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# Assessing the effectiveness of recent pension reforms: The French experiment

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ABSTRACT

Reforming public and private pension systems to address the challenges posed by population ageing and a range of economic, labour market, social, political, geopolitical, technological, legal, and regulatory shocks remains a major policy priority for many countries. A widely supported response has been to raise minimum and statutory retirement ages and restrict early exit pathways. These measures aim to boost labour force participation and employment among older individuals, stimulate potential GDP growth and consumption, ease pressure on social security systems, and improve public finances. However, it remains uncertain whether pension reforms alone can prevent a decline in the relative size of the labour force or ensure intergenerational fairness. This paper assesses the effectiveness of recent retirement age reforms in France in stabilising the old-age dependency ratio and securing long-term financial sustainability. It also examines whether these reforms promote intergenerational equity. The findings suggest that the reforms fall short of offsetting the projected decline in the labour force, achieving fairness across generations, and maintaining fiscal balance. The results underscore the need for a holistic and dynamic approach to retirement age policy design.

## 1. Introduction

Reforming public and private pension systems to address the challenges posed by population ageing and a wide array of economic, labour market, social, political, geopolitical, technological, legal, and regulatory shocks represents a significant policy challenge for many countries. Over the past three decades, numerous countries have undertaken multiple waves of pension reform – ranging from systemic transformations to gradual parametric adjustments – with the overarching aim of ensuring the long-term affordability, equity, and adequacy of pension systems.

Systemic reforms include the transition to non-financial defined contribution (NDC) schemes, as implemented in countries such as Italy, Sweden, Poland, Latvia, and Norway, as well as the financialisation of pensions, marked by the expansion of private occupational and personal pre-funded defined contribution retirement income schemes. In parallel, many countries have introduced parametric reforms, involving adjustments to contribution rates, statutory pension ages, benefit formulas, and indexation rules, and measures to strengthen the contribution–benefit link [1,2].

In many countries, there is growing political consensus on extending working lives in response to demographic pressures. Policy measures include raising both minimum and statutory retirement ages, restricting or phasing out early exit routes – such as voluntary early retirement, long-term unemployment, disability, and general welfare benefits – and strengthening financial incentives to work beyond the official retirement age. Further reforms involve lengthening contribution or employment periods for full pension eligibility and delaying the age of entitlement to public pensions [3–6].

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Raising the retirement age extends workforce participation, supports higher employment, stimulates economic growth and consumption, and eases the fiscal burden on younger cohorts [7–9]. At the individual level, aligning retirement with rising life expectancy helps preserve replacement rates, mitigating the trade-off between sustainability and adequacy. By postponing retirement as longevity increases, individuals contribute for a longer period, accumulate higher public and private pension entitlements, and draw benefits for fewer years. This adjustment helps to maintain the relationship between retirement income and pre-retirement earnings, while also reducing the pressure to cut benefits or raise contributions and taxes to address funding deficits. In this way, it alleviates the inherent tension between the financial sustainability of pension schemes and the adequacy of retirement income. Longer working lives also strengthen public finances by boosting tax revenues [10]. While raising the retirement age is an effective policy instrument, it is not a comprehensive solution to all pension system challenges.

Retirement age policies across OECD countries differ in key design features, including the presence of explicit or implicit policy objectives, the decision-making process, the triggering variable, the indexation mechanism, lag, and revision frequency [4,11,12]. For instance, the Netherlands and Denmark aim to maintain a constant expected retirement duration, while countries such as the United Kingdom, Czechia, and Malta seek a stable ratio between time spent working and in retirement. Sweden introduced an indicative retirement age to "nudge" individual decisions. Many countries have introduced automatic stabilisers linking early and statutory retirement ages, as well as pension benefits, to observed longevity trends at older ages [13]. For instance, Portugal and Finland adopted a two-thirds link between retirement age and life expectancy, implicitly sharing longevity gains between workers and retirees.[2] International bodies, including the European Commission, promote pension reform in the context of population ageing, balancing economic efficiency, financial sustainability, and intergenerational equity [21,22].

France has enacted significant pension reforms, including gradually raising the legal retirement age and introducing incentives for longer working lives. Nevertheless, the employment rate among older French workers remains below the European average, with marked gender disparities. Recent reforms may also lead to unintended outcomes, such as increased early retirement and health-related work interruptions. The growing fiscal burden of public pensions, alongside strong public resistance to reform, underscores the need for robust evaluations of their labour market impacts. Analysing recent changes to France's retirement age offers valuable insights into the complexities of pension reform and the trade-offs between financial sustainability, labour market performance, and social equity.

Against this backdrop, the paper first examines whether recent increases in retirement ages are sufficient, on their own, to halt the decline in the relative size of the labour force. To assess the effectiveness of recent retirement age reforms in France in stabilising the country's old-age dependency ratio (OADR), we generate probabilistic, age- and sex-specific population trajectories. This is accomplished by integrating the cohort-component method with non-parametric functional data models. In 1950, there were 13.9 individuals aged 65 or over for every 100 working-age individuals (aged 20–64) across OECD countries, and 19.5 in France. By 2020, these figures had risen to 30.4 and 37.3, respectively. Looking ahead, projections for 2075 indicate that the OADR will increase to 58.6 across the OECD and 55.8 in France [4].

As life expectancy rises, the pension scheme dependency ratio is projected to increase significantly unless accompanied by higher labour force participation and employment at older ages. Ongoing population ageing, rising OADR, a shrinking labour supply, and an ageing workforce in relatively poor health are likely to dampen economic growth. This shift risks turning the past demographic dividend into a future demographic drag, posing a threat to long-term living standards [23].

Secondly, we examine whether France's retirement age policies align with the principles of financial sustainability and intra- and intergenerational equity. Our analysis compares eight distinct retirement age strategies, including France's previous and current pension age policies; a policy targeting a OADR under a balanced pay-as-you-go (PAYG) scheme; two intergenerationally actuarially fair policies recently proposed by Bravo et al. [24] under steady-state demographic conditions; a prospective age-based approach; and a policy aiming to maintain constant benefits in an individual defined contribution (DC) scheme. Additionally, a robustness analysis of pension age and dependency ratio forecasts with respect to the choice of base year is conducted, in order to assess the implications of postponing pension reforms.

We focus on adjustment policies with a fixed contribution rate, treating the statutory retirement age as exogenously determined. This assumes no change in labour market behaviour, with effective retirement coinciding with the statutory age—implying that the system shapes retirement decisions among insured workers. This involves designing actuarially fair increments and decrements for early and deferred retirement to avoid distorting retirement timing decisions. Under mild assumptions regarding technology and individual preferences in an overlapping generations model, adjusting the retirement age in line with longevity gains is shown to be individually optimal [25–28]. Within this framework, we estimate the statutory retirement age increases required in France to stabilise the relative size of the labour supply.

A key contribution of our approach lies in the use of alternative conceptualisations of population age structure. We incorporate both traditional retrospective measures, such as the dependency ratio – which classifies individuals as old based on fixed chronological age while overlooking trends in health, functional capacity, and longevity heterogeneity – and innovative prospective measures, which define working-age thresholds based on expected remaining years of life [29–32].

The analysis proceeds in several steps. First, we present the theoretical framework for various retirement age policies and outline how stochastic population forecasts can be integrated with these policies to project dependency ratio dynamics and assess the sustainability and intergenerational equity of pension systems. Second, we focus on the case of France. Using historical demographic data, we generate probabilistic age- and sex-specific population trajectories. Forecasts of fertility, mortality, and net migration are derived using a combination of the cohort-component method, functional principal components analysis, and time series techniques. We then estimate the retirement age adjustments required to maintain financial balance in the French system and evaluate whether these adjustments yield equitable outcomes across generations.

Our empirical findings indicate that the recent retirement age reform in France is insufficient to halt the decline in the relative size of the labour force or to curb the growing fiscal pressure of population ageing. Even under a scenario in which the dependency ratio remains constant, the reform fails to ensure intergenerational equity and long-term financial balance. By 2050, the statutory retirement age required to stabilise the OADR at pre-reform levels converges to 67—the current full-rate guarantee age in France. Postponing pension age reforms exacerbates financial imbalances and equity concerns. Overall, the results underscore the need for periodic comprehensive reviews of retirement

[2] The primary aim of introducing automatic stabilisers linked to life expectancy is cost containment [14,15] but there are other dimensions of welfare restructuring such as: (i) recalibrating pension systems to incorporate new objectives, such as intra- and intergenerational equity; (ii) rationalising reforms by embedding economic and actuarial logic; (iii) reducing the political risks associated with repeated, often unpopular negotiations; (iv) Redefining the pension promise for younger cohorts (capitalisation); (v) recommodifying pensions [16–20].

age policies to reflect demographic shifts and changes in the labour force structure.

The remainder of the paper is structured as follows. Section 2 outlines the theoretical and policy foundations of the alternative retirement age policies examined. Section 3 describes the data and methods used to generate stochastic population forecasts for France. Section 4 provides an overview of the French multipillar pension system and recent reforms. Section 5 empirically evaluates the effectiveness of recent retirement age reforms in France. Section 6 offers a critical discussion of the results and presents the conclusions.

## 2. Retirement age policies: Conceptual background

### 2.1. Constant dependency ratio in a PAYG pension scheme

The objective of consumption smoothing is central to achieving income adequacy and security—one of the core goals of pension systems, alongside poverty alleviation and protection against life-course risks such as disability and longevity during both working life and old age. Broadly speaking, consumption smoothing may be realised through either public pay-as-you-go (PAYG) or private funded pension arrangements, with PAYG schemes serving as the primary mechanism in most OECD countries.

This section introduces a stylised PAYG pension system in discrete time with age-dependent parameters, within which retirement age policies are analysed. The fundamental principle of a pure PAYG system is that, at any given time, current pension benefits are financed directly by contributions from current workers (employees and/or employers), without reliance on financial market returns. By contrast, in funded pension schemes, contributions are accumulated and invested to finance future pension entitlements. The PAYG balanced budget condition at time $t \geq 0$ is defined as

$$c_t \cdot \overline{W_t} \cdot A_t = L_t \cdot \overline{P_t}, \tag{1}$$

where $c_t$ denotes the contribution rate, $\overline{W_t}$ the economy-wide average salary, $A_t$ the number of active workers in the scheme, $L_t$ the number of pensioners and $\overline{P_t}$ the mean pension at time $t$. Let $\eta_t$ represent the cross-sectional benefit ratio, defined as the weighted average of cohort-specific replacement rates. This ratio captures the relationship between the mean pension benefit and the economy-wide average wage (the relative pension level), i.e.,

$$\eta_t = \frac{\overline{P_t}}{\overline{W_t}}. \tag{2}$$

Let $D_t$ denote the scheme's dependency ratio (SDR), defined as the ratio between the number of pensioners $L_t$ and the number of active workers $A_t$, that is:

$$D_t = \frac{L_t}{A_t}. \tag{3}$$

The scheme dependency ratio (SDR) can be proxied by the demographic old-age dependency ratio (OADR), which is defined as the ratio of individuals considered old – typically those aged 65 and over – to the working-age population, commonly defined as those aged between 20 and 64. This approximation holds under the assumption that the pension system efficiency ratio ($SER$), defined as

$$SER_t = \frac{D_t}{OADR_t}, \tag{4}$$

is approximately equal to one, and that there are no changes in labour market behaviour (e.g., early retirement or labour force participation). Under this condition, the balanced budget constraint (1) can be reformulated as:

$$c_t = D_t \cdot \eta_t. \tag{5}$$

Eq. (5) illustrates the multiple possible combinations of the contribution rate ($c_t$), the dependency ratio ($D_t$), and the relative pension level ($\eta_t$) required to maintain balance in a pay-as-you-go (PAYG) pension system. Structural shocks – whether demographic, employment-related, or linked to changes in career duration or retirement timing – can, in theory, be absorbed through an infinite number of adjustment configurations involving these parameters. However, not all such combinations are intra- or intergenerationally equitable, economically advisable, or socially and politically sustainable. A viable reform must ensure a fair distribution of costs, benefits, and risks between current contributors and pensioners, while also establishing a credible and predictable long-term benefit framework for future generations of workers.

In pure defined benefit (DB) pension schemes, the relative pension level $\eta_t$ is held constant (i.e., $\eta_t = \eta_0$) by maintaining a stable replacement rate over time and indexing pensions in payment to wage growth. Under this arrangement, retired cohorts are fully insulated from the risks and costs associated with demographic or employment shocks that negatively (or positively) affect the dependency ratio $D_t$. As a result, the entire burden (or benefit) of such shocks is transferred to the working population, who absorb it through corresponding increases (or reductions) in the contribution rate levied on their earnings.

In contrast, in a pure defined contribution (DC) scheme, the contribution rate is fixed (i.e., $c_t = c_0$), and the benefit ratio must be adjusted – either automatically or at the discretion of policymakers – to restore PAYG equilibrium in the event of shocks affecting the dependency ratio. Such adjustments to the benefit ratio may involve modifying the pension benefits of current retirees and/or altering the replacement rates applicable to new pensioners. Under this arrangement, the entirety of the risk is borne by the retired population, who face reduced (or increased) benefits depending on the direction of the shock.

To address the distribution of risks across generations, hybrid pension schemes incorporating both DB and DC elements – often inspired by the Musgrave rule – have been proposed in the literature (see, e.g., [33–35]). These schemes aim to achieve a more equitable sharing of demographic and economic risks between active workers and retirees. Automatic adjustment mechanisms can be designed to specify how the adjustment burden is allocated across generations when the dependency ratio changes, by defining the rules under which the contribution rate and the relative pension level are updated to maintain system balance.

An alternative means of rebalancing the pension scheme – without adjusting the contribution rate and/or the benefit ratio – is to neutralise the impact of demographic and/or employment shocks on the dependency ratio $D_t$ by updating the normal and early retirement ages. This can be complemented by broader labour market policies aimed at increasing participation and employment rates, particularly at older ages. In this framework, the retirement age is endogenously determined to stabilise the dependency ratio, such that:

$$D_t = D_0 = \frac{c_0}{\eta_0}, \tag{6}$$

For instance, to offset the impact of population ageing on the financial sustainability of the pension system – such as that caused by declining fertility rates and/or rising life expectancy – the statutory retirement age must increase in order to restore balance between contributors and beneficiaries. This approach effectively assumes that the retirement age is a flexible policy instrument, adjusted as necessary to maintain both the dependency ratio and the financial equilibrium of the system.

The dependency ratio, to some extent, reflects the financial burden placed on the working-age population, as increases in $D_t$ reduce the capacity of the employed population to finance pensions and other ageing-related expenditures, including healthcare and long-term care.

### 2.2. Intergenerationally equitable policies

We now turn to the concepts of intergenerational actuarial fairness and neutrality in pay-as-you-go (PAYG) pension schemes, and their relationship with retirement age policies. Actuarial fairness is grounded in the principle of fairness over the entire life cycle. A pension scheme is considered actuarially fair if lifetime pension benefits—referred to as pension wealth—are equal to the value of lifetime contributions, both measured at the point of retirement. The pension wealth accumulated by the individual (whether notional or fully funded) through contributions levied on earnings is transformed into pension entitlements based on the individual's expected duration of retirement.

A PAYG scheme is said to be intergenerationally neutral if each generation finances the notional capital value of its own pension benefits, meaning that the contribution-to-benefit ratio remains constant across generations over time.

Following Bravo et al. [24], consider a stylised career-average re-evaluated earnings-related notional defined benefit (NDB) scheme, in which old-age pension entitlements are actuarially computed based on lifetime contributions. The actuarial intertemporal balance condition in year $t$ equates the revalued contribution effort (notional capital) to the present value of pension entitlements, and can be expressed as:

$$c_t \cdot V_t = D_t \cdot P_{x_r(t)} \cdot a^{\pi,y}_{x_r(t)} \tag{7}$$

where $V_t \equiv V\left(x_r, x_e, w_t, v_t\right)$ is the lifetime pensionable average salary $w_t$ of all active workers, earned since labour market entry age $x_e$ and revalued using a notional interest rate $v_t$; $x_r$ is the statutory retirement age; $D_t$ is the dependency rate; $a^{\pi,y}_{x_r(t)} \equiv a\left(x_r, \pi, y, {}_\tau p_{x_r(t)}\right)$ is the annuity factor computed at age $x_r(t)$ using cohort-specific survival probabilities ${}_\tau p_{x_r(t)}$, an uprating rate for pensions $\pi$ and the scheme's discount rate $y$, that is:

$$a^{\pi,y}_{x_r(t)} := \sum_{\tau=1}^{\omega-x_r} \left(\frac{1+\pi}{1+y}\right)^{\tau} {}_\tau p_{x_r(t)}. \tag{8}$$

In Eq. (7), $P_{x_r(t)}$ denotes the annual pension benefit, computed as follows:

$$P_{x_r(t)} = \theta_t \cdot N_{x_r(t)} \cdot \overline{RE}_{x_r(t)} \cdot RF_{x_r(t)} \cdot b_{x_r(t)}, \tag{9}$$

where $\theta_t N_{x_r(t)}$ represents the scheme's replacement rate (global accrued rate), $\theta_t$ is a flat accrual rate for each year of service, $N_{x_r(t)} = \left(x_{r(t)} - x_e\right)$ is the contribution period, $RF_{x_r(t)}$ is a sustainability factor (e.g., linked to life expectancy at $x_r$ like in Finland and Portugal); $b_{x_r(t)}$ are actuarially fair pension decrements (increments) for early $\left(b_{x_r(t)} < 1\right)$ or postponed $\left(b_{x_r(t)} > 1\right)$ retirement, and $\overline{RE}_{x_r(t)} \equiv \overline{RE}\left(x_{r(t)}, x_e, w_t, u_t\right)$ is the lifetime average revalued earnings at retirement age with $u_t$ the rate by which lifetime salaries are valorised (often called pre-retirement indexation) to the point of retirement. This mechanism adjusts for changes in living standards (typically in line with consumer price index inflation and earnings growth) between the time pension entitlements are accrued and the time they are claimed.

The actuarial balance constraint in Eq. (7) is influenced by a range of demographic factors – such as population size, age structure, and population dynamics – as well as by labour market developments, including changes in participation rates, employment levels, and retirement timing decisions. It is also affected by adjustments to the parameters of the pension scheme itself (e.g., the statutory pension age). To ensure that the scheme remains actuarially fair and intergenerationally neutral, the contribution-to-benefit ratio must remain constant across all generations, that is:

$$\frac{c_t}{c_0} = \frac{D_t}{D_0} \cdot \frac{\theta_t}{\theta_0} \cdot \frac{a^{\pi,y}_{x_r(t)}}{a^{\pi,y}_{x_r(0)}}. \tag{10}$$

where, without loss of generality, we have assumed that lifetime earnings are revalued at the scheme's notional internal rate of return (i.e., if $v_t = u_t \ \forall t$), workers retire at the full old-age pension age (i.e., $b_{x_r(t)} = b_{x_r(0)} = 1$) and the sustainability factor is constant over time (i.e., $RF_{x_r(t)}/RF_{x_r(0)} = 1$). The intergenerational fairness condition (10) underscores the range of dynamic and forward-looking automatic adjustment mechanisms and policy options available to absorb the effects of shocks and maintain the financial equilibrium of the pension scheme. These mechanisms enable the preservation of actuarial fairness and intergenerational neutrality, while simultaneously supporting other policy objectives such as efficiency, redistribution, and risk sharing.

This paper focuses on retirement age policies as instruments to address demographic and employment shocks, and revisits two policy frameworks recently proposed by Bravo et al. [24]: (i) the constant accrual rate per year (CAR) policy, where the annual accrual rate is held constant over time (i.e., $\theta_t = \theta_0$), such that changes in career length directly influence both the replacement rate and the overall scale of the scheme; (ii) the constant replacement rate (CRR) policy, which ensures intergenerational constancy of the replacement rate by satisfying $\theta_t N_{x_r(t)} = \theta_0 N_{x_r(0)}$. Under the CAR policy, and assuming mild conditions – specifically, that pensions are indexed at the scheme's internal discount rate (i.e., $\pi_t = y_t \ \forall t$) – an actuarially fair and intergenerationally neutral retirement age policy must satisfy the following condition:

$$\dot{e}^C_{x_r(t)} = \frac{D_0}{D_t} \cdot \dot{e}^C_{x_r(0)}. \tag{11}$$

Eq. (11) demonstrates that, under a demographic steady-state—defined here as a situation in which the labour force share (or dependency ratio) remains constant (i.e., $D_t = D_0$)—improvements in population survival must be accompanied by retirement age adjustments to ensure that pensioners enjoy a constant expected number of years in retirement.

Retirement age policies aimed at stabilising the retirement period have been adopted in countries such as the Netherlands and Denmark. These policies prescribe that increases in life expectancy result exclusively in extended working lives, thereby placing the entire longevity risk burden on working generations.

However, in scenarios characterised by a deteriorating dependency ratio, the CAR policy condition reveals that targeting a constant expected retirement period is insufficient to maintain the PAYG balanced budget condition or to ensure intergenerational fairness. Instead, working cohorts would be required to further delay retirement in order to uphold the PAYG system's financial equilibrium and sustain its conditional pension promise.

Under a CRR policy, an actuarially fair and intergenerationally neutral retirement age policy must satisfy the following condition:

$$\frac{\dot{e}^C_{x_r(t)}}{N_{x_r(t)}} = \frac{\dot{e}^C_{x_r(0)}}{N_{x_r(0)}} \cdot \frac{D_0}{D_t}. \tag{12}$$

Under a steady-state dependency ratio, the CRR intergenerational equity condition requires that, as life expectancy at retirement increases, the statutory pension age must also rise in such a way that the proportion of time spent in retirement relative to working years remains constant—regardless of the absolute level of life expectancy. This approach is being considered in pension reform discussions in the United Kingdom.

In contrast to the CAR policy, which assigns the full burden of longevity improvements to the working population, the CRR policy distributes this burden between workers and retirees. Under the CRR framework, individuals adjust their retirement age so that the share of their lifetime spent in employment remains fixed, thereby promoting a more balanced intergenerational allocation of longevity risk.

However, Eq. (12) also reveals that in a scenario characterised by a deteriorating dependency ratio – driven by population ageing, declining labour force participation, or persistent structural unemployment – intergenerational equity requires that future pensioners spend a smaller proportion of their lives in retirement compared to earlier cohorts. Put differently, under demographic pressures, the necessary increase in the retirement age exceeds the gain in life expectancy at retirement.

This result aligns with the findings of Chen and Lau [36], who, using an
overlapping-generations model with endogenous retirement and saving behaviour, conclude that in the context of population ageing and declining mortality, individuals delay retirement while the percentage of life spent working declines, and they accumulate greater savings for post-retirement consumption.[3]

### 2.3. Constant benefit in an individual DC retirement income scheme

Under this policy, the retirement age is adjusted in response to changes in life expectancy to ensure that the pension income—calculated through the annuitization of (real or notional) accumulations in an individual defined contribution (DC) scheme—remains constant in absolute terms over time. This approach implies that as life expectancy at retirement increases, additional contributions are required to finance an equivalent benefit level to that received by earlier cohorts. Typically, this is achieved by extending the working life. Formally, this retirement age policy can be defined as:

$$\frac{\Pi_{x_r(t)}}{a^{\pi,y}_{x_r(t)}} = \frac{\Pi_{x_r(0)}}{a^{\pi,y}_{x_r(0)}}, \tag{13}$$

where $\Pi_{x_r(t)}$ represents the scheme's accumulation at retirement age and $a^{\pi,y}_{x_r(t)}$ is the life annuity factor computed using a cohort approach.

### 2.4. Prospective old age threshold approach

Conventional age dependency ratios and similar indicators of population ageing classify individuals as old based on a fixed chronological threshold (e.g., 65 years), aiming to capture how demographic structure influences the balance between working and non-working populations. The working-age population is generally assumed to finance public services – such as health, pensions, education, security, and defence – through social security contributions and direct and indirect taxation. In contrast, the non-working population contributes primarily via taxes on retirement income and consumption or property, but is largely viewed as benefiting from the fiscal contributions of the working population. These age-threshold-based measures serve as proxies for the relative size of the labour force, albeit in purely quantitative terms.[4]

The reliance on chronological age assumes that the characteristics of the elderly (e.g., health, cognitive function, physical capacity) and those of the labour force (e.g., education, skills, productivity, experience, and adaptability) remain constant over time and across contexts. However, in the long term, remaining life expectancy has a greater impact on an individual's prospects than years already lived, making it a more relevant indicator for informing social policy and healthcare planning [32].

To advance the concept of prospective ageing and redefine old-age thresholds and the relative size of the elderly population, Shoven and Goda [29] and Sanderson and Scherbov [30,31,32] introduced a characteristics-based approach to population ageing. This method employs either dynamic or time-invariant characteristic schedules that map chronological age to the average or median level of a specific trait within the population—such as remaining life expectancy. The ages associated with particular levels of these traits are termed "$\alpha$-ages", meaning that individuals with the same $\alpha$-age share an equivalent level of the observed characteristic.

When remaining cohort life expectancy is used as the defining characteristic, the corresponding "$\alpha$-ages" are termed prospective ages, and ageing measures based on these thresholds are known as prospective ageing indicators (POATs) [32]. These indicators can inform pension age setting by accounting for improvements in longevity. For instance, the prospective old-age dependency ratio (POADR) reflects the share of the population exceeding a given POAT relative to the working-age population. Formally, let $C_t(\alpha)$ be a continuous and time-varying monotonic schedule of some characteristic setting its values at each chronological age $\alpha$. The retirement age policy corresponding to a particular value of this characteristic at time $t$ is then defined as:

$$x_r^{POAT}(t) = \alpha_{\dot{e}^C_x,t} = C_t^{-1}(\dot{e}^C_{x_r(t)}). \tag{14}$$

The pension age policy prescribed by the prospective age approach constitutes a specific case of the CAR policy (Eq. (11)), under the assumption that the labour force share – or dependency ratio – remains constant over time, and that the cohort life expectancy threshold is set at a level consistent with a balanced budget equation.

## 3. Stochastic population forecasts: demographic components and metrics

To evaluate retirement age policies, we follow the methodology of Hyndman and Booth [38] and Hyndman et al. [39], generating probabilistic age- and sex-specific population sample paths by combining the cohort-component method with non-parametric functional data models – notably functional principal components analysis – and the product-ratio method, alongside time series techniques for forecasting the three components of demographic change: fertility, mortality, and net international migration.[5]

Formally, let $y_t(x)$ denote the observed mortality or fertility rate for age $x$ in year $t$. The observed data are given by the set $\{x_i,\ y_t(x_i)\}$, $t = 1,\dots,n$, $i = 1,\dots,p$. The modelling approach proceeds as follows. First, for each year $t$, demographic rates are smoothed over age – but not over time – using a non-parametric smoothing technique, specifically constrained and weighted penalised regression splines. The functional data model assumes the existence of an underlying smooth function $s_t(x)$, which represents the true demographic rate at age $x$ and year $t$, observed with error at discrete age points. That is

$$y_t(x) = s_t(x) + \sigma_t(x)\varepsilon_{t,x}, \quad t = 1,\dots,n, \tag{15}$$

where $\{\varepsilon_t\}$ denotes a sequence of i.i.d. standard normal random variables, representing the stochastic variation in births, deaths, or international migration. The term $\sigma_t(x)$ allows the variance to vary both by age and over time. In the second step, the fitted curves are decomposed using functional principal component analysis (FPCA), based on the following model:

$$s_t(x) = \mu(x) + \sum_{j=1}^{J} \phi_j(x) b_{t,j} + e_t(x), \tag{16}$$

where $\mu(x)$ is a measure of location (the mean) of $s_t(x)$ across years; $\phi_j(x)$ and $b_{t,j}$ are a set of orthogonal basis functions computed using

[3] It is worth noting that in a pure PAYG system, the natural policy lever is the contribution rate. For example, from condition (10), it can be shown that achieving intergenerational equity requires the contribution rate to follow the following path over time [37]:

$$c_t = c_0 \cdot \frac{\dot{e}^C_{x_r(t)}}{\dot{e}^C_{x_r(0)}} \cdot \frac{D_t}{D_0}.$$

By contrast, in NDC schemes, the contribution rate is fixed across generations. Consequently, restoring equity in such systems necessitates adjustments to benefit generosity and/or other key pension parameters.

[4] Such measures overlook the fact that not all individuals of working age are employed (e.g., the unemployed, discouraged workers, homemakers, and students), while many older individuals remain active in the labour market.

[5] The approach proposed by Hyndman et al. [39] is one of several extensions of the classical Lee–Carter stochastic mortality model [40] widely used in demographic forecasting. This research field has expanded to include numerous methodologies, such as generalised age–period–cohort (GAPC) parametric models for single or multiple populations, principal component approaches, smoothing techniques, affine-jump diffusion models [41] and, more recently, model combination strategies (see, e.g., [15,42]).

a PCA decomposition representing, respectively, the $j$th orthogonal functional principal components of $s_t(x) - \mu(x)$ and their uncorrelated principal component scores; $e_t(x)$ is the residual error (with mean zero and no serial correlation) in modelling $s_t(x)$ using a finite set of $J$ basis functions; $J < n$ is the number of principal components used. In third place, we fit univariate time series ARIMA$(p_j, d_j, q_j)$ models to each of the coefficients $\{b_{t,j}\}$, $j = 1, \ldots, J$. Fourth, we forecast the coefficients $\{b_{t,j}\}$, $j = 1, \ldots, J$ for $t = n+1, \ldots, n+h$ using the fitted time series models. Fifth, we use the forecast coefficients with (15) and (16) to obtain forecasts of $s_t(x)$, $t = n+1, \ldots, n+h$. Sixth, given the observed data $\{y_t(x)\}_{t=1,\ldots,n}$ and the set of functional principal components $\{\phi_t(x)\}_{t=1,\ldots,j}$, forecasts of the h-step-ahead value of the target variable are given by

$$y_{T+h|T}(x) = \hat{\mu}(x) + \sum_{j=1}^{J} \phi_j(x)\, \hat{b}_{T+h|T,j}, \tag{17}$$

where $\hat{b}_{T+h|T,j}$ represents the h-step-ahead forecast of $b_{T+h|T,j}$ obtained using time series methods. To be more specific, the method is applied to log-fertility, whereas the product-ratio method applied to log-mortality and net international migration to ensure long-term sex-coherent (do not diverge) mortality and net migration forecasts. Finally, the estimated variances of the error terms in (15) and (16) are used to estimate prediction intervals for the forecasts.

Compared to the classical model proposed by Lee and Carter [40], the adopted method offers several advantages. First, it provides a coherent stochastic framework for modelling the three core demographic components, relying exclusively on historical data without the need for subjective inputs. Second, the demographic rates are smoothed prior to modelling, and the method employs functional principal components analysis – a continuous analogue of principal components analysis (PCA) – utilising more than one principal component. Third, it yields probabilistic prediction intervals for any demographic variable derived from population counts and vital events, including both period and cohort life expectancies. Fourth, unlike alternative approaches, functional data methods offer a flexible modelling framework applicable to all three demographic processes. Finally, the time series models used to forecast the principal component scores are more sophisticated than the naïve random walk with drift employed in the classical Lee–Carter model.

The calibrated models of the three components of demographic change are employed to generate sample paths for age-specific fertility rates, age- and sex-specific mortality rates, and net migration. From these, age- and sex-specific population forecasts are simulated using the cohort component method. For each simulated population trajectory and each retirement age policy, we then follow the approach of Hyndman et al. [43] to forecast the demographic dependency ratio as follows:

$$OADR_t = O_t = \frac{\sum_{x \geq \lfloor x_r(t) \rfloor}^{\omega} P_{x,t} - \lambda_t P_{\lfloor x_r(t) \rfloor, t}}{\sum_{x=20}^{\lfloor x_r(t) \rfloor - 1} P_{x,t} + \lambda_t P_{\lfloor x_r(t) \rfloor, t}} \tag{18}$$

where $\lfloor x_r(t) \rfloor$ is the floor of the retirement age in year $t$ and $\lambda_t = x_r(t) - \lfloor x_r(t) \rfloor$ is the fractional part of $x_r(t)$.

Let $\mathbf{X}_r = \{x_r(T+i)\}_{i=1,\ldots,H}$ denote the retirement age schedule over the prediction horizon $H$ with the corresponding OADR values given by $\mathbf{O} = \{O_t\}_{t=1,\ldots,H}$. From Eq. (18), we can define a target OADR threshold $O_t^*$ and implement an iterative procedure to determine the minimum pension age in each year that is consistent with $O_t^*$ together with the corresponding prediction intervals at a given confidence level. On top of finding the target pension age based on a target OADR threshold $O_t^*$, we can also search for pension age schemes that are consistent with the prediction intervals of the simulated OADR values.

## 4. Institutional framework

### 4.1. The French pension system: A multi-pillar approach

Pension expenditure constitutes the largest component of social spending – both public and private – in France, accounting for 13.5% of GDP in 2021 [44]. The French pension system is a complex, multi-pillar structure comprising a solidarity-based component, occupational pension schemes, and personal retirement savings. The system is organised into three main pillars. The first pillar consists of the pay-as-you-go (PAYG) basic scheme, which is mandatory and earnings-related. The general scheme for private sector employees forms the core of this pillar and is the largest pension scheme in France. As of 31 December 2021, it provided pension benefits to 14.9 million individuals, with 84% of direct pensioners receiving at least part of their pension from this scheme [44]. Contributions to this system are shared between employers and employees, with a small supplementary contribution sourced from a social value-added tax (VAT). The scheme also includes a means-tested minimum pension benefit and targeted assistance programmes financed by general taxation. It provides coverage for old age, early retirement, disability, and survivor benefits.

The second pillar comprises supplementary occupational pension schemes, primarily the Agirc-Arrco scheme, which is also PAYG-financed and mandatory for all employees covered by the statutory old-age insurance system. These schemes are funded by employer and employee contributions and operate on a points-based system, where annual contributions are converted into pension points based on a fixed purchase value. Full-rate supplementary pensions are granted to individuals who meet the statutory retirement age (currently between 62 and 64) and the required number of quarters for entitlement under the basic scheme, or to those who reach the age of 67, regardless of contribution length. Approximately 13.3 million people receive supplementary pensions under this pillar.

The third pillar includes voluntary private retirement savings plans, offered by banks, insurance providers, mutual associations, and provident institutions. These plans allow individuals to accumulate additional savings to supplement their public and occupational pensions. However, they currently account for less than 3% of total retirement benefits in France [44].

Although the three-pillar framework constitutes the core of the French pension system, a substantial share of the workforce is covered by special pension schemes tailored to specific professions. These include the civil service and military schemes, schemes for employees of public enterprises and establishments, and profession- or company-specific schemes (e.g., for notaries' clerks, miners, clergy, staff of the Paris Opera, and railway workers). The civil service and military scheme pays pensions to approximately 3.7 million individuals, while 1 million receive pensions from other special employee schemes, and fewer than 500,000 from schemes for the liberal professions.

Since 2005, a mandatory funded supplementary scheme for civil servants – the Additional Public Service Retirement Scheme (RAFP) – has been introduced. This scheme is financed by employer and employee contributions, each contributing 5% of additional earnings (up to 20% of gross basic salary). Contributions are converted into points, which entitle civil servants to retirement benefits in the form of either a lump sum or an annuity.

Many of these special schemes offer more generous benefits than the general system. For example, replacement rates can reach 75% for military personnel, compared to the standard 50% under the general PAYG scheme. These disparities raise concerns regarding equity and long-term financial sustainability. The relatively small contributor base in special regimes, coupled with their more favourable benefit structures, poses challenges for their viability.

The 2023 French pension reform seeks to address these imbalances by gradually aligning the retirement ages and contribution requirements of special schemes with those of the main public system, thereby enhancing coherence and sustainability across the pension landscape.

**Table 1**
French statutory retirement age following the 2023 pension reform.
*Source:* Service public, Info.gouv.fr. Notes: y = years; m = months.

| Date of birth | Retirement age | |
|---|---|---|
| | Actual | Increase |
| 1955 or before | 62 y | No change |
| 1961 (before Aug. 1961) | 62 y | No change |
| 1961 (after Sept. 1st) | 62 y + 3m | 3 m |
| 1962 | 62 y + 6m | 6 m |
| 1963 | 62 y + 9m | 9 m |
| 1964 | 63 y | 1y |
| 1965 | 63 y + 3m | 1y + 3 m |
| 1966 | 63 y + 6m | 1y + 6 m |
| 1967 | 63 y + 9m | 1y + 9 m |
| 1968 or thereafter | 64 y | 2y |

### 4.2. The French pension age policy

As in most OECD countries [2], France has raised the statutory minimum retirement age. The most significant element of the 2023 French pension reform is the gradual increase in the legal retirement age from 62 to 64, accompanied by more stringent eligibility requirements. Under the current legislation, the statutory minimum retirement age will be set at 64 for individuals born in or after 1968. This change will be introduced progressively for those born between 1 September 1961 and 31 December 1967, with the statutory retirement age increasing by three months for each successive birth cohort (see Table 1).

To qualify for a full, maximum-rate pension, individuals must complete a specified number of contribution quarters. The full-rate pension, equal to 50% of reference earnings, is payable to individuals who have completed a total insurance period of between 166 and 172 quarters, depending on their year of birth.[6] Alternatively, it is available to those aged 67 and above, regardless of the number of quarters accrued. Full-rate entitlement is also granted to individuals in specific categories, including those assessed as unfit for work (with a permanent disability rating of at least 50%), mothers employed in blue-collar occupations, combat veterans, and recipients of disability pensions.

Individuals who claim their pension without completing the required number of quarters receive a reduced pension. The rate of reduction depends on both the number of missing quarters and the individual's year of birth: 1.25% for those born in or after 1953 (equivalent to a decrease of 0.625% for each missing quarter, applied to the full rate of 50%). Once applied, the pension continues to be paid at the reduced rate permanently.

This reform implies that individuals will need to remain in the workforce for longer in order to receive full public pension benefits, a shift that is expected to influence labour force participation—particularly among those aged 55 and over. In 2022, the employment rate for older workers in France stood at 56.9%, compared to 82.5% for individuals aged 25–49, and remained below the EU average of 62.4% [45]. Following the implementation of the reform, projections by INSEE and DARES [45] estimate that the labour force participation rate for individuals aged 55 to 69 will be 4.5 percentage points higher by 2070.

Prior to the 2023 pension reform, the statutory retirement age for "active" employees under special schemes – such as maintenance workers and operations staff (including bus, tramway, and train drivers) – was set at 57 years and 52 years, respectively. Following the reform, the retirement age for these occupational groups will be deferred by two years.

[6] For pensions taking effect on or after 1 September 2023, the required insurance period will progressively increase to 172 quarters (equivalent to 43 years) for individuals born in or after 1965. This requirement, which previously applied only to those born in or after 1973, has therefore been extended to earlier cohorts.

Furthermore, as of 1 September 2023, newly hired employees in these sectors will be affiliated with the general pension scheme – applicable to private sector employees – for their basic retirement pension, and with the Agirc-Arrco scheme for their supplementary pension. They will no longer be eligible for the early retirement provisions previously granted under the special regimes. The only early retirement exception unaffected by the 2023 reform applies to disabled workers, who retain the right to retire at the age of 55.

As in most earnings-related public pension systems in OECD countries, France grants pension entitlements through a combination of pension credits and pension accruals for periods spent outside the labour market for socially recognised reasons – such as maternity or paternity leave, illness, unemployment, or caregiving responsibilities – as well as through derived pension rights [46]. Accordingly, the total insurance period used to determine the pension payment rate includes both periods in which contributions were paid to the various basic schemes (as defined in Article L. 351-1 of the French Social Security Code) and equivalent periods recognised as contributory, such as career interruptions due to unemployment, illness, maternity, disability, occupational injury, or military service.

## 5. Empirical analysis

### 5.1. Stochastic population forecasts for France

#### 5.1.1. Demographic data

The French demographic data used in this study comprise age- and sex-specific population counts as of 1 January each year, denoted $P_{x,t}$, the corresponding mid-year exposure-to-risk $E_{x,t}$, and age and sex-specific counts of births $B_{x,t}$ and deaths $D_{x,t}$ for each calendar year. The data were obtained from the Human Mortality Database (2024) and cover all individual ages within the interval $[0, 110+]$, where 110+ denotes the open-ended upper age group, and calendar years from $t = 1950$ to 2020. International net migration is estimated using the demographic balancing equation, taking into account the dynamics of births, deaths, and net migration (i.e., immigrants minus emigrants).

#### 5.1.2. Population forecasts

Fig. 1 presents the forecast of the total French population (including both Metropolitan France and the overseas territories) by sex over the projection horizon, alongside historical data and 95% pointwise prediction intervals derived from the simulated population trajectories. Both the male and female populations are projected to grow steadily over the next 30 years, with the total population rising from 65.3 million in 2020 to a mean estimate of 72.1 million by 2050. Specifically, the male population is expected to increase from 31.6 million in 2020 to 35.1 million in 2050, while the female population is projected to rise from 33.7 million to 37.0 million over the same period.

Fig. 2 shows the population age structure in 2050, along with the 2021 base population (The actual population pyramid is shown using dashed lines). Fig. 2 represents the mean and the 95% prediction interval of simulated population paths for the final year of the prediction horizon. The results show that consistently low birth rates and higher longevity prospects will transform the shape of French age pyramid, that will continue to transition towards an older population structure. As a result of demographic change, the proportion of people of working age is forecast to shrink while the proportion of those retired will continue to grow. The share of older people in the total population is expected to increase substantially over the next 30 years. The increased uncertainty of the population at young ages is largely due to a comparatively higher forecast uncertainty of fertility rates compared to the remaining components of demographic change.

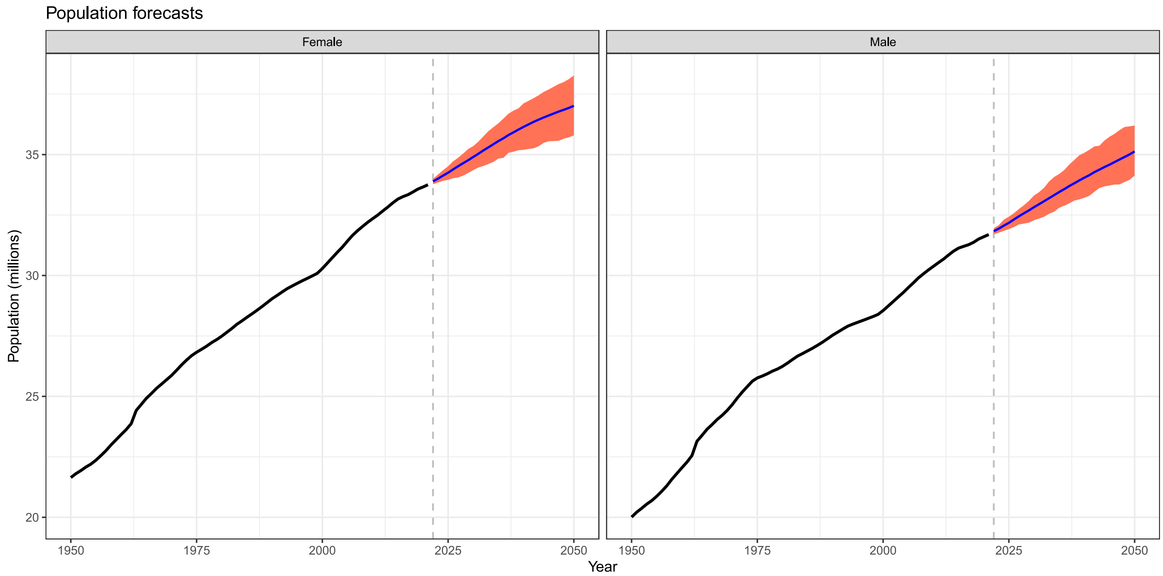


**Fig. 1.** Forecasts of the total French population by sex, accompanied by 95% prediction intervals.

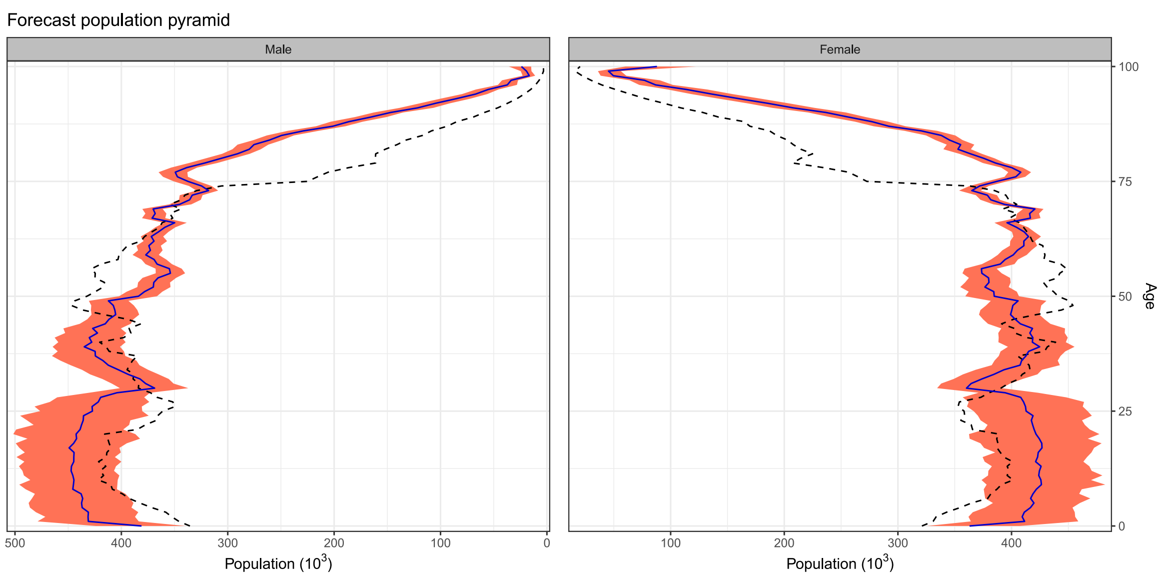


**Fig. 2.** Forecasted population pyramid for 2050 with 95% prediction intervals. The 2021 population pyramid is shown using dashed lines.

### 5.2. Measuring the outcomes of the retirement age reform in France

#### 5.2.1. Forecasts of the evolution of the retirement age

Our analysis encompasses eight distinct retirement age policies, as detailed in Section 2. The first three correspond to France's past and current pension age policies:

1. The current reform of the statutory minimum retirement age, which increases gradually from 62 to 64 years;
2. The previous constant retirement age policy, which maintains France's previous statutory pension age of 62 years;
3. The current age of full-rate pension entitlement, set at 67 years regardless of the contribution career.

The fourth and fifth policies correspond to the intergenerationally actuarially fair retirement age rules recently proposed by Bravo et al. [24], each based on an alternative policy objective, namely:

4. The constant accrual rate (CAR) policy, which under steady-state demographic conditions and mild assumptions ensures that all generations of pensioners enjoy a constant expected number of years in retirement; and
5. The constant replacement rate (CRR) policy, which prescribes that pensioners spend a constant proportion of their life in retirement relative to their working years.

6. The sixth policy (labelled DC) aligns the retirement age with the objective of maintaining a constant pension benefit in an individual defined contribution (DC) retirement income scheme.
7. The seventh policy (labelled Target OADR) considers the implementation, in the French context, of a retirement age rule designed to maintain a constant old-age dependency ratio (OADR) within a balanced pay-as-you-go (PAYG) system.
8. The eighth policy (labelled POAT) is based on maintaining a constant prospective old-age threshold (POAT), reflecting a characteristics-based approach to ageing.

Fig. 3 presents the historical, actual, legislated, and projected dynamics of the pension age over the forecast horizon. The simulation

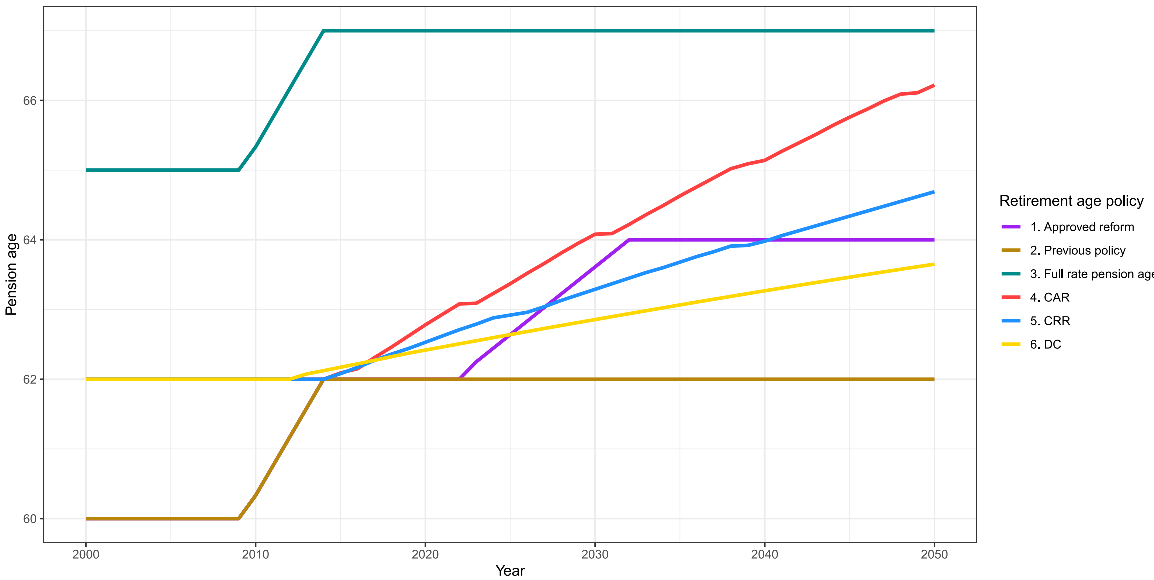


**Fig. 3.** Actual, legislated, and projected dynamics of the pension age under alternative retirement age policies.

results for the CAR, CRR, and DC retirement age policies are based on the assumption that these policies have been in effect since 2014, the year in which France's statutory minimum retirement age of 62 – established by the 2010 pension reform – was reached. Section 5.2.5 explores the sensitivity of the results to alternative implementation dates, while Section 5.2.4 provides a detailed account of the empirical findings associated with the POAT-based policy. Further information for selected years up to 2050 is reported in Table 3.

Fig. 3 illustrates that both the actual and legislated increases in the normal retirement age in France have been, and will continue to be, insufficient to accommodate the population's increasing longevity and to uphold the principles of intergenerational fairness and neutrality as prescribed under the constant accrual rate (CAR) and constant replacement rate (CRR) policies from 2040 onwards—even under the assumption of steady-state demographic conditions (i.e., a constant old-age dependency ratio, OADR). For example, the normal pension age required under the CAR (CRR) policy would need to rise from the pre-reform level of 62 years to 66.22 (64.69) years by 2050.

The gap between the intergenerationally fair and the actual or legislated pension ages is greater under the CAR policy than under the CRR alternative, with the divergence widening over time (for details, see Table 3 in the Appendix). This pattern reflects the more limited effect of additional working years on pension entitlements under a CRR framework, where longer careers do not translate into higher replacement rates at retirement, unlike in the CAR setting.

By contrast, assuming that the statutory pension age is set equal to the current age of full-rate guarantee in France would be consistent with the principles of intergenerational equity and long-term financial sustainability.

The pension age policy aimed at maintaining a constant benefit (in absolute terms) within an individual defined contribution (DC) retirement income scheme requires only limited adjustments to contribution years and the normal retirement age—specifically, an increase of 1.65 years by 2050. This outcome is expected, as—unlike the constant replacement rate pension age policy—this approach does not ensure that pension income remains a constant proportion of pre-retirement earnings, which is often considered a more accurate proxy for sustaining living standards in retirement.

Although the projected increases in the pension age reduce the expected duration of retirement and promote longer working lives and/or higher contributions, there remains a risk of lower replacement rates—particularly for individuals with lower lifetime earnings or fragmented employment histories.

#### 5.2.2. *The effect of pension age policies on dependency ratios*

Fig. 4 displays the historical values of the old-age dependency ratio (OADR) estimated for the period 1950–2022, based on the pension age policy in place prior to the 2023 reform. It also presents the mean forecasts and associated 95% prediction intervals of simulated OADR values for the retirement age policies examined in this paper. Table 4 in the Appendix complements this information by reporting the mean OADR projections for selected years up to 2050.

The empirical findings reveal, first, that maintaining the previous pension age policy would lead to a continued increase in the demographic dependency ratio – from 47.4% in 2022 to 63% in 2050 (a rise of 15.6 percentage points) – thereby exacerbating the already significant ageing burden on a shrinking labour force. Second, Fig. 4 indicates that the recently implemented pension age reform will help stabilise the OADR through the end of the current decade; however, it will be insufficient to reverse the longer-term upward trend in the fiscal pressure associated with population ageing. Without further policy adjustments, the OADR is projected to reach 55.8% by 2050. These results underscore the need for regular reviews of retirement age policies to ensure long-term stability in the demographic dependency ratio.

Third, the results for the full-rate pension age policy indicate that, by the end of the projection horizon, the retirement age required to stabilise the OADR closely aligns with France's current age of full-rate guarantee—67 years.

Fourth, the findings for the intergenerationally equitable retirement age policies reveal that assuming steady-state demographic conditions in the CAR and CRR formulations – i.e., assuming a constant dependency ratio over time – may be insufficient to safeguard intergenerational fairness and long-term financial equilibrium. This is particularly evident in the case of the CRR policy, which targets a constant expected share of adult life spent in retirement across cohorts. Had this policy been implemented, the results suggest that the OADR would continue to rise, reaching 53.5% by 2050, despite a modest decline during the final decade of the forecast period.

In other words, under conditions of population ageing, the necessary adjustment to the pension age must be more than proportional to increases in life expectancy at retirement. By contrast, the adoption of a more stringent CAR policy, which targets a constant expected number of years in retirement under steady-state conditions, appears more effective in the long term. It is more consistent with the dual objectives of maintaining a stable ageing burden and preserving intergenerational equity within a financially balanced pension system.

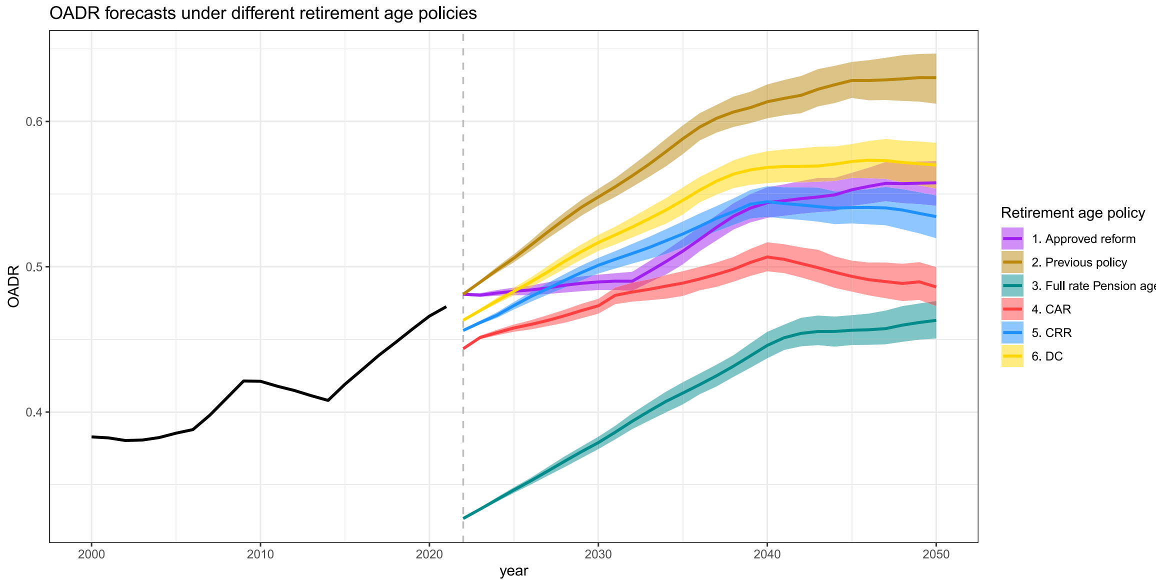


**Fig. 4.** Forecasts of the dependency ratio under alternative retirement age policies.

Fifth, the findings show that, in the context of ongoing population ageing, implementing a pension age policy aimed at preserving a constant benefit in an individual DC scheme is clearly inadequate for stabilising the dependency ratio and for containing the financial burden imposed on working generations.

### 5.2.3. Demographically sustainable pension age policy

The findings above indicate that the recently adopted pension age reforms in France will not suffice to prevent a decline in the relative size of the labour force. In this section, we reverse the perspective and aim to estimate a retirement age policy that would stabilise the old-age dependency ratio (OADR). Specifically, we assess by how many years the upper age boundary of working life would need to increase in order to maintain a constant OADR over time—thus deriving a retirement age policy consistent with demographic sustainability and a balanced pay-as-you-go (PAYG) pension system.

To this end, we follow the approach of Hyndman et al. [43] and implement an algorithm to identify the target pension age corresponding to the mean OADR derived from the simulated population trajectories. In addition, we estimate a range of pension age policies for which the target OADR falls within the 95% prediction intervals of the simulated values.

By definition, a higher effective retirement age is associated with a lower old-age dependency ratio (OADR), assuming no changes in labour market behaviour. In this empirical exercise, we consider two alternative OADR targets. The first corresponds to the observed 2022 OADR value for France, calculated using the previous normal retirement age of 62 and assuming a labour market entry age of 20. This value is estimated at 0.4744318 ($O^*_{62+/20-61} = 0.4744318$). The second one is the 2022 observed value for France of the OADR computed at the reference pension age of 65 years ($O^*_{65+/20-64} = 0.3766578$). Figs. 5 and 6 represent the retirement age policies produced by this experiment, along with 95% confidence intervals, together with the previous, current and alternative pension age schemes considered in this study. Table 5 in the Appendix complements the results with detailed information for selected years.

Fig. 5 illustrates that, as the French population continues to age, stabilising the relative size of the labour force – denoted $O^*_{62+/20-61}$ – at its 2022 level would require the normal retirement age to rise beyond the thresholds set by the recently adopted reform. Maintaining a constant old-age dependency ratio (OADR) of 47.44% necessitates increasing the normal retirement age in France to a mean forecast of 64.08 years by 2030, 66.17 years by 2040, and 66.67 years by 2050.

Compared with the legislated normal pension age, achieving the target would require an additional 0.47 years of work by 2030, 2.17 years by 2040, and 2.67 years by 2050. Fig. 5 further suggests that maintaining the relative size of the labour force at 2022 levels necessitates a convergence of the normal pension age in France towards the current age of automatic full-rate pension entitlement.

Fig. 6 illustrates that stabilising the old-age dependency ratio (OADR) at age 65 at its 2022 level would require the normal pension age to increase substantially, exceeding the current age of automatic full-rate entitlement in France. Specifically, maintaining a constant OADR Fig. 6 of 37.66% would necessitate raising the normal pension age to a mean forecast of 69.33 years by 2030, 71.17 years by 2040, and 70.00 years by 2050.

Relative to the legislated normal pension age, this would imply an additional 3.47 working years by 2030, 5.33 years by 2040, and 6.00 years by 2050. When compared with the current age of full-rate entitlement (67 years), the additional years required would be 0.08 in 2030, 2.33 in 2040, and 3.00 in 2050.

### 5.2.4. Prospective age policy

Fig. 7 presents the point estimates of prospective ages (Top Panel) derived from the implementation of a pension age policy based on the prospective old-age threshold (POAT), in which the pension eligibility age increases in line with rising longevity in order to maintain a constant expected duration of retirement. The prospective ages are forecasted for four alternative levels of cohort life expectancy, ranging from 15 years ($POAT\_15 : \mathring{e}^C_{x_r(t)} = 15$) to 30 years ($POAT\_30 : \mathring{e}^C_{x_r(t)} = 30$).

The empirical findings for France indicate that the statutory pension age required to maintain a constant expected duration of retirement increases over time in accordance with life expectancy developments. The prospective pension age is naturally higher when a lower cohort life expectancy threshold is set as the defining characteristic, and lower when the threshold is higher.

For example, in 2022, the prospective ages corresponding to a constant expected duration of retirement of 15, 20, 25, and 30 years were 74.77, 68.99, 63.48, and 57.97 years, respectively. By 2050, the forecasted prospective ages are projected to rise to 77.50, 71.97, 66.63, and 61.30 years for the same respective thresholds of expected remaining lifetime.

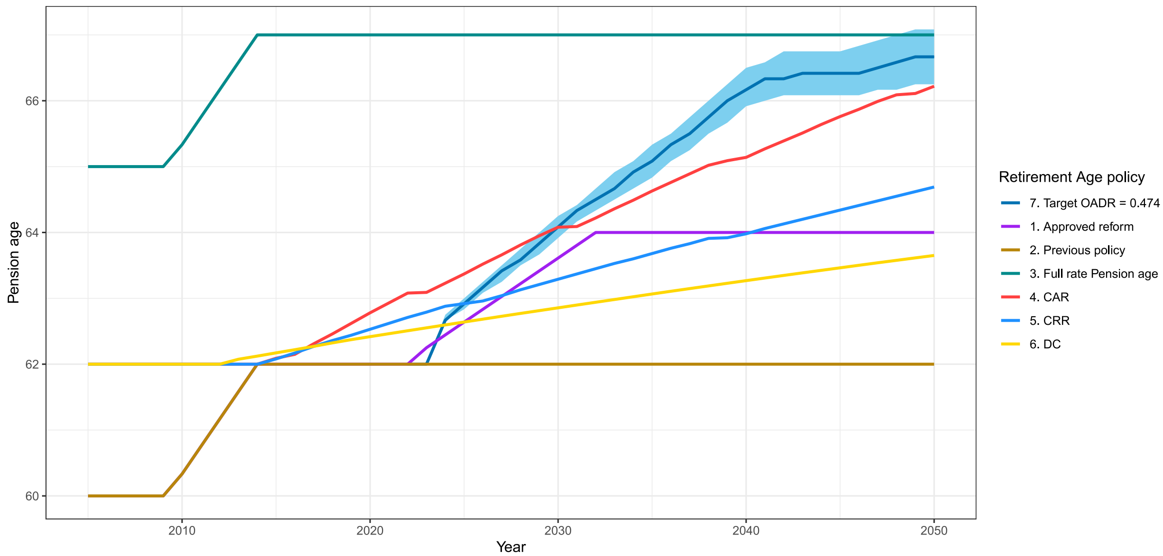


**Fig. 5.** Target OADR-based retirement age policy $O^{*}_{62+/20-61}$.

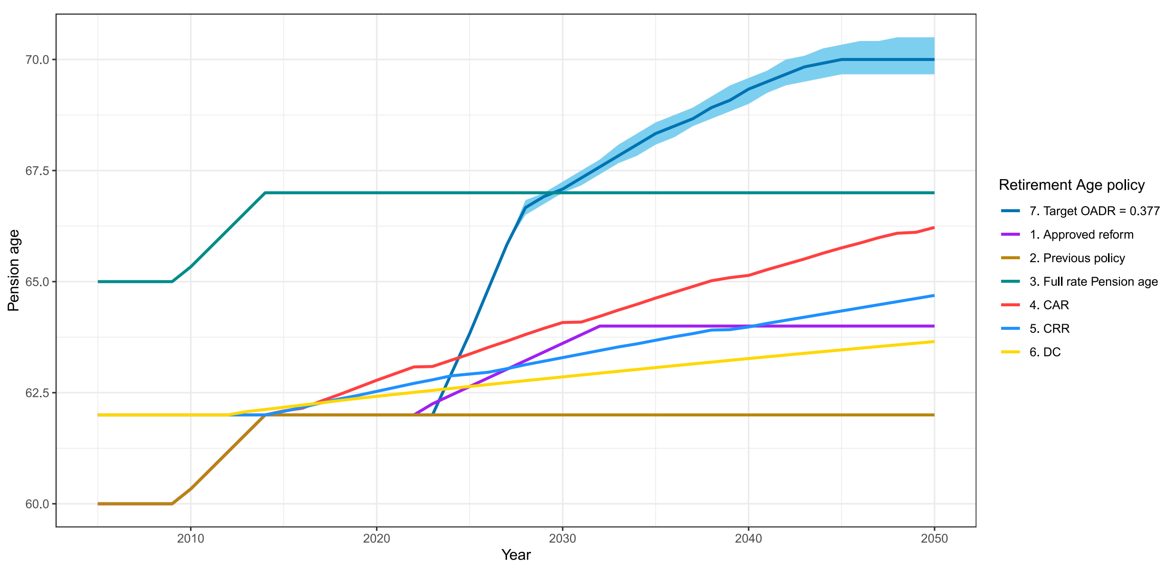


**Fig. 6.** Target OADR-based retirement age policy $O^{*}_{65+/20-64}$.

Except for the 30-year threshold, the forecasted prospective ages are significantly higher than those prescribed by the French reform and by the CAR, CRR and DC retirement age policies. For example, compared to the legislation in force, maintaining a constant expected duration of retirement of 15 (20) years would require increasing the pension age an additional 13.50 (7.97) years.

Fig. 7 also presents forecasts of the dependency ratio (Bottom Panel) corresponding to the four alternative cohort life expectancy thresholds considered in this study, along with the associated 95% confidence intervals. The results indicate that increasing the pension eligibility age in line with rising longevity – so as to maintain a constant expected duration of retirement – may not be sufficient to stabilise the labour force share.

As anticipated, the projected dependency ratio is directly influenced by the selected life expectancy threshold. Under the assumption that labour market behaviour remains stable over time, a lower threshold implies longer working lives and, consequently, a smaller proportion of retired individuals in the total population.

#### *5.2.5. Sensitivity of pension age and dependency ratio forecasts to base year selection*

The forecasts of the pension age under the CAR, CRR, and DC policies are sensitive to the base year in which these policies are enacted. In Fig. 8, we present forecasts of the pension age (Top Panel) and the dependency ratio (Bottom Panel), assuming that the retirement age policies are implemented in 2022 – concurrently with the legislated reform – rather than in 2014.

The results demonstrate that delaying the implementation of reforms which adjust statutory pension ages in line with longevity developments and demographic ageing has significant and wide-ranging implications for intergenerational equity, pension adequacy, and fiscal sustainability. As populations age and life expectancy continues to rise, postponing alignment of pension age policies with CAR, CRR, and DC principles leads to higher projected dependency ratios, exacerbates structural imbalances, and undermines the long-term resilience of the pension system.

Compared to the baseline scenario in which pension age policies are implemented in 2014, the dependency ratio is projected to be higher by 2050 by 3.34 percentage points (pp.) under the CAR policy, 2.40

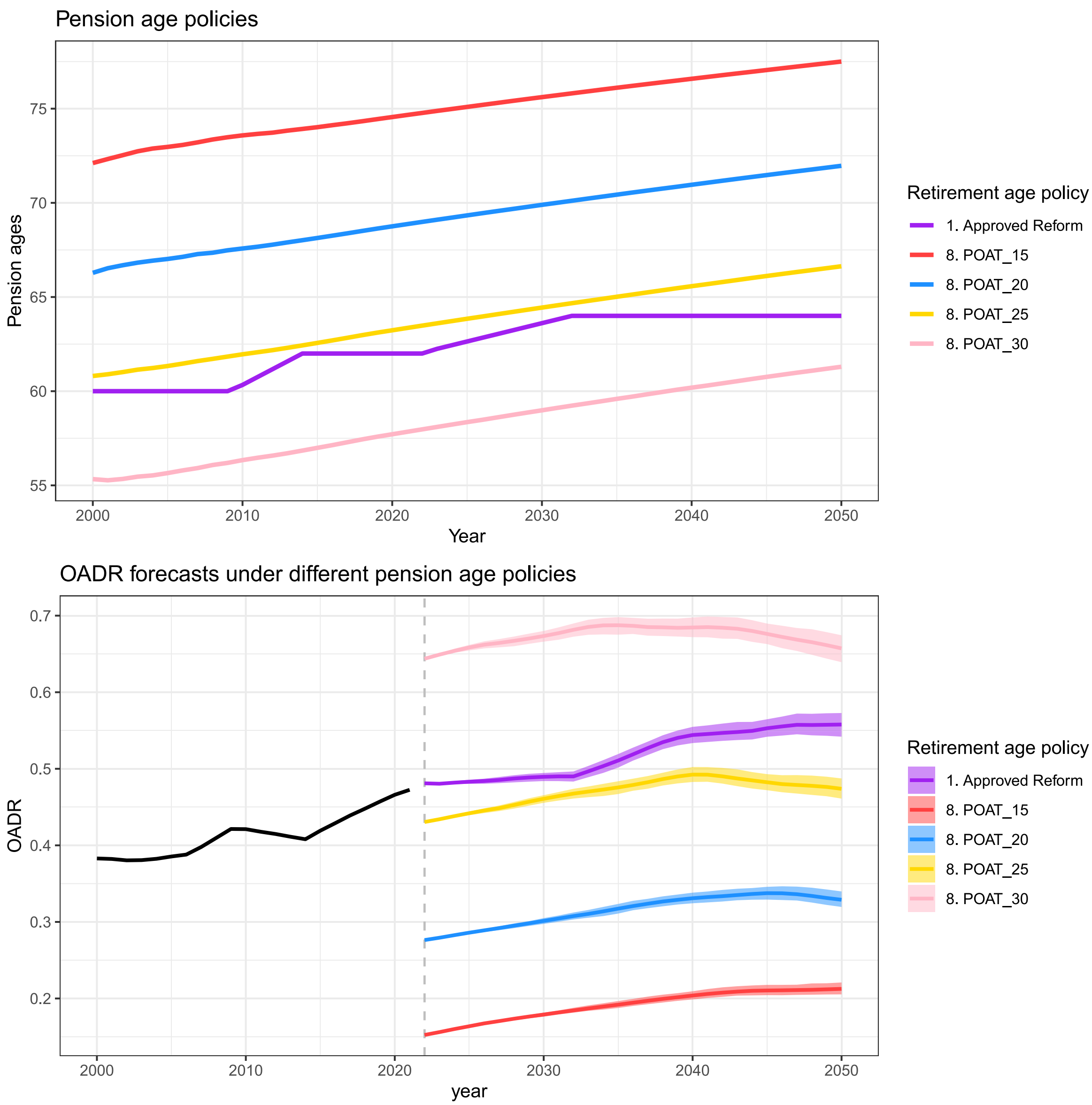


**Fig. 7.** Forecasts of pension age (top panel) and dependency ratio (bottom panel) under alternative POAT-based policies.

pp. under the CRR policy, and 1.36 pp. under the DC pension age policy. This increase places additional pressure on public finances and social services, particularly in relation to healthcare and long-term care provision.

Delaying the implementation of pension age reforms results in longer retirement durations, higher public pension expenditures, and a worsening ratio of contributors to beneficiaries—that is, a declining support ratio. Early retirements reduce the size of the active labour force, exacerbating labour shortages, particularly in ageing economies such as France. Moreover, delayed reforms may disincentivise older individuals from remaining in the labour market, particularly in the absence of clear and credible long-term policy signals.

Such delays also carry significant implications for intergenerational equity. Current retirees benefit from more generous terms and longer retirement durations, while younger cohorts are left to bear the costs through higher contribution rates or general taxation, reduced benefit adequacy, and postponed retirement eligibility. Furthermore, maintaining outdated age thresholds may encourage early retirement with reduced pensions, increasing the risk of old-age poverty—particularly among low-income earners and workers with incomplete contribution histories.

## 6. Discussion and policy recommendations

The design and reform of pension systems must carefully balance efficiency, fairness, adequacy, and insurance against individual-specific risks [47]. In particular, in a balanced PAYG pension system, stabilising the dependency ratio is essential to avoid higher contribution rates, reduced pension benefits, or financial deficits necessitating tax- or debt-based financing. Moreover, pension schemes are inherently linked to labour market dynamics, and changes in social contributions affect both employment levels and hours worked [48,49]. The extent of such distortions depends on whether individuals internalise the relationship between their contributions and future benefits. In addition, retirement age policies play a pivotal role in shaping labour force participation [50].

Recent evidence suggests that rising life expectancy can lead to delayed retirement, particularly when the productivity of older workers improves and income tax rates are reduced, although the impact on per capita output growth remains limited [51]. Furthermore, increasing the retirement age in the context of population ageing has been shown to enhance welfare in both defined benefit (DB) and defined contribution (DC) schemes [52]. Against this evolving backdrop, intergenerational

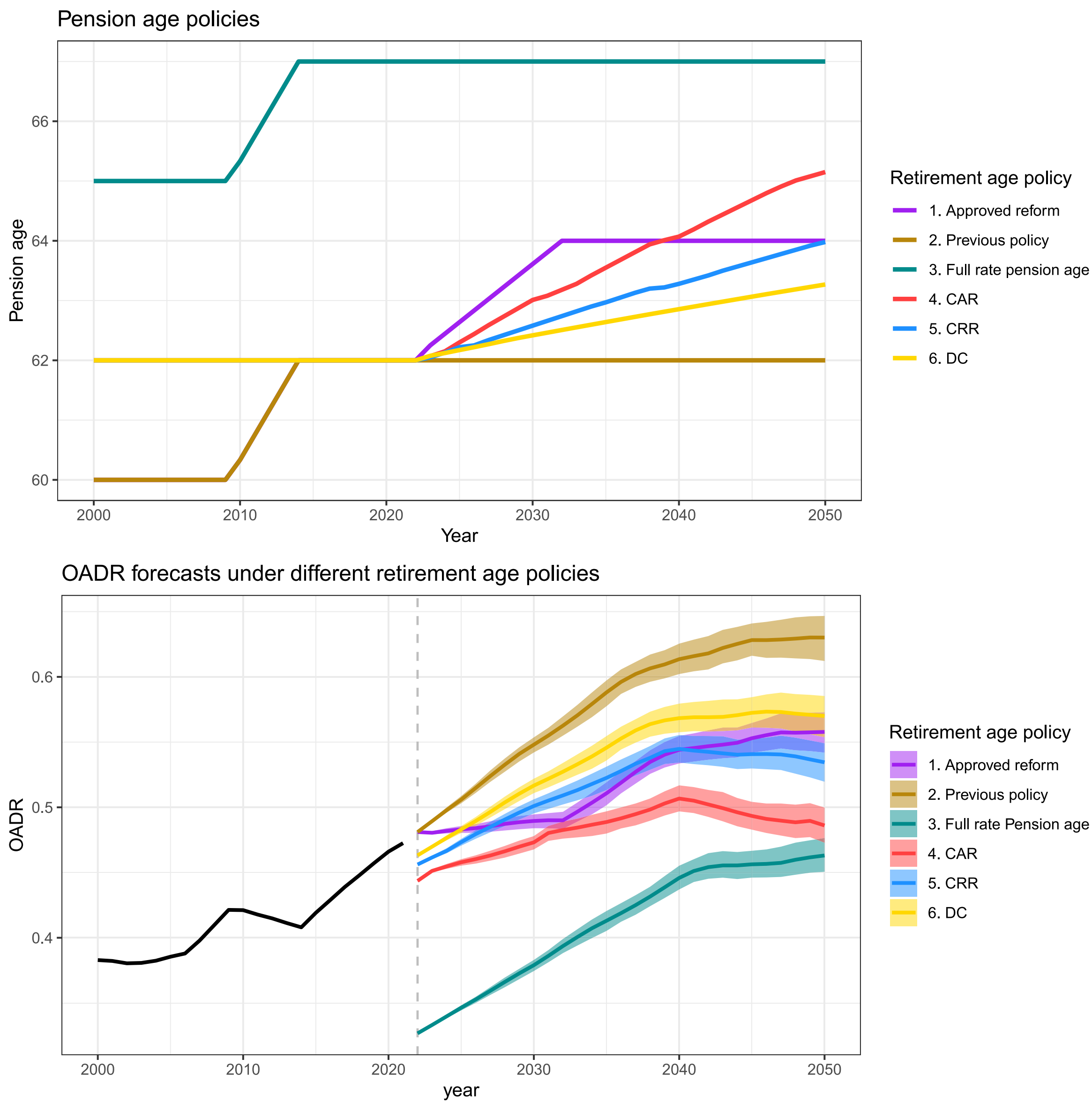


**Fig. 8.** Forecasts of pension age (top panel) and dependency ratio (bottom panel) under alternative pension age policies, assuming implementation in 2022.

justice has emerged as a central concern in social policy debates in recent decades, fuelled by demographic ageing, the fiscal aftermath of the global financial crisis, and, more recently, by climate justice considerations. In ageing societies, generational inequality manifests both as horizontal disparities across cohorts and as vertical disparities within them [53]. In response, the European Commission [22] has proposed a tripartite framework for assessing fairness in policy: Intergenerational fairness, which entails adjusting key parameters to maintain a stable OADR; Social fairness, which seeks a better balance between years in work and retirement; and Actuarial fairness, which promotes alignment between pension wealth and lifetime contributions.

Our findings indicate that recent increases in the legislated pension age in France fall short of offsetting the projected decline in the labour force and are insufficient to address the challenges posed by population ageing and rising life expectancy, while maintaining intergenerational fairness, actuarial neutrality, and long-term financial equilibrium. The analysis suggests that pension age adjustments must exceed the proportional increase in longevity at retirement to ensure sustainability.

In our projections of the impact of different retirement-age policies, we assume full compliance with the reform scenarios and broadly unchanged labour market behaviour. The uncertainty surrounding the projected dependency ratio arises primarily from the joint stochastic variation in the three components of demographic change. In practice, however, pension reforms tend to heighten uncertainty regarding the impact of population ageing on effective old-age dependency ratios, as they introduce complex behavioural and institutional variability in addition to otherwise predictable demographic trends. We acknowledge that this added variability may not be fully reflected in the confidence bands of the old-age dependency ratio forecasts reported in this study.

Past studies suggest that changes in the retirement age and other social security provisions can strengthen or weaken the financial incentives to work at older ages, as well as the implicit tax on continued employment [50,54]. These incentives depend on provisions such as the normal and early retirement ages; the minimum contribution years required for early claiming of social security benefits; the design and generosity of the benefit formula; links with non–social security early retirement schemes (e.g., employer-sponsored packages), disability insurance, and unemployment insurance programmes; the actuarial adjustments for early or delayed claiming; age-specific accrual rates; and the existence of flexible retirement pathways or earnings tests [7,55–57].

**Table 2**
Key French pension reforms since 2003.

| Year | Reform highlights | Key changes/Measures |
|---|---|---|
| 2003 | Convergence strategy | Gradual increase in contribution period (2009–2012) by 0.25 years annually; introduction of *décote-surcote* system (penalty/bonus for shorter/longer contributions). |
| 2010 | Raising retirement age and contributions | Minimum retirement age raised from 60 to 62; increased pension contributions for actuarial balance by 2018. |
| 2014 | Contribution period linked to birth cohorts | Contribution requirements based on year of birth to reflect projected longevity. |
| 2023 | Gradual increase in retirement age and contributions | Retirement age increased by 3 months per birth cohort from Sept 1, 2023, targeting age 64 by 2030; contribution period extended to 43 years by 2027. |

In addition to financial considerations, non-financial factors also play a crucial role in labour market responses following pension reforms. The list includes individual preferences, employer demand, health, cultural and social norms, labour market adaptation to an ageing workforce, caregiving responsibilities, labour market exclusion, preferences for non-market activities or present consumption, and workers' educational attainment—factors that are considerably harder to model [58]. An individual's intrinsic preference for leisure over work strongly influences retirement decisions. Moreover, labour supply and retirement timing are often closely linked to health status, with poor health being a major driver of earlier exit from the labour market. Consequently, the monetary benefits of working longer can primarily be realised by individuals in relatively good health, who tend to belong to higher socioeconomic groups [57]. Socioeconomic disparities in life expectancy at retirement age, together with broader lifespan inequality, disadvantage those with lower income or educational attainment. Such groups not only tend to have shorter life expectancies but are also more likely to be employed in physically demanding occupations, further constraining their ability to work longer. Cultural and social norms – such as societal expectations regarding retirement, gender roles, and the prevalence of one-earner households – also shape retirement behaviour.

Furthermore, empirical evidence indicates that reforms increasing the statutory retirement age and tightening pension eligibility often divert some workers – particularly those in poor health or facing weak labour demand – into alternative programmes, most notably disability insurance, unemployment insurance, or social assistance [59–62].

Collectively, these dynamics may adversely affect projections of the old-age dependency ratio in France, beyond what can be anticipated from demographic trends alone. Future research adopting a more elaborate multivariate analysis should address the combined effect of these factors.

Several key policy issues emerge from this research. French pension reforms have historically focused on adjusting retirement ages and contribution periods to enhance financial sustainability. However, these measures have insufficiently accounted for the health status and living conditions of older workers. In particular, improvements in overall life expectancy in France have not been matched by gains in disability-free life expectancy [63,64], raising concerns about the feasibility and fairness of prolonged working lives. Consequently, future reforms must adopt a holistic approach, integrating labour market dynamics and the well-being of both workers and retirees to ensure long-term viability.

As discussed, the major pension reforms of 2003, 2010, 2014, and 2023 (Table 2) progressively extended contribution periods, increased the statutory retirement age – from 60 to 62 in 2010 and to 64 by 2030 – and introduced longevity-linked requirements. In response to fiscal pressures and persistent deficits, these reforms also sought to harmonise public and private sector schemes, while including provisions for individuals with disabilities and long career histories.

To extend working lives and mitigate the impact of population ageing on dependency ratios, it is essential to narrow the gap between statutory and effective retirement ages by increasing labour market participation among older workers. The success of this strategy depends on both the capacity and the willingness of workers to delay their exit from employment. Achieving adequate and sustainable pension systems requires targeted policy and managerial interventions that support and incentivise continued labour force participation. Such measures include the promotion of lifelong learning; improvements in job quality and adjustments for physically demanding or low-control occupations; reductions in unemployment disparities and duration [46]; the curtailment of early retirement pathways; workplace safety initiatives; the adoption of new working arrangements; stricter enforcement of anti-age-discrimination policies; support for reconciling caregiving responsibilities with employment; and subsidies to encourage labour supply at older ages [65].

Moreover, ensuring that older workers have meaningful career opportunities and access to roles aligned with their skills and preferences is critical for retaining them in the labour force. Although reduced working time may enhance flexibility and match the preferences of both employees and employers, concerns over income loss and status implications may limit the attractiveness of such flexible retirement pathways.

The effectiveness of retirement age policies promoting longer working lives depends critically on the design of pension decrements for early or delayed retirement. While frameworks such as CAR and CRR assume actuarial fairness, deviations from actuarial neutrality distort retirement incentives and raise concerns about equity and redistribution. In France, current decrement rates fall below actuarially neutral levels for average individuals (see, e.g., [66]), discouraging extended employment and encouraging early exit. This undermines efforts to increase employment rates and exacerbates pension dependency ratios. Inadequate decrement design also threatens the financial sustainability of pension systems, increases fiscal pressures, and creates intergenerational imbalances. Actuarial unfairness weakens confidence in public pensions – particularly among younger and self-employed workers – reducing policy credibility and fuelling reform resistance. To ensure equity and sustainability, pension decrements must be actuarially fair, while accounting for differences in career paths, health, and life expectancy.

The evidence on the impact of financial incentives from French pension reforms on labour force participation at older ages is mixed. Some studies conclude that previous French pension reforms have had limited success with financial incentives (e.g., bonus mechanisms) intended to encourage delayed retirement because of time inconsistency in the decision-making process [67]. By contrast, Rabaté and Rochut [68] and Bozio et al. [69] find that incentives such as increased benefits for later retirement and higher normal retirement ages have significantly contributed to the recent rise in labour force participation among older workers, reversing a long-term U-shaped decline in employment rates. However, the complexity of the French pension system creates exceptions because of its multiple, unnormalised pension schemes and individual-dependent eligibility criteria, which result in nonlinearities or threshold effects.

The most recent reform reflects a strategic shift, placing greater emphasis on facilitating the combination of work and pension income (work-retirement cumulation) to promote a more sustainable balance within the French pension system. However, it falls short of adequately addressing the specific labour market challenges faced by older workers.

The ability to combine employment and retirement (*cumul emploi-retraite*) has been modified repeatedly through successive pension reforms. The 2003 reform (Law of 21 August 2003) introduced key provisions, notably allowing full combination of pension income and employment earnings when the post-retirement activity falls under a different pension scheme. However, the 2014 reform (Law of 20 January 2014) discontinued the accrual of new pension rights for activities undertaken under *cumul emploi-retraite*. More recently, the Law of 14 April 2023 reintroduced, under specific conditions and within the framework of full *cumul*, the possibility of acquiring new pension entitlements from contributions made during post-retirement employment. This measure took effect on 1 September 2023 and applies retroactively to contributions paid since 1 January 2023. The latest reform aims to encourage prolonged labour market participation by enabling individuals to accrue additional pension rights while continuing to work. Despite these developments, the system remains constrained by complex administrative procedures and limited financial incentives for working pensioners. Additional restrictions include earnings ceilings—particularly in the public sector or for individuals retiring before reaching the statutory retirement age. Exceeding these limits can lead to the suspension or reduction of pension benefits, thereby increasing uncertainty and reducing the attractiveness of post-retirement employment.

To enhance the effectiveness of this objective, removing constraints such as mandatory retirement ages and income caps, alongside tackling age-based discrimination, would be beneficial. Nonetheless, raising the retirement age risks exacerbating social inequalities, as the capacity to remain in employment beyond age 60 is frequently associated with socioeconomic and health-related advantages [62]. Empirical evidence from the 2010 French pension reform indicates that it unintentionally led to increased exits from the labour market through non-retirement pathways, including unemployment, disability, and inactivity [68,70].

French employees (Table 2) find it hard to continue working until retirement, with over half in physically demanding sectors like construction and nursing reporting such difficulties [45]. This highlights a significant mismatch between the legal retirement age and job demands, often leading to musculoskeletal disorders (MSDs) [71,72]. Beyond physical strain, work design that prioritises efficiency over well-being, coupled with limited worker autonomy, can exacerbate stress and increase MSD risk [73].

To address these challenges and promote the well-being and continued engagement of older workers, policy strategies should prioritise: redesigning work to make it more manageable; enhancing worker autonomy and mitigating workplace stress; investing in ergonomics and implementing occupational health and injury prevention programmes [71]; and developing skills training to facilitate transitions into less physically demanding roles as workers age. In addition, extending flexible pre-retirement options with actuarially reduced pension benefits could offer a viable solution for individuals facing health limitations that do not meet the threshold for disability benefits, provided a minimum contribution period is satisfied. Such a holistic approach would contribute to a healthier, more experienced workforce and enhance the long-term sustainability of the French pension system.

A key limitation of our analysis is that, although the current French pension reform introduces cohort-based calculations, it does not account for group-specific disparities in total and healthy life expectancy. This omission is significant, as both longevity and pension wealth can vary markedly across income, education, gender, occupation, health status, and geography, with lifetime earnings being closely correlated with life expectancy [15,74–79]. Lifespan inequality presents considerable challenges for pension design, as it may generate regressive redistribution effects and raise concerns about both inter- and intra-generational equity. Future research should incorporate robust socioeconomic longevity indicators to capture heterogeneity in life expectancy and to assess the equity implications of the reform.

## 7. Conclusion

We conclude that, in the context of population ageing, particularly with rising life expectancy at older ages, simply increasing the statutory pension age in proportion to gains in longevity is not sufficient to stabilise the old-age dependency ratio or ensure the financial sustainability of PAYG pension systems. Thus, to maintain a constant system dependency ratio or constant expected retirement duration, the required increase in the pension age may need to exceed the proportional gain in life expectancy at retirement age.

Policymakers have several instruments at their disposal to ensure a stable dependency ratio over the long term. These include promoting longer working lives through labour market reforms, strengthening financial incentives – such as adjusting pension decrements for early or delayed retirement or modifying the taxation of pensions – and enhancing migration and family policies.

In the case of France, the findings indicate that the recently enacted pension age reform will be insufficient to prevent the relative decline in labour force size. The legislated increases in the retirement age will not adequately address the challenges posed by population ageing and rising life expectancy, while simultaneously upholding the principles of intergenerational fairness, actuarial neutrality, and long-term financial sustainability.

## CRediT authorship contribution statement

**Jorge Miguel Bravo:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Mercedes Ayuso:** Writing – review & editing, Validation, Methodology, Investigation, Formal analysis, Conceptualization. **Najat El Mekkaoui:** Writing – review & editing, Validation, Methodology, Investigation, Formal analysis, Conceptualization.

## Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Jorge Miguel Bravo reports financial support was provided by Portuguese Public National Science Funds, Fundação para a Ciência e a Tecnologia. Mercedes Ayuso reports financial support was provided by Spanish Ministry of Science and Innovation for funding received under grant PID2019-105986GB-C21. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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**Table 3**
Retirement age trajectories under alternative policy options.
*Source:* Author's preparation based on French legislation and model results.

| Year | Previous | Reform | Full | CAR | CRR | DC |
|---|---|---|---|---|---|---|
| 2000 | 60 | 60 | 65 | 62 | 62 | 62 |
| 2010 | 60.33 | 60.33 | 65.33 | 62 | 62 | 62 |
| 2011 | 60.75 | 60.75 | 65.75 | 62 | 62 | 62 |
| 2012 | 61.17 | 61.17 | 66.17 | 62 | 62 | 62 |
| 2013 | 61.58 | 61.58 | 66.58 | 62 | 62 | 62 |
| 2014 | 62 | 62 | 67 | 62.03 | 62.03 | 62.08 |
| 2015 | 62 | 62 | 67 | 62.09 | 62.08 | 62.17 |
| 2020 | 62 | 62 | 67 | 62.78 | 62.53 | 62.42 |
| 2022 | 62 | 62 | 67 | 63.08 | 62.71 | 62.51 |
| 2023 | 62 | 62.25 | 67 | 63.09 | 62.79 | 62.55 |
| 2024 | 62 | 62.44 | 67 | 63.23 | 62.88 | 62.60 |
| 2025 | 62 | 62.64 | 67 | 63.37 | 62.92 | 62.64 |
| 2026 | 62 | 62.83 | 67 | 63.52 | 62.96 | 62.68 |
| 2027 | 62 | 63.03 | 67 | 63.66 | 63.04 | 62.73 |
| 2028 | 62 | 63.22 | 67 | 63.81 | 63.13 | 62.77 |
| 2029 | 62 | 63.42 | 67 | 63.95 | 63.21 | 62.81 |
| 2030 | 62 | 63.61 | 67 | 64.08 | 63.29 | 62.86 |
| 2031 | 62 | 63.81 | 67 | 64.09 | 63.37 | 62.90 |
| 2035 | 62 | 64 | 67 | 64.63 | 63.68 | 63.07 |
| 2040 | 62 | 64 | 67 | 65.14 | 63.98 | 63.27 |
| 2045 | 62 | 64 | 67 | 65.76 | 64.34 | 63.46 |
| 2050 | 62 | 64 | 67 | 66.22 | 64.69 | 63.65 |

**Table 4**
Forecasts of the OADR under different retirement age policies.
*Source:* Author's preparation based on model results.

| Year | Previous | Reform | Full | CAR | CRR | DC |
|---|---|---|---|---|---|---|
| 2022 | 0.481 | 0.481 | 0.327 | 0.444 | 0.456 | 0.463 |
| 2023 | 0.489 | 0.480 | 0.333 | 0.451 | 0.462 | 0.470 |
| 2024 | 0.498 | 0.482 | 0.340 | 0.455 | 0.467 | 0.477 |
| 2025 | 0.506 | 0.483 | 0.346 | 0.458 | 0.473 | 0.483 |
| 2026 | 0.515 | 0.484 | 0.353 | 0.460 | 0.479 | 0.489 |
| 2027 | 0.524 | 0.485 | 0.359 | 0.463 | 0.485 | 0.496 |
| 2028 | 0.533 | 0.487 | 0.366 | 0.466 | 0.491 | 0.504 |
| 2029 | 0.541 | 0.489 | 0.373 | 0.470 | 0.496 | 0.510 |
| 2030 | 0.548 | 0.490 | 0.379 | 0.473 | 0.501 | 0.517 |
| 2035 | 0.588 | 0.511 | 0.413 | 0.489 | 0.523 | 0.546 |
| 2040 | 0.614 | 0.544 | 0.446 | 0.507 | 0.545 | 0.568 |
| 2045 | 0.628 | 0.553 | 0.456 | 0.493 | 0.541 | 0.572 |
| 2050 | 0.630 | 0.558 | 0.463 | 0.486 | 0.535 | 0.570 |

**Table 5**
Retirement age policy based on a target old-age dependency ratio.
*Source:* Author's preparation based on model results.

| | OADR 62+/20–61 | | | OADR 65+/20–64 | | |
|---|---|---|---|---|---|---|
| Year | Mean | Lo | Hi | Mean | Lo | Hi |
| 2025 | 62.92 | 62.80 | 63.03 | 63.83 | 63.80 | 63.86 |
| 2026 | 63.17 | 63.05 | 63.33 | 64.83 | 64.79 | 64.87 |
| 2027 | 63.42 | 63.20 | 63.56 | 65.83 | 65.78 | 65.88 |
| 2028 | 63.58 | 63.40 | 63.81 | 66.67 | 66.45 | 66.89 |
| 2029 | 63.83 | 63.58 | 64.09 | 66.92 | 66.69 | 67.10 |
| 2030 | 64.08 | 63.86 | 64.36 | 67.08 | 66.93 | 67.36 |
| 2035 | 65.08 | 64.77 | 65.44 | 68.33 | 68.01 | 68.67 |
| 2040 | 66.17 | 65.82 | 66.61 | 69.33 | 68.91 | 69.70 |
| 2045 | 66.42 | 66.00 | 66.86 | 70.00 | 69.50 | 70.49 |
| 2050 | 66.67 | 66.15 | 67.14 | 70.00 | 69.49 | 70.52 |

**Note:** Confidence intervals computed at the 95% level.

## Appendix. Supplementary results

See Tables 3–5.

## Data availability

Data will be made available on request.

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