnings of workers with education h and age j. Unemployment benefits are financed with payroll taxes, described below.

Other Transfers. Households below an income level $y < \overline{t_r}$ receive a transfer from the government, denoted TR. Eligibility for transfers is conditional on income only and denoted by $\mathbb{1}_{TR} = 1$. Eligible households receive an amount $t_r = b_1 \overline{t_r}$.

We model the government budget with two separate restrictions. Unemployment benefits and unfunded pension payments, in the case of the *PAYG* system, are financed with payroll taxes and form the social security budget. Other government expenditures and revenues form the overall government budget. In the *BP* economy presented here, retirement pensions are FF and therefore are not a government expenditure.

The government taxes capital income, household income, and consumption, and it confiscates (part of the) unintentional bequests. It uses its revenues to finance an exogenous flow of public consumption and to service debt, and to make transfers to poor households. In addition, the government provides unemployment benefits and, in the economy with PAYG pension system, runs a pension system.

The government budget constraint is then[16]

$$G + T_r + (1+r)D = T_k + T_y + T_c + E + D' \tag{8}$$

16. In the *Baseline* and *PAYG* economies, the second equation is replaced by $P + U_b = T_p$, where P denotes pension payments in a given period.

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$$U_b = T_p, \tag{9}$$

where G denotes government consumption, T_r denotes government transfers, T_k, T_y, and T_c, denote the revenues collected with the capital income tax, the household income tax, and the consumption tax, and E denotes unintentional bequests. U_b denotes unemployment benefits, and T_p denotes revenues collected with the payroll tax. In the remainder of the paper, we assume that the level of general public debt is fixed at the baseline calibration year level, $D' = D$. In the policy exercises presented in Section 5, the government issues new (reform) debt to finance the reform of the retirement system, which we denote by B.

Capital Income Taxes. Capital income taxes are given by $\tau_k y_k$, where τ_k is the tax rate on gross capital income $y_k = ra$. a denotes capital holdings, and r the economy rate of return on capital.

Payroll Taxes. Payroll taxes are proportional to before-tax labour earnings: $\tau_p y$.

Backpack Taxes. Similarly, taxes to accumulate assets in the individual BP Fund account are given by: $\tau_b y$.

Consumption Taxes. Similarly, consumption taxes are simply $\tau_c c$, where τ_c is the consumption tax rate and c is consumption.

Income Taxes. We assume a simplified income tax formula according to which the income tax is proportional to the income level: $\tau_y \hat{y}$, where τ_y is a tax rate parameter and $\hat{y}$ is the tax base. The income tax base depends on the employment status. If a household is employed

$$\hat{y} = (1 - (\tau_p + \tau_b))y + r(1 - \tau_k)a. \tag{10}$$

For the unemployed and non-active agents,

$$\hat{y} = r(1 - \tau_k)a, \tag{11}$$

and for a retired household with retirement pension p^B it is[17]

$$\hat{y} = r(1 - \tau_k)a + p^B. \tag{12}$$

Insurance Markets. An important feature of the model is that there are no insurance markets for the stochastic component of the endowment shock, for unemployment risk, or survival risk. We model different public insurance systems that help agents in the economy smooth consumption in the face of these shocks.

17. With the PAYG system, pension payments are given by p_h^S. In the PS economy, there are no pension payments.

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2.5. *Individual Decision Problem*

As noted above here, we describe only the problem in the *BP* economy. The household's problem is described recursively. To simplify the notation, we omit in the main text the dependence of the value functions on the state variables age, education, PS, BP savings, and unemployment duration.[18]

We first state the decision problem of a worker at the beginning of the period after the job acceptance was taken. Only after all the value functions are introduced, we define the job acceptance and retirement decisions. An individual who is currently employed decides how much to consume c, save a', and work $l \in [0, 1]$, according to the following optimization problem:

$$W = \max_{c,l,a'} \quad \left\{u(c,l) + \beta\mathbb{E}[(1-\sigma_j)J + \sigma_j U]\right\} \tag{13}$$

$$\text{subj. to:} \quad (1+\tau_c)c + a' + \tau_y \hat{y} + (\tau_p + \tau_b)y \le (1 + r(1-\tau_k))a + y + TR(y), \tag{14}$$

the BP law of motion, $b' = \tau_b y + (1 + r(1-\tau_k))b$, and the no-borrowing constraint: $a' \ge 0$.

Gross labour income is $y = \omega\varepsilon z l$, income tax base $\hat{y} = (1 - \tau_p - \tau_b)y + r(1-\tau_k)a$, and government transfers for low income households are denoted by $TR(y) = t_r \mathbb{1}_{TR}(y)$, where $\mathbb{1}_{TR}(y) = 1$ if $y < \bar{t_r}$ and zero otherwise, as explained above.

Equation (13) above reads in the following way: The first term inside the curly brackets represents the utility flow from consumption and labour. The expected continuation value, discounted by β, takes into account the survival probability, all possible continuation histories of the realization of the stochastic component $z' \in \mathcal{Z}$, and two distinct labour market outcomes that are explicit in the notation. With probability $1 - \sigma_j$, the worker keeps the job in the next period (and therefore is not eligible to claim unemployment benefits), with value denoted J that depends on the next period's private and BP assets, respectively a' and b', and the new realization of idiosyncratic productivity z'. Alternatively, with probability σ_j, the job is destroyed and the worker starts the next period without a job, with value U. This value depends on the number of periods after an involuntary job separation (relevant to determine eligibility for unemployment benefits), d. In the first period after a layoff, $d = 0$. z' follows the Markov chain described in (1).

Workers can start the period without a job. In the BP economy, a job searcher who faced a job separation shock and has yet to start a new job has access to his BP savings and, depending on low long he has been without working, may be eligible to receive

18. The problem in all the economies considered in the text can be found in the Online Appendix C written with full state variable notation.

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unemployment benefits from the government. He therefore solves a consumption-savings problem, a job-search problem, and a portfolio problem for the allocation of his private and BP savings. At the beginning of the period, the state vector for the agent is given by private asset holdings a, BP savings b, stochastic productivity z, and layoff duration d. Given the current state, the agent chooses consumption, future asset holdings, and the search effort $e \in \{0, 1\}$ according to

$$U = \max_{c,a',b',e} \left\{ u(c) - \gamma e + \beta \mathbb{E}\Big[e\big(\lambda_j^{\mathbf{u}} J + (1-\lambda_j^{\mathbf{u}})U\big) + (1-e)\big(\lambda_j^{\mathbf{n}} J + (1-\lambda_j^{\mathbf{n}})N\big)\Big] \right\}, \tag{15}$$

$$\text{subj. to: } (1+\tau_c)c + a' + b'(e) + \tau_y \hat{y} \leq (1 + r(1-\tau_k))(a+b) + UB(d,e) + TR(y), \tag{16}$$

$$a' \geq 0, b'(0) = (1 + r(1-\tau_k))b \text{ and } 0 \leq b'(1) \leq (1 + r(1-\tau_k))b. \tag{17}$$

Equation (15) can be read as follows. The first term inside the curly brackets is the flow utility from consumption and the utility cost of search, given by γe. The expected continuation value takes into account the survival probability and the evolution of the stochastic productivity component, z. High search effort ($e = 1$) translates into higher probability of finding a job: $\lambda_j^{\mathbf{u}} > \lambda_j^{\mathbf{n}}$. The tradeoff in the job-search problem can be found inside the expectation operator. With high search effort during the current period, with utility cost γ, the agent finds a job next period with probability $\lambda_j^{\mathbf{u}}$. With no search effort ($e = 0$), a job arrives with lower probability, $\lambda_j^{\mathbf{n}}$. In the event the worker finds a job, he decides in the beginning of the next period whether to work or not, with associated option value J, which depends on beginning of period assets, and labour productivity. If search is not successful the worker continues unemployed next period with probability $(1 - \lambda_j^{\mathbf{u}})$, with value U, which again depends on assets, productivity, and unemployment duration d', which increases deterministically by 1. If the unemployed worker decides not to search, $e = 0$, and does not find a job, he becomes non-eligible for unemployment insurance benefits and he cannot use his BP assets, but he may again search for a job next period, with associated value N.

Equation (16) represents the budget constraint. Total income is used to finance consumption expenditures, next period assets, and income taxes, with the income tax base given by $\hat{y} = r(1 - \tau_k)a$. The right hand side is the sum of beginning of period private and BP assets, plus after-tax return, unemployment benefits $UB(d, e)$, and government transfers for low-income households, $TR(y)$. The laid off worker may be entitled to unemployment benefits: $UB(d, e) = u_b \mathbb{1}_{UB}(d, e)$, with $\mathbb{1}_{UB}(d, e) = 1$ indicating eligibility for unemployment benefits, with $\mathbb{1}_{UB}(d, e) = 0$ otherwise.

Finally, an agent may start the period without a job because he has decided not to work or not to search in previous periods, not having found a new job yet. In this scenario, he solves the following problem:

$$N = \max_{c,a',e} \left\{ u(c) - \gamma e + \beta \mathbb{E}\big[e\big(\lambda_j^{\mathbf{u}} J + (1-\lambda_j^{\mathbf{u}})N\big) + (1-e)\big(\lambda_j^{\mathbf{n}} J + (1-\lambda_j^{\mathbf{n}})N\big)\big] \right\}, \tag{18}$$

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$$\text{subj. to:} \quad (1 + \tau_c)c + a' + \tau_y \hat{y} \leq (1 + r(1 - \tau_k))a + TR(y), \tag{19}$$

$$a' \geq 0, \quad \text{and} \quad b' = (1 + r(1 - \tau_k))b. \tag{20}$$

As above, $\hat{y} = r(1 - \tau_k)a$. The decision problem is similar to (15), with key differences related to eligibility to unemployment benefits and access to BP savings. Specifically, in this case the unemployed worker is not eligible for unemployment benefits, and he also cannot use BP assets. Accordingly, the evolution of BP assets is given by (20).

We consider now the the problem of the retiree. Retired individuals are not in the labour market and have no endowment of efficiency units of labour. They finance consumption with past PS 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 exits the economy next period with probability 1. During retirement, the retired household solves a standard problem:

$$V(a) = \max_{c,a'} \quad \{u(c) + \beta \mathbb{E}[V(a')]\}, \tag{21}$$

$$\text{subj. to:} \quad (1 + \tau_c)c + a' + \tau_y \hat{y} \leq (1 + r(1 - \tau_k))a + p^B(b) + TR(y). \tag{22}$$

Pension income is part of the right hand side of the constraint. In this case, $\hat{y} = r(1 - \tau_k)a + p^B(b)$. After retirement, labour market productivity is always zero and hence expectations take into account only the survival risk.

To close the description of the household's problem, we define the job acceptance and retirement decisions. These jointly pin down the value of having a job offer at the beginning of a period:

$$J = \max\{V, \max\{W, N\}\}. \tag{23}$$

The outermost max operator represents the retirement decision, while the inner operator is the job acceptance decision.

2.6. Definition of Stationary Equilibrium

The definition of a stationary equilibrium is standard and can be found in Online Appendix D. The Spanish economy is modelled as an open economy in the main text. This means that the difference between total assets held by households, A, which include both BP and private assets in the BP economy, and the capital stock K, are invested (or borrowed from) abroad.

2.7. Steady State

The steady state of the economies under study have the following characterization. Given a distribution of households entering the economy ($j = 20$ and $a = 0$; say, at T)

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they all receive a job opportunity and make their consumption, asset, and employment decisions. These households' decisions together with their survival probabilities define the distribution of this cohort the following year $(T + 1)$ at $j = 21$, but also the distribution of households of $j = 21$ at T. Similarly, for $j = 22, \dots, 100$; that is, the different cohorts coexisting at T mirror the evolution of the distribution of households entering the economy at T up to the end of their potential survival $j = 100$. In other words, the decisions that agents of generation T make throughout their lives are already made in the year they enter the labour market by older agents if they have the same state. By construction, this is a steady-state distribution, which is our benchmark distribution. Different economies simply expose the T cohort distribution to different public insurance systems and, therefore, all the cohorts coexisting at T behave as if the given system were in place when they entered the economy. In a steady-state economy, all cohorts face the same age-dependent survival rates and distribution of education levels.

3. Calibration

We describe the calibration process in detail, including the data sources, in Online Appendix E. In order to calibrate the model parameters using Spanish data, we need to modify the environment described in Section 2 to take into account the PAYG pension system that is part of the Social Security system in Spain. These modifications are however restricted to the pension system itself, and therefore the decision problem facing households, described above, is almost unchanged. In this economy, there is no BP fund, BP assets (and contributions) are zero, and claims on future consumption take only two forms: PS and PAYG retirement pensions. Hereinafter, we use the following designation:

Baseline economy. The status quo economy, calibrated to the Spanish data in 2018, which includes a PAYG retirement pension system (see Online Appendix G for details about the PAYG system in Spain). There is no BP system: $\tau_b = 0$.

The full description of the Baseline economy is included in Online Appendix C; the description of the PAYG system is given below.

3.1. PAYG System

The PAYG system is an unfunded defined contribution pension system, in which pension payments mostly depend on individual workers' history of salaries. In the model, pension payments depend on average earnings during the N_b years prior to retirement. In Spain, as in many other countries where a PAYG system exists, there is a minimum retirement age after which the worker can decide to retire. We denote it by R_0. In order to capture the heterogeneity in pension payments that arises from different lifetime earnings histories, but at the same time reduce the dimensionality

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of the problem, we model pension payments that differ for each educational group (instead of each individual). Specifically, pension payments for retirees of educational group h are

$$p_h^S = p_r \bar{y}_h^S, \tag{24}$$

where $\bar{y}_h^S$ is the average earnings of households in educational group h during the last N_b years before the retirement age, R_0, and p_r is a replacement rate. $\bar{y}_h^S$ is computed as

$$\bar{y}_h^S = \frac{1}{N_b} \sum_{j=R_0-N_b}^{R_0-1} \bar{y}_{j,h}, \tag{25}$$

where $\bar{y}_{j,h}$ is the average gross labour earnings of workers aged j and with education h. We assume that there are no early retirement penalties, nor minimum or maximum pensions. As mentioned above, this system is an unfunded system, financed through taxes. We model it as part of the Social Security budget, separately from the general government budget (8):

$$U_b + P = T_p, \tag{26}$$

where, as above, U_b are aggregate unemployment benefit expenditures and T_p are payroll tax collections, and now P are aggregate retirement pension expenditures. These are a liability of the Social Security system (and a claim on pension payments for households). The consumption tax rate clears the government budget (8), and the payroll tax rate τ_p clears condition (26).

To calibrate our model economy, we do the following: First, we choose a calibration target country—Spain herein—and a calibration target year—2018. We then 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 the institutional details of our chosen country in the target year. More specifically, to characterize our model economy fully, we must choose the values of 4 initial conditions and 38 parameters. To choose the values of these 38 parameters, we need 38 equations or calibration targets.

As already mentioned, an important assumption we maintain in the main text is that we treat Spain as a small open economy. This means that the interest rate (and therefore, from the representative firm optimization conditions, the capital-labour ratio and the wage rate) is constant. We follow this assumption here in order to isolate the direct effects of population ageing on pension system sustainability, but present all the closed economy (i.e. general equilibrium) results in Online Appendix A.

The next subsection presents the most relevant calibration targets and model statistics. We also present the government expenditure and tax revenue ratios, which are important ingredients in the analysis of the reforms of retirement pension systems presented below.

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TABLE 1. Macroeconomic aggregates and ratios in Spain and in the model in 2018.

	K/Y	C/Y	I^a/Y	h
Spain	2.94	50.70	26.95	34.59
Model	3.06	41.76	34.90	33.11

Notes: Variable Y denotes GDP at market prices. I^a denotes investment. h denotes average share of disposable time allocated to the market. Data source: Fundación BBVA and Spanish National Institute of Statistics (INE).

TABLE 2. Macroeconomic aggregates and ratios in Spain and in the model in 2018.

	P/Y	U/Y	T_r/Y	GW^c	W^d	I^e
Spain	**10.47**	**1.32**	**0.83**	**0.67**	**59.59**	**5.16**
Model	10.54	1.15	0.88	0.68	58.50	4.93

Notes: Y denotes GDP at market prices. U/Y is unemployment benefits as a share of output. GW is the Gini Index of wealth. W is the share of workers in the Spanish population with 20 years old and older. I is the share of inactive in the Spanish population with 20 years old and older. Data source: Spanish National Institute of Statistics (INE), Spanish Social Security, Cañón et al. (2016), Anghel et al. (2018).

TABLE 3. Government budget in Spain and in the model in 2018 (% of output, Y, at market prices).

	Public expenditure				Public revenues				
	G	T_r	P	U	T_c	T_k	T_y	T_p	E
Spain	**17.40**	**0.83**	**10.47**	**1.32**	9.07	**2.24**	**7.05**	9.47	**0.20**
Model	17.40	0.88	10.54	1.15	8.68	2.33	7.05	11.67	0.20

Notes: G: government consumption, T_r: welfare transfers, P: pension payments, U: unemployment benefits expenditures; T_c: consumption tax collections, T_k: capital income taxes, T_y: household income tax revenue, T_p: payroll tax revenue, E: accidental bequests revenue. Data source: Spanish Social Security (Resumen de Ejecución del Prespuesto) and Spanish National Institute of Statistics (Cuentas Nacionales).

3.2. *Baseline Economy*

The tables presented above summarize the calibration exercise. The values shown in bold are data targets.

The model is able to capture the main output ratios in the calibrated year, shown in Tables 1 and 2. As shown in Table 3, we target government expenditures and revenue ratios in order to determine the simplified tax system in the model. The payroll tax rate finances pension and unemployment benefit expenditures. Capital income and household income tax rates are chosen to collect 2.24% and 7.05% of GDP, as is the case in Spain in 2018. Finally, the consumption tax rate clears the government budget. Some Spanish regions feature a proportional tax on bequests. We use the aggregate revenue of this tax in 2018 as the data point for E (0.20% of output). In the model aggregate accidental bequests as a fraction of output is significantly higher (2.63). In the results shown below, we assume that the portion of the accidental bequests that is not taxed by the government is wasted.

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TABLE 4. Policy parameters in the model economy, in 2018.

	Tax rates (%)			
	τ_c	τ_y	τ_k	τ_p
Model	26.2	14.2	25.0	26.0

Notes: τ_c: consumption tax rate, τ_y: household income tax rate, τ_k: capital income tax rate, τ_p: payroll tax.

TABLE 5. Labour market shares in 2018 (% of population).

	W	U	I	R
Spain	59.59	10.72	5.16	24.51
Model	58.50	11.92	4.93	24.65

Notes: W: workers, U: unemployed, I: inactive, and R: retirees. Data source: The Spanish data is from both the Encuesta de la Población Activa 2018, excluding the non-participants who are either housewives or students. Encuesta de Población Activa (INE).

TABLE 6. Inequality in Spain and in the model in 2018*.

	GE	GI	GW
Spain	0.34	0.33	0.67
Model	0.34	0.36	0.68

Notes: GE: Gini Index of net earnings, GI: Gini Index of net income, and GWI: Gini Index of net wealth. *The sources 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 BDE (2018).

The tax rates implied by the calibration are shown in Table 4.

The model also does a good job in replicating the aggregate labour market stocks (Table 5) (share of workers and inactive targeted in the calibration), and the age-distribution of workers, unemployed, inactive and retirees shown in Figure 2—which are not part of the calibration targets.

Standard heterogeneous agent models with idiosyncratic earnings risk fail to replicate earnings and wealth inequality found in most developed economies (Castaneda, Diaz-Gimenez, and Rios-Rull 2003). Our overlapping generations model with labour market frictions and a detailed description of government tax and transfer systems is able the capture the inequality in after-tax earnings, income, and net wealth in the Spanish economy, as summarized in Table 6.

Figure 3 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 (2022) for Spain (see Figure 5 in that paper).

Figure 3 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

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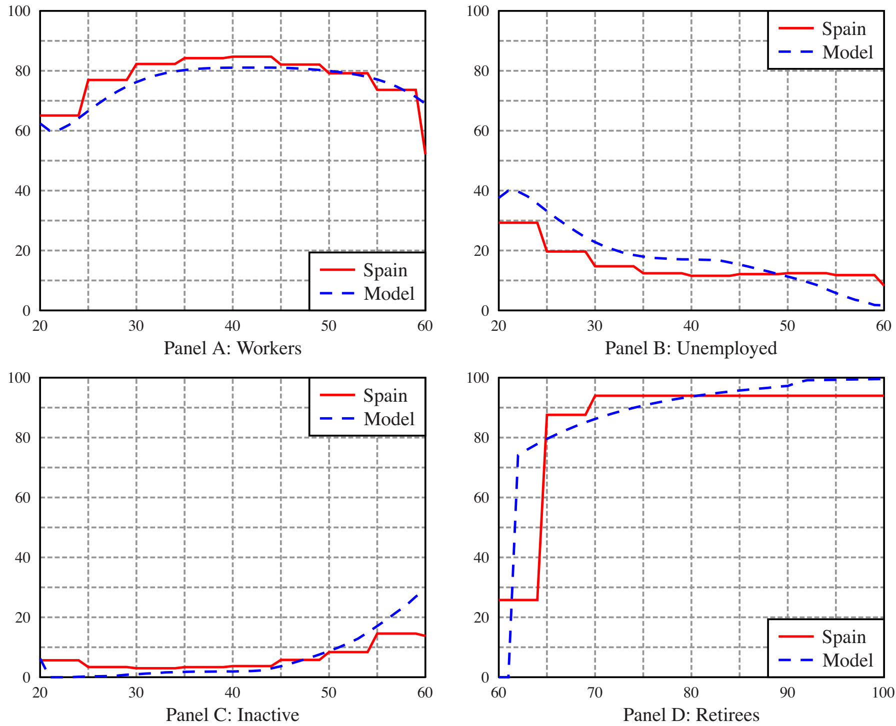

FIGURE 2. Labour market stocks by age in the data and in the model. Data source is the survey Encuesta de Población Activa.

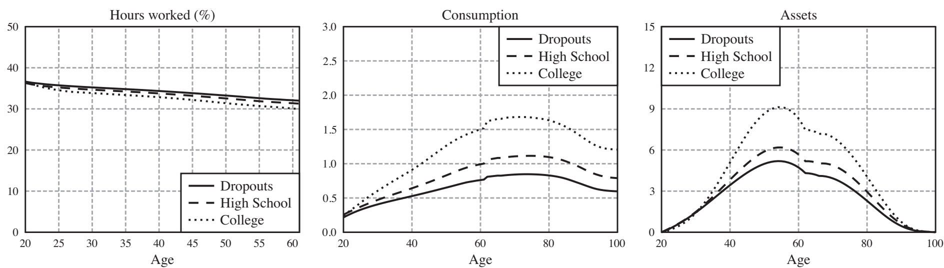

FIGURE 3. Life-cycle profiles of hours worked, consumption, and assets in the Model Economy

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 70, as workers deplete their assets after leaving the labour market at a higher rate than they would if they were to leave inheritances.

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4. Ageing Transition with a PAYG Pension System

After calibrating the initial steady-state economy, we simulate the transitional dynamics starting in 2018, until some decades after 2068, the year we assume that the population ageing process has converged.[19] We solve the transition with the PAYG pension system in the following way. First, we solve for the long-run steady-state equilibrium, with the age-survival rates that are forecasted for the the Spanish population in year 2068, assumed to be the final state of the ageing process. In the final steady state, we solve for the consumption and payroll tax rates that clear the government budget, with much higher PAYG pension expenditures. We loosely refer to this long-run steady state as the "2068 economy". The age profile of survival probabilities and the corresponding age distribution in 2018 and in the 2068 forecast, shown in Figure 4, are taken from INE.[20] We also update the share of households in each education level that is expected for Spain in 2068.[21]

Next, we solve the equilibrium transition path between the initial steady state (the 2018 economy) and the final steady state. Along the transition, the survival probabilities of each cohort are updated each year according to the INE forecast, and PAYG system rules are updated according to the Spanish law.[22] Because the model variables may take more than 50 years to converge, we guess (and verify) that convergence in all aggregate variables is achieved after 80 years following the last demographic change (see Auerbach and Kotlikoff 1987a for a detailed explanation). As a consequence of the ageing process, the share of households older than 65 increases from 24% in 2018 to 36% in 2068. Despite the changes in pension rules, the increase in the share of persons older than 65 implies that pension payments increase over time. We assume that the payroll tax rate τ_p increases to balance the increase in pension payments every period. Additionally, we assume that the consumption tax rate τ_c adjusts every period to balance the government budget constraint.

19. Numerically, we solve the model 130 years after the ageing process stops, to make sure the economy reaches its final steady state. With constant factor prices and taxes, the economy is in steady state when all cohorts face the same age-dependent survival probabilities and all education levels.

20. Instituto Nacional de Estadística, 2018–2068 series: https://ine.es/dynt3/inebase/es/index.htm?padre=4749.

21. To update the distribution of education levels, we assume that from 2018 on, 7.33% of the 20 year-old entrants have not completed their secondary education, that 62.62% have completed their secondary education, and that 30.05% have completed college. This was the educational distribution of Spanish households born between 1980 and 1984, which was the most educated cohort in 2018 data. We assume that the probabilities to find/lose a job do not change.

22. We increase the number of years used to compute the pension, N_b, from 21 to 25 years in 2022. Also, the minimum retirement age is increased by one year to 63 years old in 2024. We do not account for the Sustainability Factor, because its implementation has been suspended. These changes follow from the 2011 and 2013 pension reforms in Spain.

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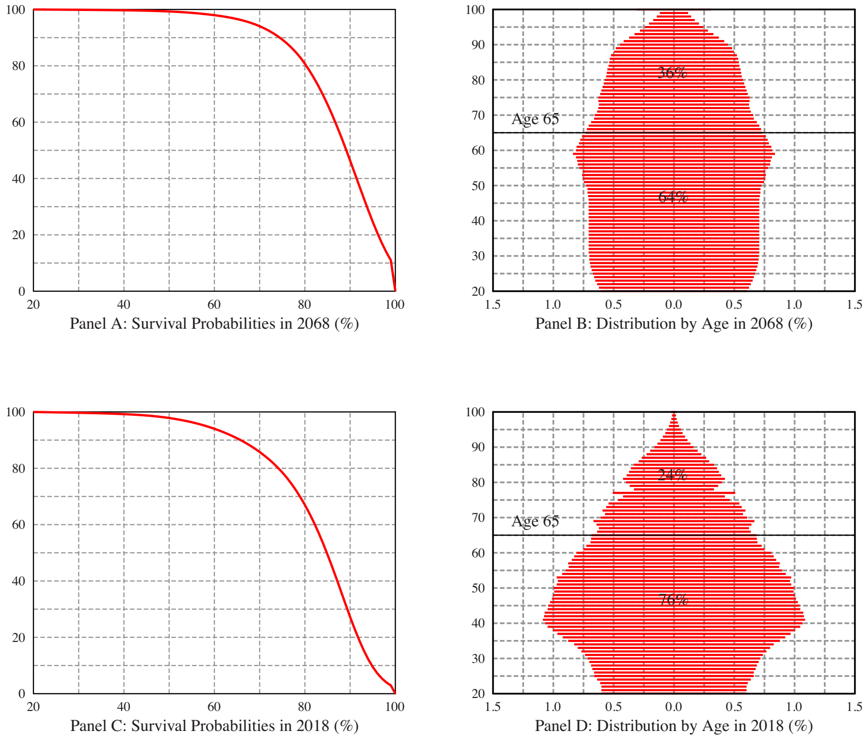

FIGURE 4. Survival Probabilities and Age distribution in Spain in 2018 and the 2068 forecast. Source: Instituto Nacional de Estadística, 2018–2068 series.

TABLE 7. Labour market shares in the baseline 2018 model economy, and in the PAYG 2068 simulation (% of population).

	W	U	I	R
Baseline (2018)	58.50	11.92	4.93	24.65
PAYG (2068)	50.80	10.80	3.70	34.69

Notes: W: workers, U: unemployed, I: inactive, and R: retirees.

We start by comparing the initial economy in 2018 and the long-run 2068 steady state. We fix the following notation for the results shown below.

PAYG. A long-run economy, with a demographic structure as predicted for Spain in 2068, assuming the PAYG pension system is in place (with small parametric changes to minimum retirement age and pension payments formula, as described above).

The increase in the share of households aged 65 years old and older leads to a significant increase in the share of retirees in the 2068 population. As Table 7 shows, this group represents almost 35% of the population in 2068. All the other labour market

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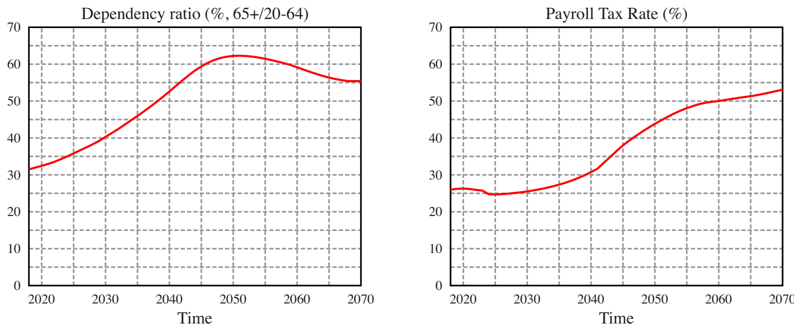

FIGURE 5. The expected evolution of the dependency ratio and payroll tax rate in Spain.

groups decrease their share, with the largest fall in the stock of employed, 8 percentage points. Workers decide to retire later, with the average retirement age increasing from 63.7 in 2018 to 65.1 in 2068. The increase in the retirement age is not enough to compensate for the increase in life expectancy. Consequently, the increase in the share of retirees increases pension payments. Pension payments as a share of output double: from 10.5% in 2018 to 21% in 2068 (Table 10). The payroll tax rate reaches 51.1% in 2068 (Table 8), and total payroll tax collection increases from 11.7% to 22.2% of output in 2068.

The results are in line with previous papers, for example Díaz-Giménez and Díaz-Saavedra (2017), De la Fuente, García Díaz, and Sánchez (2019), and Díaz-Saavedra (2020). Specifically, Díaz-Giménez and Díaz-Saavedra (2017) and De la Fuente, García Díaz, and Sánchez (2019) find that pension payments may reach around 21% of output at market prices in 2050. Díaz-Saavedra (2020) finds that, with the Sustainability Factor (abandoned by the Spanish legislator), this number would reach 16% of output that same year.

The decrease in the share of households who work and in average hours worked reduces labour and capital in the economy: output is 5% lower. Among the workers, hours worked decrease due to an increase in the effective marginal labour tax rate. Private savings decrease due to a large distortion of earnings from high payroll taxes. Capital and income tax collections fall. Lower lifetime disposable income and savings reduce aggregate consumption.

We present additional results on changes along the demographic, income, and wealth distributions when we compare the PAYG 2068 economy with alternative reformed economies, below.

In the period between 2018 and 2068, the economy undergoes an ageing transition with the dependency ratio (share of households older than 65 relative to 20–64 years old) increases during the first three decades, peaking above 60% around 2050, and stabilizing at 55% in 2068. Figure 5 shows this evolution. As a consequence, pension payments increase, which in turn, according to our balanced budget assumption, leads to an increase in payroll taxes. The initial hump after 2018, shown in the right hand side panel in Figure 5, comes from the parametric reform to the PAYG system according

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TABLE 8. Consumption and payroll tax rates in 2018 and 2068 under the PAYG pension system.

	Tax rates (%)	
	2018	2068
τ_c	26.2	25.7
τ_p	26.0	51.1
τ_e	48.1	65.6

Notes: τ_c: consumption tax rate, τ_p: payroll tax rate. τ_e effective labour tax rate (see Footnote 10).

TABLE 9. Main macroeconomic aggregates in the baseline 2018 economy, and in the PAYG 2068 simulation.

	Y	L	A	C	h^a
Model (2018)	2.36	0.69	3.94	0.78	0.1936
PAYG (2068)	2.24	0.65	2.19	0.76	0.1707

Notes: In this table, variable Y is output at market prices, and variable A is total assets.
a. Variable h denotes total hours of work in the economy.

TABLE 10. Government budget in the 2018 model economy and in the PAYG simulation of 2068 (% of output, Y, at market prices).

	Public expenditure			Public revenues			
	T_r	P	U	T_c	T_k	T_y	T_p
Model (2018)	0.88	10.53	1.13	8.68	2.33	7.05	11.67
PAYG (2068)	0.76	21.02	1.17	8.76	2.33	6.82	22.17

Notes: T_r: minimum income, P: pension payments, U: unemployment benefits expenditures; T_c: consumption tax collections, T_k: capital income taxes, T_y: household income tax revenue, and T_p: payroll tax revenue.

to existing Spanish pension rules. As becomes clear from the figure, the demographic evolution quickly undoes its small initial effect, and the payroll tax rate steadily increases to above 50%.

The evolution of the demographic structure between 2018 and 2068, summarized by the dependency ratio shown in Figure 5, shapes the transition of the main aggregates, pension payments, and the payroll tax rate. Recall that under the small open economy assumption, prices are constant, and the only exogenous variation introduced in the economy comes from the evolution of the survival probabilities and education shares, which in turn indirectly induce changes in the government and social security budget and ultimately in taxes. The ageing transition in the decades up to 2060 doubles the ratio of retirees per worker, which in order to finance pension payments in the PAYG system requires increasing the payroll tax rate under our balanced budget assumption. The effective labour tax increases from 48.1% to 65.6%. Aggregate labour supply responds inversely as payroll taxes increase. Since the capital labour ratio is constant during the transition, capital decreases in the same proportion and consequently output. The increase in the payroll tax is partially offset by a percentage point decrease in the

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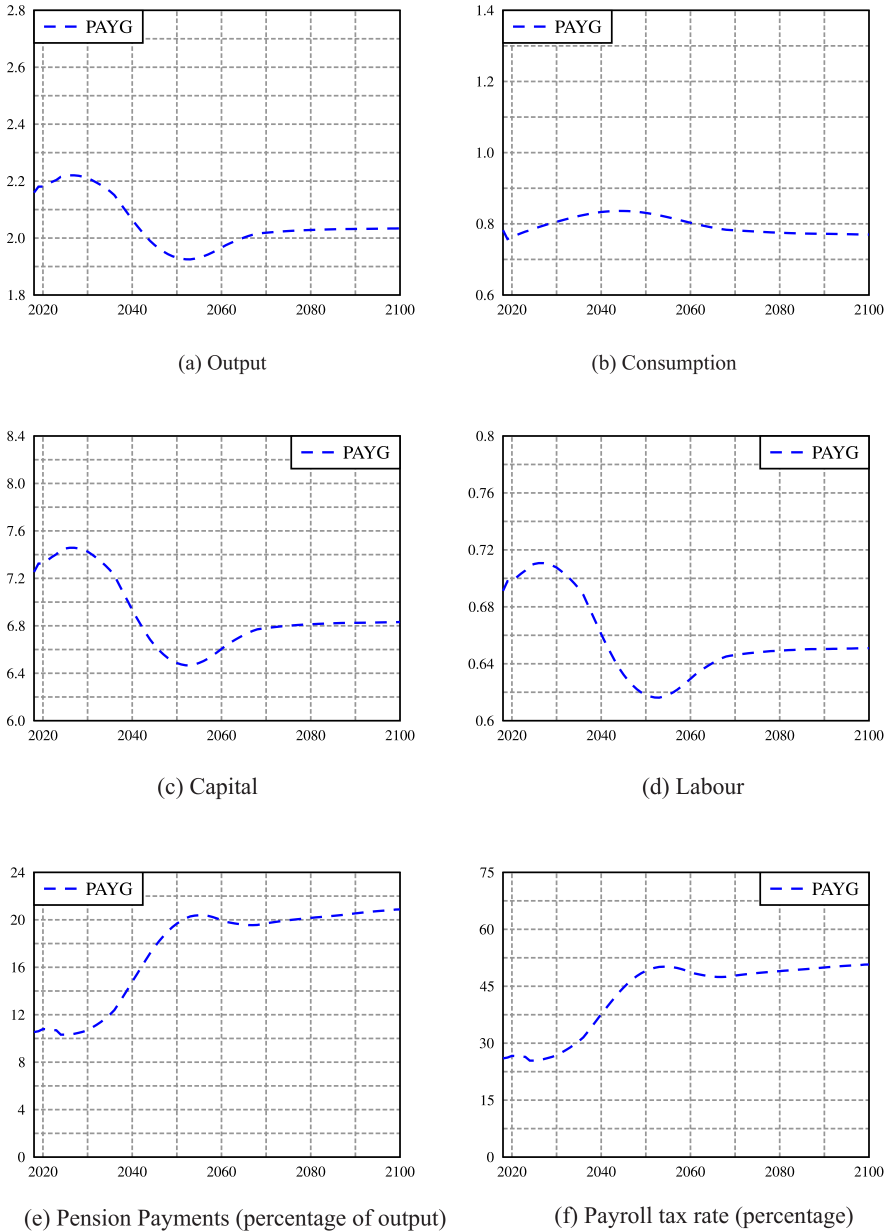

FIGURE 6. Main aggregates, PAYG pensions and payroll tax rate during the transition.

consumption tax rate (Table 8), and aggregate consumption is almost constant (Table 9), but households who derive most of their income from wages see a large increase in payroll tax and are forced to reduce consumption. Table 10 summarizes the simulated change of the government budget between 2018 and 2068, and Figure 6 shows the evolution of the main aggregates during the ageing transition.

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In the next two sections, we present the main results of the paper. We study the BP employment fund, and the reform of the baseline 2018 economy PAYG system taking into account the ageing transition between 2018 and 2068.

5. Ageing Transition and the Reform of the Pension System

In this and the following sections, we solve equilibrium transition paths and final steady states with alternative reforms of the Spanish PAYG pension system.

In this section, we study the replacement of the PAYG system with a BP pension plan. We are interested in a transition that implements a BP with a BP tax rate that is welfare maximizing in the long run and without losers during the transition period—with respect to the status quo of maintaining the PAYG pensions system. During the transition period the age-education distribution is updated according to ageing process that is expected for the coming decades (as in the previous section).

We use as welfare criteria the average lifetime utility of a given cohort. To find the welfare maximizing BP tax rate, we use the same criterion applied to the cohort of individuals aged 20 years old (the first model age) in the final steady-state economy, that is, the economy with age and education distributions achieved at the end of the ageing transition. To implement a Pareto-improving reform, we additionally check the welfare effects at individual level. In the reform, the government respects all PAYG promises and pensions: During the transition period, working age individuals who switch to the BP system are offered a BP subsidy so that they (weakly) prefer to move to the BP (and to give up claims to PAYG pensions); additionally, all retirees with PAYG pensions receive the pension payments they are entitled to until they die.[23]

The reform is financed as follows. BP asset subsidies are debt financed, and two tax rates change to clear the two-equation government budget: the payroll tax, for those moving to the BP system, only finances UI benefits (equation (9)), and the consumption tax to guarantee that (8) is satisfied every year.[24] We assume that debt is raised in the international capital market and is costly, with interest payments included in the expenditure side of the government budget constraint. Consumption taxes must increase to cover interest payments.[25] As a benchmark, in line with the current low

23. As we discuss below, these retirees may require an additional compensation to make the transition Pareto improving.

24. This exercise follows the baseline optimal policy exercise in Conesa and Garriga (2008), which restricts the planner's instruments to the labour tax, asset transfers to individuals, and government debt. We let the payroll tax change, and use BP asset transfers and government debt to fund the reform. In contrast, McGrattan and Prescott (2017) consider an overall reform of the income tax and transfers schedule simultaneously with the privatization of the pension system.

25. Alternatively, if we assume that the cost of debt is part of the social security budget, this raises payroll taxes. Our results are qualitatively not affected by this choice.

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interest rates paradigm, we assume that the real interest rate on public debt r^* financing the reform is 1% per year.

We restrict the reform problem to the choice of: (a) a long-run welfare maximizing BP tax rate, τ_b^*, (b) which cohort is the last to collect PAYG pensions, and (c) which cohort is the first to enter the BP system. We also assume that workers who join the BP system face τ_b^*.[26] Herein we consider two canonical choices of (b and c), corresponding to a *slow* and a *fast* transition. In a fast transition, presented below, all workers move to the BP system in the first period of the reform (a front-loaded reform). In a slow transition (Online Appendix B), only 20 year old (i.e. newborn) workers enter the BP system during the reform, while all vintage workers in the initial period stay in the PAYG system until they retire. Different choices of (a–c) imply different final debt levels that finance the BP asset subsidies. If debt is costly, the higher is the final post-reform debt level, the higher are taxes necessary to service it and the lower is aggregate welfare in the long-run reformed economy.

5.1. A Front-Loaded Transition

A front-loaded transition is one in which all workers move to the BP system in the first year of the reform. It can be implemented, starting in 2019, following four simple principles:

1. All retirees in 2019 remain in the PAYG system, collecting their pensions according to the PAYG pension rules.
2. All the working-age population in 2019 enters into the BP system, as well as those above the minimum retirement age who are still working in 2019.
3. Those who enter the BP system in year $t \geq 2019$ receive an initial amount of BP assets $b_{t,h,j,}(a) \geq 0$ (a government subsidy paid into the BP account) that makes them weakly prefer entering the BP system than to remain in the PAYG economy; in particular, at $t \geq 2019$ those with $j = 20$ receive $b_{t,h,j,}(a) = 0$, and in 2019 those with $j \geq 20$ receive $b_{t,h,j,}(a) \geq 0$ as to make them (weakly) prefer the BP reform to their PAYG retirement plan.[27]
4. The BP assets subsidies, as well as all PAYG pensions (from 2019 until the year the last retiree with PAYG claims dies) are financed with public debt.

26. In other words, we exclude reforms in which a given cohort has some workers in the BP system, and other workers in the PAYG system. And for all workers, the time path of BP tax rates considered are step functions: $\tau_b = 0$ before and $\tau_b = \tau_b^*$ once a worker enters the BP system.

27. Precisely, the individual BP subsidy is computed so that each individual is indifferent between the economy in which all workers are in the BP system, and an economy in which all workers are in the PAYG system (the baseline economy).

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Denote debt issued in the first period of the reform by B_1. The government issues debt to fund initial BP asset subsidies and PAYG pension payments, given by

$$B_1 = BP^S + P_1, \tag{27}$$

where BP^S is the aggregate amount of BP asset subsidy distributed to compensate all vintage workers, and P_1 is the amount of PAYG pension payments distributed in the first period of the reform. In the second period, the government rolls over the initial debt and borrows additionally P_2, which is the amount due in that period to existing PAYG pensioners:

$$B_2 = P_2 + B_1, \tag{28}$$

and similarly in the following decades, until the last PAYG retiree dies. When the last PAYG pension is paid, the reform debt reaches its final level B. During the transition, the government raises debt, collects taxes, and pays for expenditures as in the steady-state equation (8), and additionally pays for interest payments, with a given interest rate r^*:

$$G_t + T_{r,t} + r^* B_t = T_{k,t} + T_{y,t} + T_{c,t} + E_t, \tag{29}$$

$$U_{b,t} = T_{p,t}. \tag{30}$$

In the final steady state, the government rolls over the reform debt in perpetuity and finances interest payments equal to $r^* B_\infty$. Two tax instruments adjust so that both components of the government budget restriction are satisfied during the transition and at the final steady state: consumption tax rate $\tau_{c,t}$ to satisfy (29) and payroll taxes $\tau_{p,t}$ to clear (30). Note that the Social Security budget (30) now has only unemployment insurance on the expenditure side. Hence, the payroll tax rate will be much lower than in the PAYG economy.

We perform a grid search procedure to find the welfare maximizing BP rate τ_b in the final steady-state economy, taking into account the transition path between the initial and the final steady state. The welfare criterion is the average lifetime utility of a newborn (20 year old) in the final steady state. This procedure, described in detail in Online Appendix F, delivers an optimal BP tax rate of $\tau_b^* = 22\%$ (Figure 7).

We now present a front-loaded transition to a $\tau_b^* = 22\%$ BP system in which all workers move to the BP system in the first period of the reform. As Figure 8(a) shows, the initial level of debt—that finances the initial BP asset subsidies—increases the level of public debt by 203% of GDP and the payment of PAYG pensions in the following years increases this level of debt until it reaches circa 340% at the end of the 2050s, when PAYG claims disappear.[28] A high level of debt, but only 28.5% of what it would had been with a gradual and slow transition discussed in Online Appendix B. Note

28. Note that we have not included the existing level of debt, which in 2019 was 95.5% of GDP (AMECO) and, consistently, we have excluded debt payments from government expenditures, as well as the corresponding taxes. That is, starting the reform requires tripling the level of public debt of Spain in 2019.

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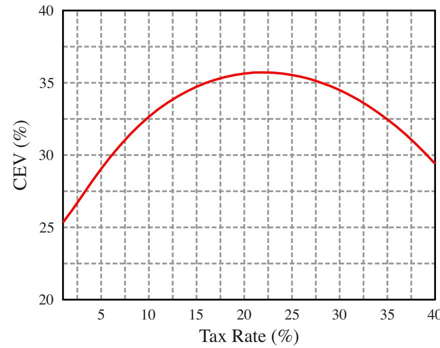

FIGURE 7. Average increase in welfare (CEV) at age 20 as a function of BP contribution rate (τ_b) in economies with a BP system relative to the PAYG economy, with a final debt level of 3.4 times output and $r^* = 1\%$.

that this debt reflects the elimination of the PAYG pension system: initial BP subsidies in 2019, shown in Figure 9, and funding of PAYG pensions after 2018, Figure 8(b), but not the BP system, which is FF by individual contributions. After the last PAYG pensions are paid, the stock of debt is constant (Figure 8(a)). As Figure 8(c) shows, aggregate BP assets jumped in 2019 due to the initial BP subsidy (the 2019 cohort starts with zero assets). Some of the initial assets are converted to liquid private assets by unemployed or retirees in 2020, at which point the stock of BP savings starts to steadily increase to the final steady-state level. Figure 8 also shows how the payroll tax is not affected by the ageing transition during the BP reform, because it is determined only by unemployment insurance expenditures (stable during the transition path). Accounting for the additional 22% BP tax, the total payroll wedge is at least 20 percentage points less than in the PAYG economy by the end of the ageing transition (Figure 8(d)).

Figure 9 shows that the BP asset transfers to vintage workers in 2019 (working age individuals who are 21 or older in 2019) increases with age and is zero up to the cohort of those who are 25 years old in that year. The younger cohorts require no BP contributions because they value positively the change in future tax payments that the pension system reform implies. First, payroll taxes decrease immediately and permanently in the reformed economy. Additionally, the consumption tax increases during the first decade, to compensate for the decrease in tax revenues from capital income (i.e., private savings) and increase in interest payments, but declines steadily from 2030 on (see Figure 10). The former dominates and young workers require no BP subsidy to vote in favour of the BP reform.

Figure 11 shows the transitional gains on output, capital, labour, and aggregate consumption in the BP transition compared to the PAYG baseline. With the decline in payroll taxes and increase in consumption tax in 2019, hours worked increases and with the elimination of PAYG pension rules for all workers, the retirement decision is delayed. Consequently, labour supply increases initially. With the ageing transition, aggregate labour supply declines to converge to the final steady state after 2030. The

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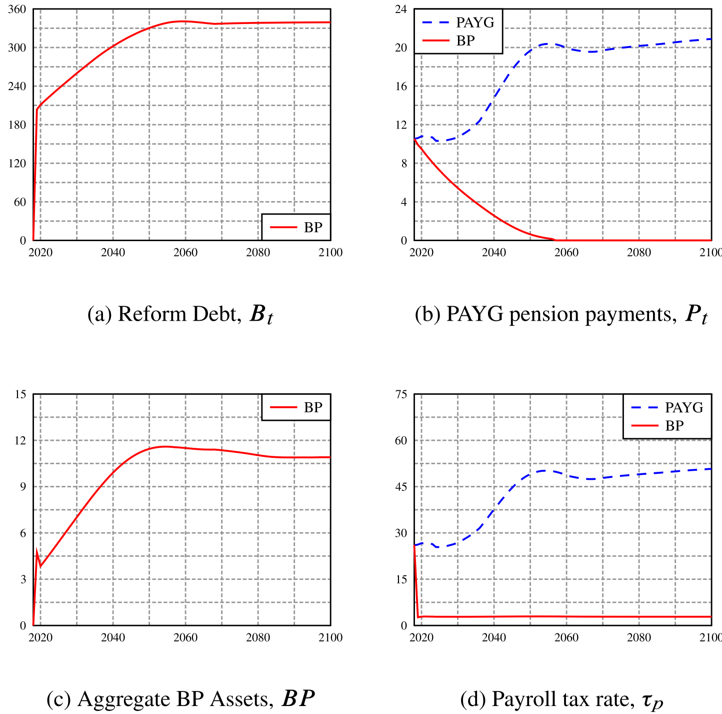

(a) Reform Debt, B_t

(b) PAYG pension payments, P_t

(c) Aggregate BP Assets, BP

(d) Payroll tax rate, τ_p

FIGURE 8. Reform debt and PAYG pension payments (% of output), Aggregate BP assets, and payroll tax rate (percentage) during the transition.

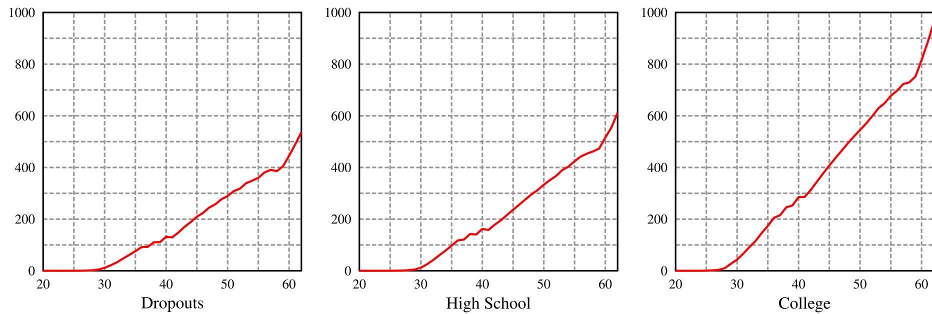

FIGURE 9. Average BP asset subsidies BP^S by age, for vintage workers in 2019 (% of per capita output).

share of workers older than 65 increases, but average productivity declines.[29] An older population implies a larger share of retirees and lower share of workers in the aggregate. Nevertheless, aggregate labour is higher than in the PAYG transition and in

29. Recall that we assume that the age profile of productivity is fixed during the transition.

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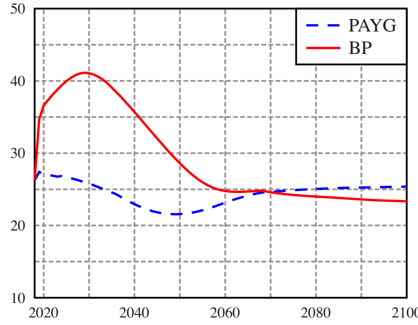

FIGURE 10. Consumption tax rate τ_c in the baseline scenario and during the BP reform (%).

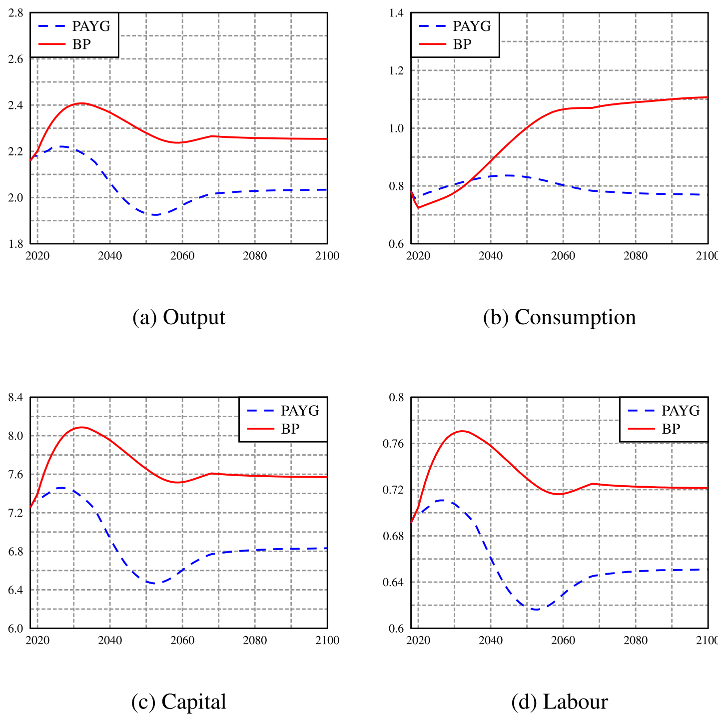

FIGURE 11. Main aggregates during the reform.

the long run. Aggregate consumption declines in the first two years due to the initial increase in consumption taxes. After the initial impact, consumption steadily increases after the increase in lifetime income, in particular after retirement (see Table 11).

By construction, during the reform all those who move from the PAYG to the BP system are (weakly) better off. All the individuals who enter the reformed economy during the transition are better off too, even though the government does not set any compensatory transfers to these workers. The reason is that in the BP economy the

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TABLE 11. Average retirement income as a percentage of per capita output in the PAYG and BP economies in 2068.

	Dropouts	High school	College
PAYG	44.03	57.87	89.48
BP	78.58	102.12	136.95

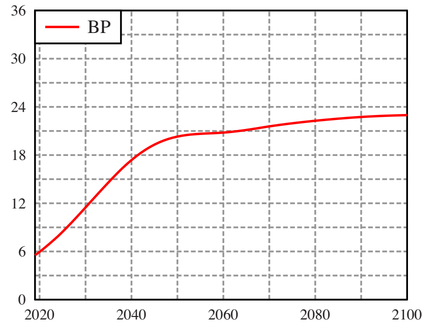

FIGURE 12. Average increase in lifetime utility for cohorts entering the economy in the front-loaded BP transition, relative to the baseline PAYG status quo.

payroll tax is reduced permanently (see Figure 8). Even though the consumption tax rate increases significantly in the first three decades following the reform (Figure 10), and aggregate consumption is slightly lower in the first 15 years (Figure 11), we find that all existing workers in 2019 and all new entrants after that year prefer the BP economy transition. The reform shown is almost but not a full Pareto improvement for all households alive and unborn as of 2019, because PAYG retirees alive in 2019, while receiving their full PAYG pension, also face higher consumption taxes. Nevertheless, as Figure 12 shows, there is room to compensate the losses of the (relatively) small group of 2019 PAYG retirees and construct a full Pareto improving BP transition, for instance with a small initial transfer to 2019 retirees that compensates them for the increase in taxes. The large long-run gains can make the reform a full Pareto improvement (i.e. without any losers) and robust to other specifications (such as, higher cost of debt or general equilibrium effects not accounted for in the current analysis).[30]

In the next subsection, we compare the two long-run scenarios: the PAYG and the reform BP economy.

5.2. *BP and PAYG Pension Systems in the Long Run*

In the tables below, the *BP* economy refers to the long-run, reformed economy with a BP fund as described in Section 2. This is the final steady state of the front-loaded

30. We find that general equilibrium effects increase the welfare gains of the reform, see Online Appendix A. Additionally, in an open economy setting, we have checked that the BP system is still welfare improving with an interest rate on reform debt of 2.5%.

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TABLE 12. Aggregates in the PAYG and BP simulations of 2068.

	Y	L	A	K	BP	C	h^a
PAYG	2.24	0.65	2.19	6.86	—	0.76	0.17
BP	2.51	0.72	13.9	7.57	10.91	1.11	0.19

Notes: In this table, variable Y is output at market prices, and variable A is total assets.
a. Variable h denotes total hours of time allocated to the market.

TABLE 13. Labour market shares in the PAYG and BP simulations of 2068 (% of population).

	W	U	I	R
PAYG	50.80	10.80	3.70	34.69
BP	58.88	13.29	5.03	22.79

Notes: W: workers, U: unemployed, I: inactive, and R: retirees.

reform to a $\tau_b = 22\%$ BP. This economy is reached after the transition shown above, with a stock of reform debt equal to 3.4 times output (permanent if, as assumed here, there is no growth).

The Tables 12 and 13 compare the BP economy with the status quo PAYG economy in the long run.

The first order effect of a mandatory retirement savings system is on PS behaviour before and after retirement. The retirement pension system in the PAYG economy, by taxing a large fraction of workers' wages that are then paid back after retirement, discourages PS, since workers expect pension payments during retirement. Eliminating PAYG pensions provides a strong incentive to save during working years, in order to finance consumption after retirement. On the other hand, the BP system features a fixed 22% contribution rate out of gross labour income, which is capitalized and available for consumption during involuntary unemployment and after retirement. Additionaly, workers can convert BP savings into a life annuity at retirement, which eliminates a precautionary motive to save for the event of an above average life time. While these features of the BP system reduce incentives to save, BP contributions are invested in productive capital in the international capital market (in contrast to the PAYG pension system, which transfers resources from workers to retirees within any given year, via the Social Security budget), earning the market interest rate. Table 12 shows that total private assets A (PS together with BP savings) in the BP economy are much higher, at 13.9. In the PAYG economy, assets consist of PS exclusively. The stock of capitalized BP contributions is almost 5 times output. As explained above, these capitalized contributions are then converted into annuities after retirement, contributing to a large gain in post-retirement income in the BP economy and consequently large increase in consumption.

Another direct effect of the reform is on the timing of the retirement decision. Since there is no minimum or maximum retirement age in the BP economy, workers decide when to retire according to the earnings-leisure tradeoff, taking into account labour productivity and job finding prospects in the last years of life. Table 13 shows that this drives the share of retirees substantially down in the BP economy, by 8

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TABLE 14. Average retirement age and the percentage of workers older than 65 in the PAYG in and the BP economies in 2068.

	Age	Workers 65+
PAYG	65.13	9.09
BP	74.37	26.64

TABLE 15. Policy parameters and tax revenues in the PAYG and in the BP economies.

	Tax rates (%)	
	PAYG	BP
τ_c	25.7	23.7
τ_p	51.1	2.8
τ_b	—	22.0
τ_e	65.6	47.9

Notes: τ_c: consumption tax rate, τ_y: household income tax rate, τ_k: capital income tax rate, and τ_p: payroll tax. τ_x fund tax rate; for example, $x = b, f$, τ_e efficient labour tax (see Footnote 10).

percentage points, and the share of workers up by almost the same amount. In 2068, the average retirement age in the PAYG economy is 65.1 and in the BP economy is 74.4 (Table 14).[31] The effective labour tax is higher in the PAYG economy (reducing work incentives), and the cost of delaying retirement relative to wage salaries tends to increase with age (as productivity starts to decline), after the minimum retirement age. Therefore, the PAYG system provides a strong incentive to retire and leave the labour force close to the minimum retirement age. In contrast, the effective labour tax is lower in the BP economy and annuity payments increase with BP savings, which accumulate by working. This provides an incentive to work until later. The share of workers older than 65 in the PAYG economy is 9%, while it is 26% in the BP economy. Greater work incentives increase job search, and, hence, unemployment is higher (and inactivity lower) in the BP economy.

Other important effects come indirectly through taxes (Table 15). Government expenditure with retirement pensions is zero and the payroll tax rate is only 2.8% in the BP economy. On the expenditure side, government transfers increase as more low income households qualify Table 16. On the revenue side, capital income tax collection as a share of output is constant (since capital income as a share of output is constant, due to the small open economy assumption). Household consumption is higher in the BP economy, and despite the additional cost of debt in the BP economy, the consumption tax rate required to clear the government budget is lower: $\tau_c = 23.7$ compared to 25.7% in PAYG.

31. Recall that life expectancy, education, the age profile of labour market productivity, job destruction, and job finding rates are the same in the two economies.

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TABLE 16. Government budget in the PAYG and BP simulations of 2068 (% of output, Y, at market prices).

	Public expenditure				Public revenues			
	T_r	P	U	rB	T_c	T_k	T_y	T_p
PAYG	0.76	21.02	1.17	—	8.76	2.33	6.82	22.17
BP	0.98	0.00	1.12	3.40	10.42	2.33	8.55	1.12

Notes: G: government consumption, T_r: minimum income, P: pension payments, U: unemployment benefits expenditures; T_c: consumption tax collections, T_k: capital income taxes, T_y: household income tax revenue, and T_p: payroll tax revenue.

TABLE 17. Consumption equivalent variation (Δ, %) in welfare of household of different education levels in the BP economy with $\tau_b = 22\%$, relative to the PAYG economy in 2068.

	Education			
	Dropouts	High school	College	All
CEV	35.22	36.45	35.53	36.08

In order to interpret the magnitude of the welfare gains in the reformed economy, we use a CEV measure that converts average welfare into consumption units. As explained above, we found the welfare maximizing BP contribution rate relative to the PAYG economy. To convert the increase in welfare into a CEV, we compute the percentage change in a household's lifetime consumption that equates its expected lifetime utility in the PAYG economy, to that in the reformed economy BP economy. Formally, let $i \in J \times H \times \mathcal{Z} \times \mathcal{L} \times A$ denote the household's type. Define $v^{PAYG}(i, \Delta(i))$ as the equilibrium value function of a household of type i in model economy PAYG, whose equilibrium consumption plan is changed by a fraction $\Delta(i)$ every period and whose leisure (and search) plan is unchanged. Then the CEV measure is found according to

$$v^{PAYG}(i, \Delta(i)) = v^R(i), \tag{31}$$

where $v^R(i)$ denotes the equilibrium value function of household of type i in the reformed BP economy.

Table 17 displays the large welfare gains at age $j = 20$ from entering a $\tau_b = 22\%$ BP economy, relative to entering the PAYG economy in the long-run steady state, where in the former the government has to finance the interest on the reform debt (3.4% of GDP). The gains are of the order of magnitude of the decrease in the payroll tax distortion, which is very high with the PAYG pension system. All education types are at least 35% better off in the BP economy despite the relatively high contribution rate of the BP pension system. The main reason for this is that despite the high BP contribution rate, the effective labour tax is lower, BP savings are capitalized instead of transferred between few workers and many retirees, and workers decide to leave the labour force later. Hence, retirement pensions are higher than in the PAYG economy (Table 11), which allows for higher consumption and lower PS during the entire

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lifecycle. Consumption is much higher in the BP economy, especially before the first retirement in the PAYG system (age 63), and average work hours are lower. The fact that agents retire later does not have a significant effect on utility, given the effective discount rate (β times survival probabilities).

In this section, we show that it is possible to implement a reform of the PAYG pension system during a ageing transition that doubles the ratio of individuals older than 65 relative to the 20–64 group, that is welfare improving for all cohorts that enter the economy during the transition period, with the introduction of the FF BP saving system.[32]

The PAYG and BP long-run economies, compared above, although sharing many important features (technology, demographics, and government tax structure), differ considerably in terms of the retirement pension system available to households—with large aggregate consequences, as discussed above. Nevertheless, there are several dimensions of the pension reform that contribute to its large welfare gains. These can be isolated and analysed separately: eliminating the PAYG system, introducing a FF pension system, and adding flexibility to this system by allowing workers to use BP contributions during a period of involuntary unemployment. The BP reform is the sum of these three elements. By studying these different features separately, we show how the BP system delivers higher welfare when compared to standard (i.e. defined contribution) FF pensions or the full privatization of savings.

Section 6 presents a comparison with alternative funded pension systems, comparing their performance against the BP system.

6. Comparison with Alternative Funded Pension Systems

We consider two alternative long-run economies: one in which the PAYG pension system is eliminated and workers save for retirement only through PS (we label it PS economy), and another in which the PAYG pension system is replaced by a standard defined contribution funded pension system. Additionally, we discuss effects at the individual level, and compare the different economies in terms of welfare.

In order to do so, we solve the stationary equilibrium of these alternative economies, assuming the 2068 age distribution and the elimination of PAYG pensions. For the defined contribution pension system, we perform a grid search as in the BP exercise and find a welfare maximizing mandatory pension contribution rate of $\tau_f = 16\%$ (Figure 13).

32. We perform the same exercise assuming that survival probabilities depend not only on age, but also on education (data taken from Díaz-Saavedra 2022). In this case, we find that the BP tax rate that maximizes the average newborns' welfare is 20%, and that the average welfare gain is 33%.This is because households with less (higher) education receive a higher (lower) annuity given their lower (higher) life expectancy; since households with less education have a lower weight within the population than their more educated group, the average welfare gain decreases. For households with average education, there is no significant difference.

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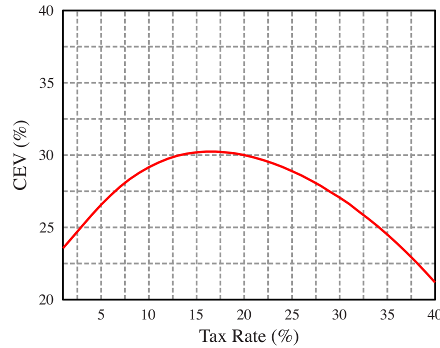

FIGURE 13. Average increase in welfare (CEV) at age 20 as a function of FF contribution rate (τ_f) in economies with a FF pension system relative to the PAYG economy, assuming a final debt level of 3.39 times output and $r^* = 1\%$.

PS. In the PS economy, there is no explicit retirement pension system, and households support consumption after retirement exclusively using PS.

FF. The FF, defined contribution, pension scenario is labeled *FF*. In this case, agents save a mandatory contribution as a fixed fraction of their labour earnings, which accumulate in an individual notional account until retirement. At retirement, the capitalized lifetime contributions are converted into a pension payment as an actuarily fair annuity.

The PS economy is computed after eliminating the public pension system, by setting $p_r = 0$. This implies that aggregate pension payments are zero, $P = 0$. The economy with a FF pension system is similar to the BP economy, with the important distinction that worker contributions to the pension system are claimed at retirement, but not after job loss.

The full description of the two economies above is included in Online Appendix C. Below, we clarify the differences relative to the pension system available to workers in each economy.

6.1. FF System

The *FF* economy features a standard FF, defined contribution, and pension system. Retirement pensions are financed by individual own contributions accumulated while working. Specifically, each worker has a mandatory contribution rate of τ_f of gross labour earnings y. The contributions are remunerated at the rate of return of capital. We assume, as in the BP system, that notional returns are taxed at the same rate as PS returns, τ_k; and that they are not part of the income tax base, as in the BP case. Hence, denoting by m_t the notional account of pension claims of a given worker at the

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beginning of period t, the evolution is given by

$$m_{t+1} = \tau_f y + (1 + r(1 - \tau_k))m_t \tag{32}$$

and

$$m_{t+1} = (1 + r(1 - \tau_k))m_t \tag{33}$$

in periods out of work. When a worker of age R retires with accumulated pension claims m, he is entitled to a pension payment per year given by

$$p^F(m) = \frac{(1+r)^{R-T}}{\sum_{j=R}^{T} \psi_j} m. \tag{34}$$

In expectation, at retirement age R, given his capitalized career contributions m, the retiree receives an actuarily fair annuity $p^F(m)$. The aggregate amount of pension claims is invested in the international capital market. As in the BP case, the system is FF because pension payments due to retirees who live longer than average are transferred from pension claims of retirees who leave earlier than average, and no other (taxed) resources are necessary to finance pension payments.

6.2. Results

As in the BP policy reform, changing or eliminating the pension system requires an assumption about which tax instrument is changed in order to balance the government budget. We maintain the assumption that the payroll tax rate τ_p adjusts to clear the social security budget, which in both the FF and PS economies (as in the BP economy), since there are no government liabilities with retirement pensions, consists only of unemployment benefit expenditures. As before, we assume that the consumption tax rate τ_c adjusts to clear the budget (government debt and government consumption are constant). Also as before, we assume that government subsidies—pension claims in the FF reform, and private asset transfers in the PS reform—are set so that during the transition, no worker is worse off compared to the PAYG baseline. These subsidies are financed with newly issued government debt, as in the previous section. In any scenario, PAYG pensions are always paid to retirees who are alive during the transition period.

In the following tables, we include the PAYG 2068 economy results, presented in Section 4, for comparison.

Table 18 shows the main aggregates in the three reformed economies. Since we have discussed above the differences between the PAYG and the BP economies, we will focus here on the main differences across the three reformed economies. The elimination of the PAYG pension system drives most of the differences in macroeconomic aggregates in the three economies: The three reformed economies are closer to each other than any of them is to the PAYG economy. It has a large direct effect on disposable income through the reduction in payroll taxes, and a large direct effect on savings behaviour due to the elimination of pension payments. Unsurprisingly,

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TABLE 18. Aggregates in the PAYG, PS, FF, and BP simulations of 2068.

	Y	L	A	K	X	C	h
PAYG	2.24	0.65	2.18	6.86	—	0.76	0.17
PS	2.85	0.81	11.22	8.48	—	0.95	0.22
FF	2.54	0.72	13.89	7.59	8.99	1.09	0.19
BP	2.51	0.72	13.90	7.57	10.91	1.11	0.19

Notes: In this table, variable Y is output at market prices, A is total assets, and X is total backpack assets in the BP economy and aggregate pension claims in the FF economy. Recall that in an open economy, A need not be equal to K, with the difference held by international investors.

TABLE 19. Retirement statistics in the PAYG, PS, FF, and BP economies of 2068.

	Retirement age	Workers 65+	Dropouts	High school	College
PAYG	65.12	9.09	44.03	57.87	89.48
PS	95.56	49.49	21.81	28.52	37.61
FF	77.18	29.18	73.58	96.00	131.62
BP	74.37	26.64	78.58	102.12	136.95

Notes: Columns from left to right: Average retirement rate, share of workers among population older than 65, average income after retirement as a share of per capita output for dropouts, and high school and college educated households.

all of the reformed economies have higher asset levels than the PAYG economy. The retirement pension system in the PAYG economy discourages PS before retirement. In contrast, both the FF and the BP economies display the highest stock of PS, 13.9. Recall that PS in the BP and FF economies include capital assets and pension savings.

Household consumption and total savings are higher in all reformed economies but there are important differences between the three scenarios. Households save much more in the PS economy, as PS are the only means to finance consumption after retirement. Savings continue until later in life, while annuity payments in the FF and BP economies allow agents to start de-saving when they are around 60 years old, on average (roughly 10 years earlier than in the PS economy). Consequently, consumption is higher in the FF and BP economies, especially during the last decades of life. The BP economy features the highest consumption (in all education groups) due to higher pension payments. Since the optimal BP tax rate is 22%, compared to the contribution rate of 16% in the FF system, pension payments are higher in the BP case. With higher aggregate retirement savings in the BP economy, workers can afford to retire earlier in comparison to the other two reformed economies (Table 19). In contrast, the PS economy displays the lowest share of retirees and the highest share of workers (Table 20). This is explained by the average retirement age in each economy.[33]

33. Note that the average retirement age in the PS economy is above 95, higher than average life expectancy in the 2068 economy. The reason is that many households stay inactive (do not search but remain in the labour force) until they die, while others decide to retire. In both cases, they do not have access to a retirement pension in the PS economy. Conditional on retiring, the average age at which agents leave the labour force is 96.

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TABLE 20. Labour market shares in the PAYG, PS, and BP simulations of 2068 (% of population).

	W	U	I	R
PAYG	50.80	10.80	3.70	34.69
PS	67.31	13.97	5.42	13.30
FF	59.10	11.75	5.16	23.99
BP	58.88	13.29	5.03	22.79

Notes: W: workers, U: unemployed, I: inactive, and R: retirees.

TABLE 21. Government budget in the PAYG, PS, FF, and BP simulations of 2068 (% of output, Y).

	Public expenditure				Public revenues		
	T_r	P	U	rB	T_c	T_y	T_p
PAYG	0.76	21.02	1.17	—	8.76	6.82	22.17
PS	1.55	0.00	1.11	2.92	11.28	7.60	1.11
FF	1.14	0.00	1.09	3.39	10.50	8.59	1.09
BP	0.98	0.00	1.12	3.40	10.42	8.55	1.12

Notes: T_r: minimum income, P: pension payments, U: unemployment benefits expenditures; rB: interest payments; T_c: consumption tax collections T_y: household income tax revenue, and T_p: payroll tax revenue.

TABLE 22. Policy parameters and tax revenues in the PAYG, PS, FF, and in the BP economy*.

	Tax rates (%)				Revenue Y ratios (%)			
	PAYG	PS	FF	BP	PAYG	PS	FF	BP
τ_c	25.7	33.7	24.3	23.7	8.76	11.28	10.50	10.42
τ_k	25.0	25.0	25.0	25.0	2.33	2.27	2.29	2.29
τ_y	14.2	14.2	14.2	14.2	6.82	7.60	8.59	8.55
τ_p	51.1	3.1	2.8	2.8	22.17	1.11	1.09	1.12
τ_x	0.0	0.0	16.0	22.0			7.37	10.15
τ_e	65.6	37.8	43.9	47.9				

Notes: τ_c: consumption tax rate, τ_y: household income tax rate, τ_k: capital income tax rate, τ_p: payroll tax. τ_x fund tax rate; for example, $x = b, f$, τ_e efficient labour tax (see Footnote 10). * : As a share of output at market prices.

Table 21 shows the output shares of the government taxes and revenues in the three scenarios.[34] Pay-as-you-go pension payments (P) are zero in the reformed economies, whereas they represent 21% of output in the PAYG economy. This difference explains the large decrease in the payroll tax rate in Table 22, from 51% in the PAYG economy to less than 3% in the reformed economies. Despite unemployment increasing once the PAYG system is eliminated, unemployment benefit expenditures as a ratio of output slightly decrease because output increases. Table 22 shows an increase in social income

34. Recall that government consumption as a share of output is fixed, and the level unintentional bequest taxed by the government also fixed. The other components react to any changes in the economy.

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TABLE 23. The distributions of earnings, income, and wealth.

	Gini	Bottom 10	Quintiles 1st	2nd	3rd	4th	5th	Top 10
			The earnings distributions (%)					
PAYG	0.38	3.1	7.4	10.4	14.9	22.3	45.0	28.7
PS	0.34	3.5	8.1	11.6	15.3	23.3	41.7	26.5
FF	0.34	3.5	8.4	11.5	15.6	23.2	41.3	26.0
BP	0.34	3.4	8.3	11.6	15.5	23.2	41.4	26.1
			The income distributions (%)					
PAYG	0.34	1.9	5.5	11.5	19.3	22.9	40.8	24.6
PS	0.45	1.6	4.0	8.4	14.9	23.4	49.3	31.1
FF	0.42	1.3	3.9	9.9	15.1	24.4	46.7	28.0
BP	0.42	1.3	4.0	9.6	15.0	24.2	47.2	29.5
			The wealth distributions (%)					
PAYG	0.76	0.0	0.0	0.7	4.0	17.2	78.0	57.7
PS	0.54	0.0	0.8	5.8	13.4	24.9	55.1	34.4
FF	0.67	0.0	0.0	1.5	9.2	22.9	66.4	43.8
BP	0.78	0.0	0.0	0.0	1.6	17.8	80.6	56.4

transfers to the poorest agents in the economy once PAYG pensions are eliminated. The reason for this is the following: by eliminating PAYG pensions, some low productivity and low savings workers over 65 eventually lose their job but keep searching, staying unemployed, while they do not find one (they would mostly choose to retire with PAYG pensions). After two years of unemployment, unemployment benefits expire and, once falling below the poverty threshold to qualify for social assistance, they start collecting government transfers. In the PS and BP economy, more households reach this state and hence aggregate transfers to low income households are higher. The aggregate amount of transfers is lower in the BP economy, among the reformed scenarios, because households retire relatively earlier and retirement pensions are higher in that economy, and thus fewer households reach the minimum income level to quality for government assistance. Higher retirement pensions also imply higher income tax collections in the FF and the BP economies. This allows for lower consumption tax rates (Table 22) and still relatively large consumption tax bases, due to higher aggregate consumption, in order to balance the government budget at the steady state.

There are also important differences in terms of income and wealth inequality between status quo and reformed economies. Table 23 shows the distribution of income, earnings, and wealth in the four economies. Changes in all inequality measures are mainly driven by the longer working lifetime in the reformed economies (PS, BP, and FF) compared to the PAYG economy. In the reformed economies, earnings inequality decreases mainly because the difference in the deterministic labour productivity by educational type, which strongly decreases for the more educated workers as they become older. Recall that people retire later in the reformed economies. In the reformed economies, income inequality increases mainly because of the following. Retirees replace public retirement income (evenly distributed since there are only three types

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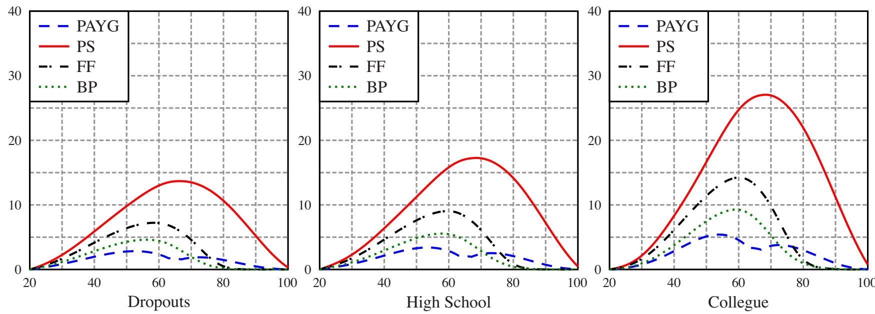

FIGURE 14. Life-cycle profiles of liquid assets.

of public retirement pensions) by capital income and/or annuity income, which is more unevenly distributed. Wealth inequality refers only to private assets holdings. In the PS economy, dropouts increase by more their saving rates, as there are no public pensions (the main income source for low educated retired people), so wealth inequality decreases. In the BP and FF economies, wealth inequality is higher than in the PS economies, as they deliver a forced savings scheme for the retirement period, so low educated people reduce by more savings during their working lifetime. The higher this compulsory saving, the higher this effect, so the higher the wealth inequality.

Some of these results are sensitive to the small open economy assumption. If changes in the pension system affect interest rate and wages, PS and labour supply react and the optimal BP contribution rate (τ_b) and the pension contribution rate (τ_f) also differ. In particular, eliminating the PAYG system encourages PS in any alternative reformed economy. More savings reduce the interest rate and increase the wage rate in a closed economy, which in turn decreases incentives to save and the return on the FF and BP pension systems savings. This leads to lower optimal contribution rates in the defined contribution systems. We report the closed economy results in Online Appendix A.

Figure 14 shows the life-cycle profiles of liquid assets in all the model economies. First, the figure shows that during the working lifetime, liquid assets are accumulated at a faster rate in all the reformed economies, mainly because the higher disposable net earnings since the payroll tax rate is only about 3% in comparison to the 51% of the PAYG economy. Second, the figure shows that liquid assets are higher in the PS economy, as households have to save privately in order to finance the consumption at older ages. And lastly, this figure also shows that after age 60, liquid assets are depleted at a faster rate in both the FF and BP economies, as households are guaranteed an annuity payment that is typically higher than PAYG pensions.

6.3. *Welfare Effects*

We use the same consumption equivalent measure as above (CEV) to quantify the increase in average lifetime utility at age 20 across steady-state economies, for each education group.

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TABLE 24. Consumption equivalent variation (Δ, %) in the PS, BP, and pension fund economies, relative to the PAYG economy.

Simulation	Education			All
	Dropouts	High chool	College	
PS	26.26	26.69	24.70	26.49
FF	31.14	31.07	29.48	30.93
BP	35.22	36.45	35.53	36.08

TABLE 25. Consumption equivalent variation (Δ, %) in the FF and BP economies, relative to the PS economy.

Simulation	Education			All
	Dropouts	High school	College	
FF	3.86	3.45	3.83	3.50
BP	7.10	7.70	8.68	7.58

Welfare is much higher in all the reformed economies, and the BP system dominates among the three alternatives because of the additional flexibility of BP savings during periods of unemployment (Table 24). This makes it possible to increase the contribution rate (relative to what is socially desirable in the FF pension system) and deliver higher retirement pensions, compensating for the distortionary effect of a fixed contribution rate for all workers (regardless of age, earnings, or wealth). The PAYG, FF, and BP systems provide a stable income stream after retirement, whereas in the PS economy retirees rely exclusively on PS. Households value a stable pension payment because of the presence of survival risk. Additionally, the BP and FF systems deliver an actuarily fair pension payment, given each worker's lifetime pension savings. Private savings provide only partial insurance against survival risk, and therefore agents end up saving too much compared to what they would do if they had a stable source of retirement income (Table 25). In addition, the BP system has a higher asset value when compared to a standard FF pension system, due to the possibility to use BP savings in periods of involuntary job loss, even before retirement. Additionally, the long-run BP economy is reached with a level of reform debt that is virtually the same as the FF economy, that is, the cost of reform debt is almost the same. Figure 15 shows the time series of the debt to output ratio in all of the reformed economies.

Table 26 shows the extent to which unemployed workers use BP savings in the first period of involuntary unemployment, compared to PS.

If we remove the BP feature that allows unemployed workers to use some or all of the BP savings during periods of involuntary unemployment, the BP system is equivalent to the FF system. The BP is the best retirement pension system among the alternatives we consider because it combines the "forced" worker contributions (common to both the PAYG system via payroll taxes, and to the FF system) with the

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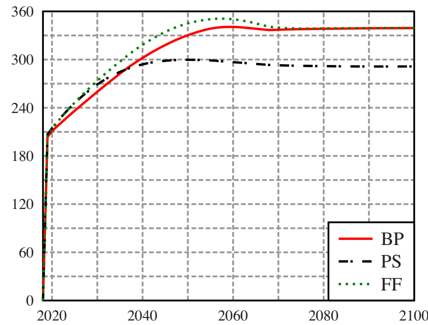

FIGURE 15. Public debt to output ratio in all of the reformed economies (%).

TABLE 26. Average private and backpack (de-)saving rates by age (as a proportion of unemployment benefits), for unemployed workers who search for a job.

	Private savings	Backpack savings
Age 25	−11.89	−5.32
Age 35	−27.95	−13.85
Age 45	−48.79	−9.32

possibility to use some of the retirement savings during unemployment. This is valued the most by the unemployed with low PS, and it allows for higher contribution rates and pensions after retirement. Table 26 shows average unemployed de-saving rates by age as a proportion of unemployment benefits, for liquid assets and for BP savings, in the BP economy.

7. Concluding Discussion

Using an overlapping generations model with labour market frictions, we have shown that there can be important allocative and welfare gains in the reform of an economy with a PAYG pension system ahead of an ageing transition. The main mechanism behind these gains is to have a FF pension system in a aged population, with partial substitution of PS by pension savings. The BP pension fund ranks first in social welfare among the standard FF alternative we considered. Associated with the reform, there is a better allocation of employment, with higher share of employed—in particular, a higher percentage of high productive agents within the employed—and a lower share of inactive and retirees. Effectively, there is a more efficient allocation of savings in the economy, with a shift from pure transfers (to the unemployed and retirees) to savings and, therefore, investment in productive capital. Unemployed are better off due to the prospect of higher earnings, and retirees are better off since in our economy pension benefits are linked to productivity, which is higher in the BP economy. The welfare gains are even greater if we consider the Spanish economy as a closed economy (the

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average CEV is 58% instead of 36% in the open economy), since there is a higher capitalization, with corresponding lower interest rates and higher wages (see Online Appendix A) and, also as a result, a larger active population. This means that insofar as EU economies are not fully open, the gains from a PAYG reform for a BP system are even greater than the ones described in the main text.

The main result is that a Pareto improvement can be achieved by replacing the PAYG system with the BP system. The BP reform dominates the simple elimination of the PAYG, letting agents freely choose their savings for retirement; that is, the PS economy. In comparing the two, the PS has a lower effective labour tax, but all the savings are part of the taxable income and retirement income is not insured. Welfare is also higher in the BP economy than in an economy with a FF pension fund, since agents can better manage their savings as to insure not only their retirement, but also their unemployment spells beyond what the existing unemployment insurance provides, avoiding excessive precautionary savings to further insure unemployment spells with FF systems. To our knowledge, we are the first to analyze employment and welfare effects in comparing alternative social security systems, among them the BP.

Furthermore, our analysis accounts for the incoming "ageing transition", which raises the question of how to implement a Pareto improving transition across pension systems; that is, a reform with no losers among the generations involved in the transition from the current PAYG to the final steady-state BP economy (or FF or PS economies). This would already be challenging in a steady-state economy in which pension payments are more than 10% of GDP and the dependency is 31% (as in Spain 2018), if this ratio were to be the same in the decades to come, but it is even more difficult when the country faces an ageing transition whereby the dependency ratio for the PAYG system doubles to 60%; that is, from 3.2 workers per retiree to 1.6. Nevertheless, we show that a Pareto improving transition can be based on two elements. First, the large welfare gains that the reform can achieve in the long run once it has been implemented provide fiscal space to finance the cost of the "entitlement debt" generated by the elimination of the PAYG system. This suggests the second element, which is the timing of such transition: a reform that anticipates the ageing transition—in which all current and future workers move to the BP system, and all PAYG entitlements are financed with debt (current PAYG pension payments and sufficient compensation to current and future workers not to lose with the reform)—minimizes the final "entitlement debt" cost of the reform. In our calibrated Spanish economy, the amount of financing debt is large (203% of GDP in the first year, which becomes 340% at the end of the transition) but much lower than in a slow transition (less than half) and it is sustainable with reasonable low interest rates (our benchmark is 1% annual rate, a steady-state cost of 3.4% of GDP if there is no growth).

All the alternative reforms to the PAYG that we have considered involve a substantial increase of assets in the economy—either private or fund (BP or FF) assets—a fraction of them borrowed abroad. In the open economy analysis (main text), the increase of assets translates into an increase of capital and a capital account surplus, while in the closed economy analysis (Appendix) the increase of assets translates

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only into a substantial increase of capital, with an even larger "entitlement debt" (see Figures 15 and A.3). In both analyses of the long-run steady state, the cost of debt must be financed with primary surpluses (i.e. increased steady-state taxes), as in the Fiscal Theory of the Price Level. Alternatively, following Andolfatto et al. (2022), we could have considered economies with credit-market frictions—such as, non-state contingent nominal contracting—in which a first tranche of the "entitlement debt" plays the role of interest-bearing money that households acquire in exchange of private assets to ease these frictions and smooth consumption. For them, the two-tranche formulation helps to explain the puzzle of having high sovereign debts in a context of low interest rates. In our economies, this formulation would also result in a lower capital adjustment (and lower capital account surplus in the open economy) and lower "entitlement debt" (the second tranche) to be financed with primary surpluses, making our proposal easier to implement with even larger welfare gains.[35]

In our analysis, we have made some assumptions and restrictions. A reform may be (fully or partially) financed by other means (more efficient taxation, broader labour market reform, higher growth, etc.), but the *fast* transition from PAYG to BP pensions presented in this article is a benchmark of the overall costs and benefits of a reform without losers; short of this, there will be losers, given the costs associated with maintaining the current PAYG system or of engaging in only partial reforms. Nevertheless, the latter may be politically easier to implement, especially in already indebted economies facing tight fiscal pressures, due to the current accumulation of crises, as we mention at the outset. However, with a farsighted view, the "Next Generation" is more likely to be better off with the legacy of a BP system and the "entitlement debt" than with the legacy of a PAYG system without the "entitlement debt".

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35. According to James Bullard, in an application of their framework to the U.S. economy, the optimal first-tranche debt to GDP is 100%. If a similar result were to hold in our benchmark BP reform and the first-tranche applied to "entitlement debt" the long-run yearly cost could be reduced from 3.4% to 2.4% of GDP.

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Supplementary Data

Supplementary data are available at *JEEA* online.

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