University years' redemption: is it advantageous?

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Abstract

Redeeming university years to increase contributory seniority and pension entitlements is a valuable instrument that enhances workers' flexibility in shaping retirement decisions. In Italy, this option exists: graduate workers can redeem university years in order to better control retirement outcomes. Such instrument increases both contributory seniority and the accumulated contributory amount, allowing workers either to anticipate retirement or to retire with higher pension benefits. Choosing whether to redeem university years represents a fundamental decision, with potentially significant implications for the retirement outcomes of millions of workers. Given its relevance, a crucial question arises: is the redemption option convenient? And under which conditions? This question is particularly important in the context of the Italian pension system, which is expected to provide only partial income replacement, thereby increasing the importance of supplementary saving mechanisms. To the best of our knowledge, there is no study that rigorously addresses this issue. In this paper, we fill in this gap by proposing a novel and comprehensive framework to evaluate the redemption decision. Our approach provides a structured and consistent methodology to assess whether redeeming university years yields tangible benefits for Italian graduates, offering insights that improve current understanding and provide solid foundations for future research.

Keywords: defined contribution pension scheme, public pension provision, pension adequacy, replacement ratio

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1 Introduction

Europe is aging: according to Eurostat's *Projected age dependency ratios, 2025-2100*,[1] the old-age dependency ratio in the EU (defined as the ratio of individuals aged 65 and over to the population aged 20–64) is expected to increase from 37.6% in 2025 to 67.5% in 2100. In particular, Italy is one of the leaders of the aging population phenomenon, with the old-age dependency ratio reaching 75.9% in 2100 from 42.4% in 2025. If the trend is not reversed or a significant migratory flow does not occur, Italy will have enormous difficulties in maintaining the pay-as-you-go social security system. Many pension reforms in the last decades addressed this issue by cutting future pension benefits, with the first dating back to the 1990s. Due to these reforms, the public pension is now calculated according to a contribution-based method and no longer as an earning-related pension income. In particular, each worker joins a public Notional Defined Contribution (NDC) pension scheme and her pensionable earnings are determined based on career contributions. As a consequence, it is more difficult to reach an adequate replacement ratio, that is the ratio between the initial pension installment and the final wage, also due to the late entry in the workforce and career discontinuities of many individuals. Official long-term projections confirm an overall worsening of workers' future retirement conditions. According to the Italian State General Accounting Department (Ragioneria Generale dello Stato, 2025), the effective retirement age is expected to rise progressively and approach 70 years by 2070. At the same time, holding contributory seniority fixed at 38 years, the net public pension replacement ratio for a private-sector employee is expected to decline from 82.7% in 2010 to 64.1% in 2070. This decreasing trend is confirmed for the gross replacement ratio (from 79.5% in 2010 to 52% in 2070) also by the Economic Policy Committee-Working Group on Ageing (EPC-WGA) simulations (European Commission and Directorate-General for Economic and Financial Affairs, 2012, 2024).

In this context, workers face two conflicting needs: maximizing their pension benefits while avoiding retirement at an excessively old age. With reference to the first objective, it is important to note that, as public pensions have become less generous, complementary pension schemes have gained increasing importance in retirement planning to ensure an adequate standard of living in retirement. According to Ragioneria Generale dello Stato (2025) the net replacement ratio for private employees can reach 74% in 2070 with participation in complementary pension schemes. Thus, the second and third pillars of pension provision comprising collective and individual complementary pension schemes have gradually been integrated into the overall pension system, reflecting an awareness that the public pillar alone is no longer sufficient to guarantee the financial security of future retirees.

[1] See: `https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Population_projections_in_the_EU`.

In addition to joining complementary pension schemes, another tool frequently promoted to Italian graduate workers as a means to take control of their future is the redemption of university years, in exchange of paying an initial amount. This mechanism is presented as a strategic option for those seeking to influence both the timing and the value of their pension benefits. Indeed, the redemption of university years within the Italian National Social Security Institute (INPS) framework serves two fundamental purposes: first, it increases contributory seniority, allowing individuals to retire earlier; second, it boosts the total contribution amount, potentially enhancing the final value of the pension. In fact, this process converts academic years into contributory periods, thereby strengthening pension entitlements and increasing the potential for a more comfortable retirement.

In the situation of future low replacement ratios described above, every possible vehicle of retirement saving is worth investigating. Therefore, in this current pension landscape of high uncertainty, and given that redeeming university years is not mandatory, the following research question arises:

RQ: is redeeming university years advantageous for Italian graduates? And what do we mean by *advantageous*?

Surprisingly, up to our knowledge, there is no academic article that tackles these issues: as a matter of fact, the existing literature on the topic is intended for a broad audience and largely non-technical. This paper fills in this gap by presenting a novel approach to evaluate whether redeeming university years provides tangible benefits for graduates. In tackling this research question, the study offers a well-reasoned answer, acknowledging the inherent complexity of the task. Regarding the meaning of advantageous, we abstract from the subjective value associated to anticipated retirement and focus instead on pension adequacy. Recalling that, according to OECD (2013), retirement income is adequate if *"it replaces a worker's earnings at a level which enables him or her to maintain a standard of living in retirement comparable to that enjoyed in working life"*, we adopt the replacement ratio as the key metric for comparing alternative retirement scenarios.

Our analysis begins by evaluating pension outcomes under the mandatory public pension system in the absence of university years' redemption. This benchmark case serves as the reference point for all subsequent analyses. We then examine the effects of redeeming university years within the public pension system, distinguishing between scenarios with and without anticipated retirement in order to highlight the trade-off between retirement timing and pension adequacy under the net replacement ratio criterion. The analysis is subsequently extended to alternative uses of the redemption cost over a short time horizon, namely participation in a defined contribution (DC) pension fund and investment in financial markets (ETF), which are described via stochastic modeling. We then move to a more realistic life-cycle framework over the individual's entire working life, comparing comprehensive retirement strategies that either combine or substitute university years' redemption with supplementary pension investments. A preview of the results shows that, among the alternative retirement accumulation strategies considered — including university years' redemption — investment in a DC pension fund generally delivers the highest replacement ratios under standard economic assumptions.

The remainder of the paper is as follows. Section 2 illustrates in detail the university years' redemption mechanism. Section 3 introduces the analytical framework required to perform a consistent and economically meaningful comparison between the alternative choices of redeeming or not redeeming university years and provides the reference point for all subsequent comparisons. In Section 4, the effects of redeeming university years are examined, distinguishing between scenarios with and without anticipated retirement. In Section 5, we consider participation in a DC pension fund and investment in financial markets as alternative uses of the redemption cost. In Section 6, we extend the comparison of alternative accumulation strategies to the entire working life. Section 7 reports sensitivity analyses, and Section 8 concludes.

2 The Italian pension system and the redemption mechanism

In this section, we briefly outline the main features of the Italian public pension system and the mechanism that allows individuals to redeem their university years.

Until the early 1990s, pension benefits in Italy were calculated under an earning-based pay-as-you-go (PAYG) scheme, where current workers' contributions financed the pensions of current retirees. However, economic growth slowed and demographic conditions deteriorated, with declining fertility and increasing life expectancy. Both factors undermined the key conditions required for the proper functioning of the earnings-based PAYG system, which relied on intergenerational balance. Pension expenditure became progressively unsustainable, and as a result the 1990s marked a period of substantial pension reforms. [2]

The structural break occurred with the Dini Reform (1995), which introduced the so-called Notional Defined Contribution (NDC) system, that is still run on a PAYG basis. The NDC scheme is a contribution-based system: each worker contributes a fixed share of earnings (33% for private-sector employees) to an individual notional account; contributions are annually capitalized at the five-year moving average of nominal GDP growth; at retirement, the accumulated notional capital is converted into an annuity through transformation coefficients that depend on retirement age and life expectancy.

The introduction of the contribution-based system has generated three main concerns for Italian workers: declining replacement ratios, increasing retirement age and centrality of contribution continuity. As a consequence, individuals may seek instruments that mitigate these concerns and improve their

[2]For a detailed report of the evolution of the Italian pension system, see Appendix A.1.

retirement prospects. Within this context, the university years' redemption (*riscatto del corso di laurea*) represents a tool through which individuals can directly influence either their replacement ratio or their eligibility timing.

2.1 Redeeming the university degree: eligibility, costs and the subsidized option

Originally introduced in 1974, university years' redemption allows graduates to convert the legal duration of their degree (up to five years) into contributory periods. Its effects are twofold: (i) it increases contributory seniority and may therefore help individuals meet the minimum requirements for pension eligibility, and retire earlier; (ii) it increases the amount of contributions credited to the individual's account, thereby enlarging the accumulated pension capital and potentially raising the future pension benefit.

The relevance of university years' redemption is growing alongside the expansion of higher education: in academic year 2023–24, 415,553 degrees were awarded, more than double the number in 2001.[3] University enrollment also increased, with 2,026,925 students admitted in 2024–25, marking a 2.3% rise from the previous year.[4] In 2024, 22.3% of individuals aged 25 to 64 held a university degree, increasing to 31.6% among those aged 25 to 34 (ISTAT, 2025). Overall, a large and growing share of the Italian workforce — amounting to several millions of individuals — potentially faces the decision of whether to redeem university years.

To apply for university years' redemption, the following eligibility criteria must be met:

- the applicant must be graduated at the time of submitting the redemption request;
- the periods to be redeemed must not be covered by contributions in any pension scheme;
- the applicant must have paid at least one mandatory contribution in the pension scheme where the redemption is requested (except for individuals who have been unemployed since 2008).

Redemption concerns only the legal duration of the degree programme, up to a maximum of five years, regardless of how long the individual actually took to complete their studies. Periods already credited with mandatory or figurative contributions — or previously redeemed for other reasons — are excluded.

The degrees eligible for redemption include: old-system degrees; three-year Bachelor's degrees (*lauree triennali*) and two-year Specialist/Master's degrees (*lauree specialistiche* o *lauree magistrali*), including single-cycle programs (up to five years); postgraduate specialization diplomas (e.g. medical specializations);

[3] Source: USTAT, Higher Education Data Portal, Ministry of University and Research. Data on the number of degrees awarded accessible at: https://dati-ustat.mur.gov.it/dataset/laureati.

[4] Source: USTAT, Higher Education Data Portal, Ministry of University and Research. Data on the number of enrolled students by disciplinary group accessible at: https://dati-ustat.mur.gov.it/dataset/iscritti.

Ph.D. programs (only if not already covered by contributions); first- and second-level academic diplomas, research training diplomas, and AFAM qualifications (Higher Artistic and Musical Education). University Master's programs (which are different and shorter than Master's degrees) are not eligible for redemption.

The cost of redeeming university years depends strictly on the pension calculation method applicable to the period being redeemed, namely whether it falls under the earnings-based regime or the contribution-based regime. In this paper, we concentrate only on workers falling completely under the contribution-based regime, and we refer the reader interested in the earnings-based regime to Appendix A.2.

When the period to be redeemed falls under the contribution-based regime, the cost is calculated using a *percentage-based method*. In this case, the redemption cost of a single year to be redeemed is equal to the applicable IVS (Invalidity, Old-Age and Survivors) contribution rate in force at the time of the request, applied to the individual's taxable wage during the 52 weeks preceding the application. The amount due may be paid either in a lump sum or in monthly installments (up to 120). Furthermore, the amounts paid are fully deductible from taxable income, implying a fiscal advantage that depends on the individual's marginal tax rate.

To reduce the monetary burden associated with university years' redemption, an alternative subsidized cost calculation method (*riscatto agevolato*) was introduced in 2019 for workers under the contributions-based regime. With this option, the IVS contribution rate is applied not to the worker's actual earnings, but to a statutory minimum taxable income level, that is the minimum annual income used to compute IVS contributions for artisans and commercial workers. It is updated annually in line with changes in the consumer price index for households of blue-collar and white-collar workers. For example, the minimum annual income for IVS contributions was set at €18,555 in 2025. Therefore, under this scheme, the redemption is typically less expensive than under the ordinary procedure. As a consequence, the subsidized redemption option quickly gained popularity among applicants. According to INPS (2021), the total number of redemption applications rose substantially in 2019 compared with the previous year — a rise that has been attributed in part to the uptake of the subsidized scheme.

Example 2.1. *Consider a worker whose taxable wage over the last 52 weeks in 2025 amounts to €35,000. Suppose the worker completed a three-year degree and applies for redemption, with the IVS contribution rate equal to 33%. The respective cost for ordinary and subsidized redemption are as follows:*

- *Ordinary redemption cost for a single university year:* $€35,000 \times 33\% = €11,550$
- *Total ordinary redemption cost:* $€11,550 \times 3 = €34,650$
- *Subsidized redemption cost for a single university year:* $€18,555 \times 33\% = €6,123.15$

- *Total subsidized redemption cost:* €$6,123.15 \times 3 =$ €$18,369.45$

Compared with the ordinary redemption cost of €34,650 computed earlier, the subsidized option implies a reduction of approximately 47%.

3 Preliminaries for the analysis of the convenience of the redemption option

Comparing the positions of two otherwise identical graduate workers who choose to redeem or not redeem university years is not straightforward, as the decision can be driven by different and potentially conflicting objectives. Broadly speaking, two main motivations emerge: anticipating retirement and increasing pension benefits. Redeeming university years may therefore serve different purposes depending on the worker's preferences.

Importantly, we should stress that these two objectives are distinct and, in general, cannot be simultaneously achieved. In other words, redemption does not allow the worker to maximize benefit adequacy and anticipate retirement at the same time. The underlying mechanism is as follows. If retirement age remains unchanged, additional redeemed years increase the accumulated notional capital and thus the pension benefits. If, instead, retirement is anticipated, the worker gains earlier access to pension income but gives up future years of labor income and contributions; moreover, the accumulated capital is converted into an annuity using a transformation coefficient associated with a younger retirement age, which is less favorable as benefits are expected to be paid over a longer period. As a result, using redemption to retire earlier is likely to reduce the annual pension amount.

The convenience of redemption therefore depends crucially on the worker's objective. If the aim is to maximize the annual pension benefit or the replacement ratio, exercising redemption while still retiring early may be suboptimal, since the full accrual effect of additional contributions is typically better exploited when retirement is not anticipated. If, instead, the aim is to leave the labor market earlier, redemption becomes part of a broader intertemporal trade-off: the worker accepts a reduction in future pension adequacy and foregoes additional years of salary in exchange for additional leisure time.

For these reasons, university years' redemption should not be regarded as a universally optimal choice, but rather as a strategic instrument whose convenience depends on many factors, including income, career continuity, contribution accumulation, desired retirement timing, benefit adequacy and fiscal conditions. It is precisely the interaction between these factors that motivates the economic analysis developed in the following sections.

Considering all possible decision criteria within a single framework is beyond the scope of this paper.

For the purposes of the present analysis, we restrict our attention to pension adequacy and adopt the replacement ratio as the relevant measure in the decision-making process of the worker. Consequently, the decision to redeem university years will be evaluated by comparing the Net Replacement Ratios achievable under the two alternatives — redeeming versus not redeeming — accounting for meaningful and representative alternative retirement strategies.

3.1 Methodology

The analysis presented in this paper focuses on Italian graduate workers who completed their studies in 2021. In particular, we consider two representative individuals holding, respectively, a Bachelor's degree and a Master's degree, in order to capture differences in the length of education and the associated contribution periods. The methodological framework is structured in five main steps:

1. First, we evaluate the pension outcome generated exclusively by participation in the mandatory public pension system. This analysis, presented in Section 3.4, provides a reference point upon which all subsequent strategies will be based.

2. Next, in Section 4 we explore the effects of redeeming university years, considering two scenarios: one where individuals choose to retire earlier and another where they opt to maintain their original retirement date. This comparison allows us to clearly identify the trade-off embedded in the redemption decision, showing that the objectives of earlier retirement and better pension adequacy are not jointly attainable.

3. Third, Section 5 compares the outcomes associated with university years' redemption — seen in Section 4 — to those obtainable through alternative saving strategies. In particular, we consider the case in which the redemption cost is invested in a defined contribution (DC) pension fund or in financial markets (ETF). This first comparison is designed to ensure full comparability in terms of timing and monetary amounts, as the investment is assumed to take place at the same points in time at which redemption would occur and with the same payment flows.

4. In addition, in Section 6 we consider a slightly more complex comparison in which individuals choose, at the beginning of their career, between redeeming their university years and subsequently investing in a DC pension fund, or investing exclusively in the DC pension fund without redeeming. This analysis is motivated by the need to evaluate university years' redemption within the context of comprehensive, career-long retirement strategies.

5. Finally, in Section 7, we complete the study with a sensitivity analysis in which we vary the key parameters underlying our framework. This allows us to assess the robustness of the results and to evaluate how variations in the main economic and institutional drivers affect the relative convenience of the retirement strategies considered.

The analysis focuses on projecting or simulating the future Net Replacement Ratios (NRRs) under each strategy, while explicitly accounting for the associated tax savings arising from the deductibility of redemption costs and contributions to DC pension schemes.

3.2 Assumptions on the graduates

The representative graduate workers considered in the analysis are characterized by the following assumptions:

1. They hold either a Bachelor's or a Master's degree, and have not paid social security contributions during their university years.
2. They enter university at age 19 and complete their studies within the standard duration, graduating in 2021 after three years (Bachelor's degree) or five years (Master's degree).
3. They enter the labor market immediately upon graduation, and are therefore entirely subject to the contribution-based regime for pension calculation.
4. They satisfy the eligibility requirements for retirement by 2067, consistently with the projections provided by Ragioneria Generale dello Stato (2025), according to which about 46 years of contributions are needed to get access to retirement.[5]
5. If the individual redeems the full legal duration of their degree program, this allows (though does not oblige) them to anticipate retirement by exactly three years in the case of a Bachelor's degree and five years in the case of a Master's degree. Under this assumption, anticipated retirement would occur in 2064 and 2062, respectively.

Table 1 summarizes the implied demographic and career characteristics of the representative individuals, including birth year, age at graduation, and retirement age under both the baseline scenario and the anticipated retirement redemption scenario.

[5] At the moment, there are mainly three sets of requirements to get access to retirement: one requires a minimum of contributory years, regardless of the age; the other two require a combination of contributory years and personal age. In this paper, we consider only the first set of requirements to get access to statutory retirement. On the other side, we refer to *anticipated retirement* as the one allowed by the university years' redemption option.

	Birth Year	Graduation Age in 2021	Retirement Age in 2067	Redeemable Years	Anticipated Retirement Age
Bachelor's	1999	22	68	3	65 (2064)
Master's	1997	24	70	5	65 (2062)

Table 1: Demographic characteristics of the graduate workers under analysis

To ensure internal consistency and transparency, we further impose the following set of assumptions, which will hold throughout the subsequent analysis:

i. Graduate workers are employed on permanent contracts in the private sector and receive 13 monthly installments per year.

ii. Graduate workers are assumed to have continuous employment with no contribution gaps, and are assumed to survive until retirement.

iii. Individuals have their tax domicile in Turin (Piedmont), so that regional and municipal surtaxes applicable to that jurisdiction are included.

iv. The Italian fiscal system distinguishes between deductions (which reduce taxable income) and tax credits (which reduce gross tax liability). In this analysis, we consider only two types of deductions: contributions to DC pension schemes (up to € 5,300 per year) and the cost of redeeming university years, which is fully deductible from taxable income. Employee tax credits are incorporated to obtain the net salary from the gross one and viceversa, as described in Appendix B.1.

v. The regulatory framework is assumed to remain constant over time and to be applied uniformly across the entire projection horizon. In particular, the analysis is based on the legislation in force in 2026.

3.3 Assumptions on salaries

To carry out the analysis, it is necessary to specify a set of assumptions regarding the earnings profiles of the representative individuals. In order to do so, we rely on the report by AlmaLaurea (2023), which provides detailed evidence on the occupational outcomes of 2021 graduates — both Bachelor's and Master's — one year after graduation, across 15 disciplinary groups.[6] For the sake of conciseness, the analysis

[6]The 15 disciplinary groups are: Economics and Finance; Medical-Healthcare and Pharmaceutical; Industrial and Information Engineering; Scientific Fields; Political-Social and Communications; Law; Education; Foreign Languages; Literature; Psychology; Architecture and Civil Engineering; Art and Design; Sports and Physical Education; Computer Science and ICT; Agriculture-Forestry and Veterinary.

only focuses on one of the largest disciplinary groups, namely Economics and Finance, which accounts for approximately 17% of total graduates according to data from the Italian Ministry of University and Research.[7]

We assume that the entry-level salary is in line with the national average salary of 2021 graduates in Economics and Finance one year after graduation, as reported by AlmaLaurea (2023). Accordingly, the net monthly salary is set equal to €1,292 for Bachelor graduates and €1,414 for Master graduates.

Consistently with Assumption i in Section 3.2, annual net salaries are obtained by multiplying monthly earnings by 13. This yields annual net incomes of $S_n^{\text{Bachelor}}(2022) = €16,796$ for Bachelor graduates and $S_n^{\text{Master}}(2022) = €18,382$ for Master graduates. By contrast, recovering the corresponding gross amounts requires a more articulated procedure, as it depends on the underlying tax and contribution structure. Using Assumptions i–v in Section 3.2, we derive gross annual salaries equal to $S_g^{\text{Bachelor}}(2022) = €19,366.27$ for Bachelor graduates and $S_g^{\text{Master}}(2022) = €21,891.34$ for Master graduates (see Appendix B.1 for a detailed description of the procedure).

At this point, we must specify a projection rule for the evolution of the salary over time. To this end, we rely on OECD data on average annual gross wages in Italy over the period 2000–2024.[8] The corresponding time series is reported in Figure 9a, Appendix B.1. Based on this evidence, we model the evolution of nominal gross salaries according to a deterministic exponential growth process:

$$S_g^d(t) = S_g^d(2022) \cdot e^{\gamma(t-2022)}, \qquad \gamma = 1.85\%, \quad d \in \{\text{Bachelor}, \text{Master}\}, \quad t = 2021, 2022, ..., \tag{1}$$

where $S_g^d(2022)$ denotes the gross annual salary of the representative individual earned one year after graduation, i.e., in 2022, while the parameter γ represents the average logarithmic growth rate of nominal gross wages observed in Italy over the period 2000–2024. Figure 9b in Appendix B.1 illustrates the resulting projected salary paths for the two representative individuals.

3.4 Mandatory public pension and replacement ratios

Within the NDC scheme, the public pension at retirement depends on two main elements: (i) the total lifetime contributions, accumulated and revalued according to nominal GDP growth; and (ii) the transformation coefficients, which convert the accumulated notional capital into an annuity and depend on demographic factors such as life expectancy and the survival probabilities of the member and of the spouse.

[7]For detailed data on Italian graduates by disciplinary group, see: https://dati-ustat.mur.gov.it/dataset/laureati/resource/4783e6b6-eac2-4dfa-a2c6-5b27e1298464.

[8]See https://stats.oecd.org/index.aspx?DataSetCode=AV_AN_WAGE for further details.

Building on this institutional framework, we now describe the methodology used to compute the pension benefits obtainable at retirement for the two representative individuals considered in this study.

The procedure for determining the total lifetime contributions is the following:

1. For each year, we determine the gross annual salary. Under our assumptions, this corresponds to the wage process specified in (1).

2. Annual social security contributions are then obtained by applying the statutory contribution rate, equal to $c = 33\%$, to the gross salary.

3. Contributions are then accumulated over time, with past contributions revalued annually using a revaluation coefficient based on the average growth rate of nominal GDP over the previous five years. Formally, the coefficient from December 31 of year $t-1$ to December 31 of year t is defined as

$$RV(t) = \max\left\{1, \left(\frac{GDP(t-1)}{GDP(t-6)}\right)^{\frac{1}{5}}\right\}, \qquad t = 2022, 2023, \ldots$$

   The lower bound of 1 implies that adverse macroeconomic conditions do not reduce the accumulated capital. Revaluation is applied on a compound basis at year-end and excludes contributions paid within the same year, which are treated as if credited in full at the end of the year.

Accordingly, assuming labor market entry on September 1, 2021 and retirement on September 30, 2067 — as projected by Ragioneria Generale dello Stato (2025) — total lifetime contributions accumulated up to December 31 of year t, for $t = 2022, \ldots, 2066$, are given by

$$\begin{aligned} TLC^d(t) = TLC^d(t-1) \cdot RV(t) + c \cdot S_g^d(t) &= \frac{4 + \frac{4}{12}}{13} \cdot c \cdot S_g^d(2021) \cdot \prod_{k=2022}^{t} RV(k) \\ &+ c \cdot S_g^d(2022) \cdot \sum_{j=2022}^{t-1} \left(e^{\gamma(j-2022)} \cdot \prod_{k=j+1}^{t} RV(k) \right) + c \cdot S_g^d(2022) \cdot e^{\gamma(t-2022)}, \end{aligned} \tag{2}$$

while, for the retirement year $t = 2067$, are expressed as

$$TLC^d(2067) = TLC^d(2066) \cdot RV(2067) + \frac{9 + \frac{9}{12}}{13} \cdot c \cdot S_g^d(2067), \tag{3}$$

where $c = 33\%$, $\gamma = 1.85\%$, $d \in \{\text{Bachelor}, \text{Master}\}$. The fractional coefficients appearing in (2) and (3) reflect the fact that contributions are paid over partial working years and are distributed across 13 annual salary installments. In particular, the term $\frac{4+\frac{4}{12}}{13}$ accounts for contributions accrued between September and December 2021, while $\frac{9+\frac{9}{12}}{13}$ captures contributions earned from January to September 2067, both expressed as fractions of the corresponding annual salary.

Given the forward-looking nature of the analysis, it is necessary to project the revaluation coefficients up to 2067, the expected retirement year of the 2021 graduate cohort. This requires assumptions on the future path of nominal GDP. Institutional projections differ markedly in this respect. The official simulator provided by INPS[9] to assess the pension implications of redeeming university years implicitly assumes zero GDP growth, thereby setting all future revaluation coefficients equal to one. By contrast, the long-term projections of Ragioneria Generale dello Stato (2025) assume a substantial nominal GDP growth of approximately 2–3% per year — with GDP growing from 1.6 to 7.3 billion euros — implying a significant revaluation of notional contributions and, consequently, higher replacement ratios. A plausible explanation for this divergence lies in the different institutional objectives. INPS, within a tool designed to assess the convenience of university years' redemption, may adopt a deliberately conservative perspective, generating relatively low replacement ratios and thereby encouraging individuals to strengthen their contributory position through redemption. By contrast, Ragioneria Generale dello Stato operates within a broader policy framework, where more optimistic growth assumptions convey the message that the contribution-based system can deliver adequate, or even favorable, pension outcomes compared to the past earnings-based regime.

In this study, we adopt the prudential INPS assumption as a baseline, i.e. null GDP growth over time, interpreting it as a lower bound for pension outcomes. To assess the quantitative relevance of alternative macroeconomic scenarios, this assumption is relaxed in the sensitivity analysis presented in Section 7. In Figure 1, we present the evolution of the total lifetime contributions for the two representative individuals from 2021 up to their year of retirement.

Once total lifetime contributions at the retirement year 2067 have been determined via (3), the gross annual pension P_g^d, with $d \in \{\text{Bachelor}, \text{Master}\}$, is obtained by applying the transformation coefficient $\beta_x(2067)$ corresponding to the worker's age x at retirement:

$$P_g^{\text{Bachelor}} = \beta_{68}(2067) \cdot TLC^{\text{Bachelor}}(2067) \tag{4}$$

$$P_g^{\text{Master}} = \beta_{70}(2067) \cdot TLC^{\text{Master}}(2067) \tag{5}$$

As we already anticipated, the transformation coefficients $\beta_x(2067)$ depend primarily on age at retirement and demographic conditions, with later retirements yielding higher benefits due to a shorter expected lifespan. According to the Italian legislation, the transformation coefficients are revised periodically to

[9] See: https://serviziweb2.inps.it/AS0207/SimCalPrePen/riscatto/.

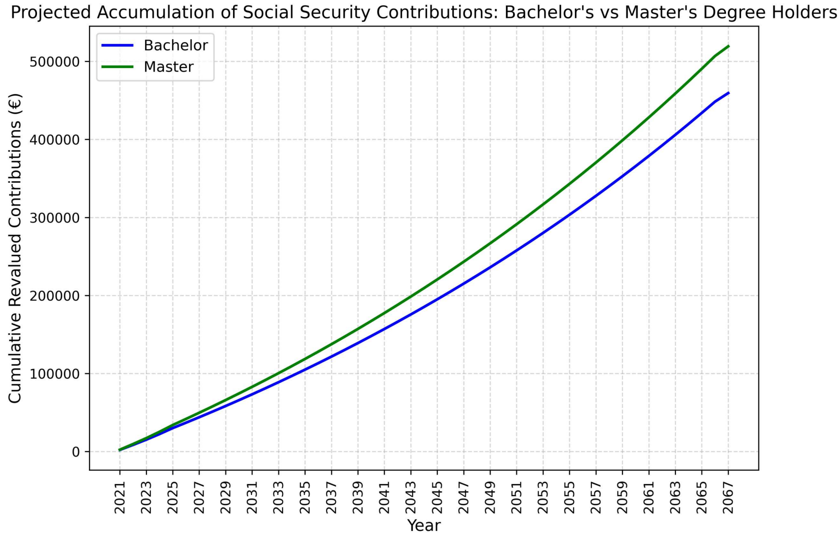

Figure 1: Evolution of the Total Lifetime Contributions for the Bachelor and Master 2021 graduate workers

account for changes in both economic and demographic indicators. Historical evidence (see Table 2 and Figure 2) highlights some key patterns.

Age	1996–2009	2010–2012	2013–2015	2016–2018	2019–2020	2021–2022	2023–2024	2025–2026
57	4.720%	4.419%	4.304%	4.246%	4.200%	4.186%	4.270%	4.204%
58	4.860%	4.538%	4.416%	4.354%	4.304%	4.289%	4.378%	4.308%
59	5.006%	4.664%	4.535%	4.447%	4.414%	4.399%	4.493%	4.419%
60	5.163%	4.798%	4.661%	4.589%	4.532%	4.515%	4.615%	4.536%
61	5.330%	4.940%	4.796%	4.719%	4.657%	4.639%	4.744%	4.661%
62	5.514%	5.093%	4.940%	4.856%	4.790%	4.770%	4.882%	4.795%
63	5.706%	5.297%	5.094%	5.002%	4.932%	4.910%	5.028%	4.936%
64	5.911%	5.432%	5.259%	5.159%	5.083%	5.060%	5.184%	5.088%
65	6.136%	5.620%	5.435%	5.326%	5.245%	5.220%	5.352%	5.250%
66	6.136%	5.620%	5.624%	5.506%	5.419%	5.391%	5.531%	5.423%
67	6.136%	5.620%	5.826%	5.700%	5.604%	5.575%	5.723%	5.608%
68	6.136%	5.620%	6.046%	5.910%	5.804%	5.772%	5.931%	5.808%
69	6.136%	5.620%	6.283%	6.135%	6.021%	5.985%	6.154%	6.024%
70	6.136%	5.620%	6.541%	6.378%	6.257%	6.215%	6.395%	6.258%
71	6.136%	5.620%	6.541%	6.378%	6.513%	6.466%	6.655%	6.510%

Table 2: Transformation coefficients of the revalued total lifetime contributions. Source: *Istat, Ministry of Labor & Social Policies and Ministry of Economy & Finance data.*

First, the transformation coefficients exhibit a direct proportionality to age across all observed periods. Specifically, higher retirement ages correspond to greater coefficients. This relationship reinforces the principle that individuals opting for later retirement receive enhanced pension benefits. The spike in the transformation coefficients for ages 67 to 70 during the years 2012–13 (see Figure 2) can be attributed to substantial reforms and adjustments in the Italian pension system designed to incentivize later retirement.

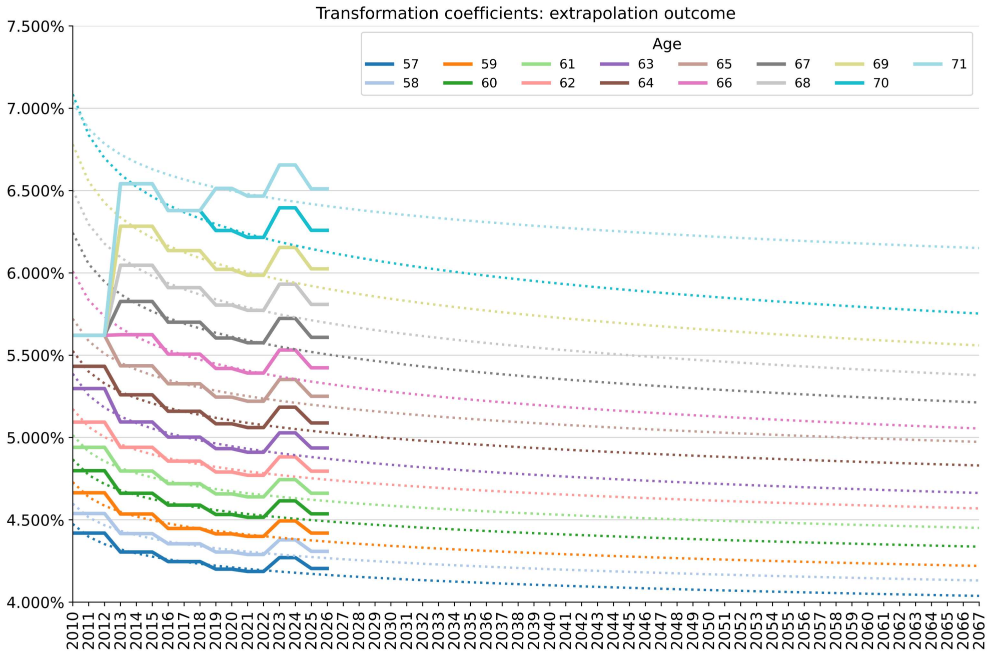

Figure 2: Transformation coefficients for each age between 57 and 71 years old. The solid lines represent the historical values (source: *Istat, Ministry of Labor & Social Policies and Ministry of Economy & Finance data*), while the dotted lines represent the relative projections.

Finally, the coefficients for the years 2023–24 reflect a slight increase due to rising mortality rates and the reduction in life expectancy, which can be attributed to the impact of COVID-19.

Given the ongoing rise in life expectancy, one might anticipate a decrease in all the coefficients in the future. It is precisely this last insight that guides our deterministic extrapolation approach, in which future coefficients are obtained by fitting a smooth trend to their historical evolution.[10] To obtain a clean and meaningful extrapolation, we restrict the estimation sample to observations from 2010 to 2022 for ages 57–65, from 2013 to 2022 for ages 66–70, and from 2019 to 2022 for age 71, thereby excluding periods affected by institutional changes or exceptional events. On this basis, for each age $x = 57, \dots, 71$, we estimate via ordinary least squares method the following log–log specification:

$$\log\left(\hat{\beta}_x(t)\right) = \hat{a}_x + \hat{b}_x \log(1 + t - 2010), \qquad t \in \mathcal{T}_x, \tag{6}$$

where $\mathcal{T}_x = \{2010, \dots, 2022\}$ for $x = 57, \dots, 65$, $\mathcal{T}_x = \{2013, \dots, 2022\}$ for $x = 66, \dots, 70$, while $\mathcal{T}_{71} = \{2019, \dots, 2022\}$. This specification captures a gradual and decelerating decline over calendar years in the coefficients $\hat{\beta}_x(t)$, reflecting longevity improvements with diminishing marginal impact over time. With the calibrated vectors $\hat{a}_x$ and $\hat{b}_x$, one can extrapolate the future transformation coefficients using (6), obtaining:

$$\hat{\beta}_{68}(2067) = 5.378\%, \qquad \hat{\beta}_{70}(2067) = 5.753\%.$$

Combining the projected transformation coefficients with total lifetime contributions, and applying (4)–(5), we compute the gross annual pensions for the two representative workers. We also obtain the corresponding net pension benefits, whose detailed computation is reported in Appendix B.2. We then compute the gross and net replacement ratios, defined respectively as

$$GRR^d = \frac{P_g^d}{S_g^d(2067)}, \qquad NRR^d = \frac{P_n^d}{S_n^d(2067)}, \qquad d \in \{\text{Bachelor}, \text{Master}\}.$$

The resulting pension benefits and replacement ratios are reported in Table 3.

As expected, the Master graduate attains a higher pension level in both gross and net terms. This reflects the combined effect of higher lifetime contributions, driven by higher earnings, and a later retirement age, which implies a more favorable transformation coefficient.

Replacement ratios are systematically higher in net terms. This reflects the progressive structure of

[10] A simulation-based approach could also be exploited: for each age $x = 57, ..., 71$, one could consider the empirical range of observed coefficients over the available period and assume that future realizations lie within this interval. One could then draw simulated values from a uniform distribution defined over the historical minimum and maximum, and estimate the future coefficient as the average of these draws. For instance, this is the approach used in Forzan (2024).

	Gross Annual Pension Benefit	Net Annual Pension Benefit	Gross Replacement Ratio	Net Replacement Ratio
Bachelor	€ 24,707.36	€ 19,235.76	55.49 %	59.42 %
Master	€ 29,876.25	€ 22,559.25	59.36 %	64.37 %

Table 3: Annual pension benefits and replacement ratios for the two representative individuals in 2067

the tax system: pension income is typically lower than pre-retirement earnings and is subject to a lower average tax rate. Moreover, pension income is not subject to the payment of social security contributions, unlike labor income.

Overall, these results suggest that, under prudential macroeconomic assumptions — namely, zero GDP growth over the considered period — the Italian NDC system is capable of delivering moderate income replacement, thereby highlighting the potential importance of supplementary saving mechanisms.

4 Public pension scheme outcomes when redeeming university years

In this section, we analyze the outcomes of the mandatory public pension scheme in the presence of university years' redemption. We assume that the application for redemption is submitted to INPS at the beginning of 2022, and that the redeemed period corresponds to the standard legal duration of the degree program (three years for the Bachelor's degree and five years for the Master's degree). The redemption cost is computed according to the percentage-based approach under the ordinary procedure described in Section 2.1.[11]

Under these assumptions, the total redemption costs are:

$$TRC^{\text{Bachelor}} = 33\% \cdot S_g^{\text{Bachelor}}(2021) \cdot 3 = €18,821.18,$$

$$TRC^{\text{Master}} = 33\% \cdot S_g^{\text{Master}}(2021) \cdot 5 = €35,458.62.$$

These amounts reflect both the proportionality of the redemption cost to gross earnings and the longer duration of Master's studies. The cost is assumed to be paid in ten equal annual installments between 2022 and 2031, yielding the following annual redemption costs:

$$RC^{\text{Bachelor}} = €1,882.12, \qquad RC^{\text{Master}} = €3,545.86.$$

[11]The subsidized redemption option is not explicitly analyzed. Nevertheless, the analytical framework can be readily adapted to this case: all formulas in this section remain unchanged, except that $S_g^d(2021)$ is replaced by the minimum taxable income reported in Section 2.1. This results in lower redemption costs and, consequently, lower accumulated contributions and pension benefits.

This installment structure mitigates the short-term financial burden while preserving the full pension entitlement associated with the redeemed periods.

Without anticipated retirement, the redemption increases total lifetime contributions by adding the stream of redeemed contributions to the baseline accumulation defined in (3). In particular, recalling the setup in Section 3.4, the total lifetime contributions at retirement in 2067 become:

$$TLC^{d,R}(2067) = TLC^{d}(2067) + RC^{d} \sum_{j=1}^{10} \prod_{k=2022+j}^{2067} RV(k), \qquad d \in \{\text{Bachelor}, \text{Master}\}. \tag{7}$$

In the case of anticipated retirement through redemption, contributory seniority is increased by the number of redeemed years, allowing retirement to be anticipated by *3 years* for Bachelor's graduates (retirement in 2064), and by *5 years* for Master's graduates (retirement in 2062), respectively. Thus, analogous expressions for $TLC^{\text{Bachelor},R}(2064)$ and $TLC^{\text{Master},R}(2062)$ can be derived. In turn, the availability of the amounts $TLC^{d,R}(y)$, with $y \in \{2062, 2064, 2067\}$ and $d \in \{\text{Bachelor}, \text{Master}\}$, allows the calculation of the public pension in the case of redemption, with and without anticipated retirement.

We then have all the elements to evaluate six alternative scenarios, which differ along two dimensions: (i) whether university years are redeemed, and (ii) whether retirement occurs at the earliest possible date or at the statutory retirement age. The six scenarios are illustrated in Figure 3 and can be summarized as follows:

I. Bachelor, no redemption, retirement in 2067;

II. Bachelor, redemption, retirement in 2064;

III. Bachelor, redemption, retirement in 2067;

IV. Master, no redemption, retirement in 2067;

V. Master, redemption, retirement in 2062;

VI. Master, redemption, retirement in 2067.

When redemption is combined with anticipated retirement, the working horizon is shortened. Conversely, when retirement timing is unchanged, redemption increases total lifetime contributions according to (7) without affecting the retirement age.

Table 4 summarizes the implied demographic characteristics.

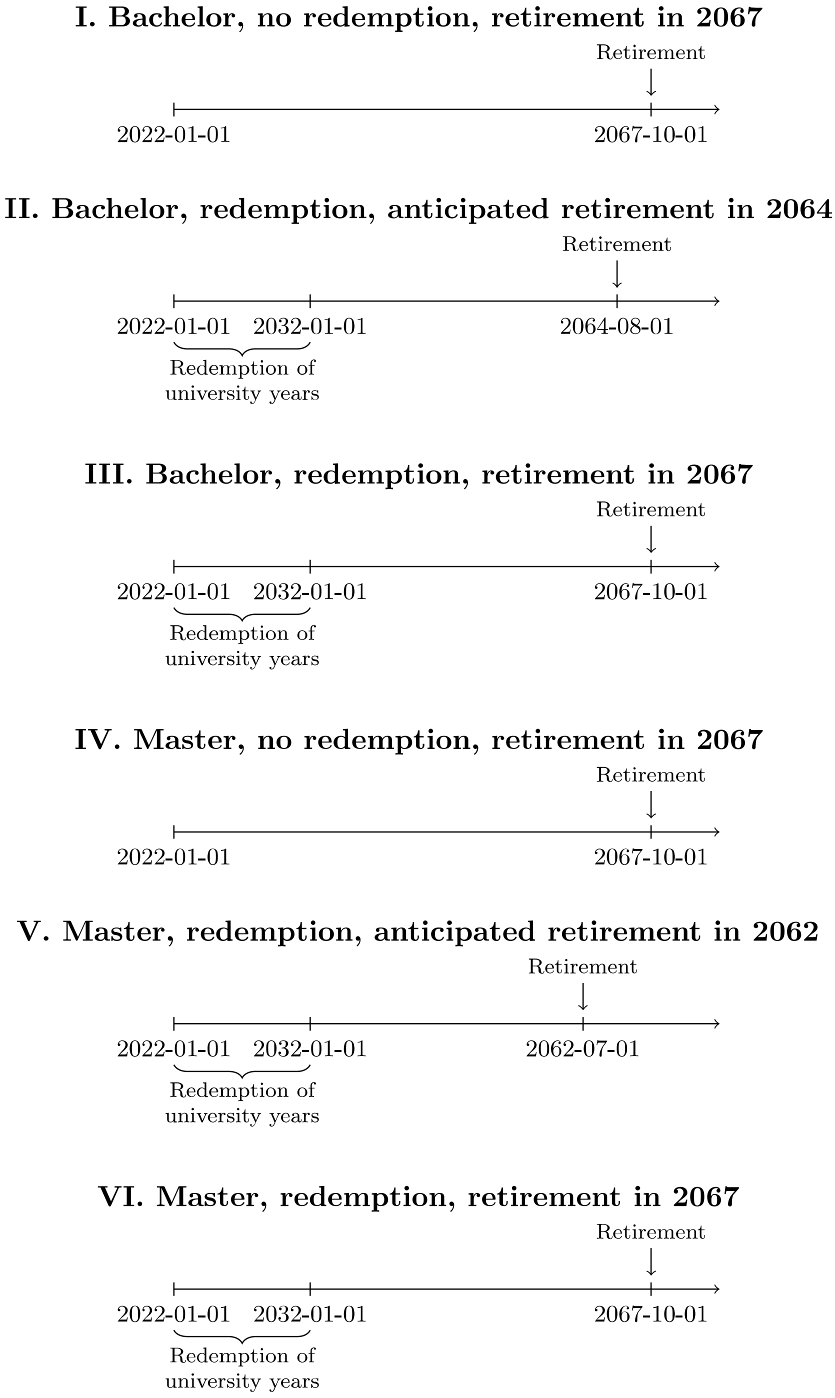

Figure 3: Timeline representation of the six retirement scenarios. The months worked in year 2021 are omitted for simplicity.

	Bachelor	Master
Graduation Age (in 2021)	22	24
Retirement Age with Redemption and Anticipated Ret.	65 (in 2064)	65 (in 2062)
Retirement Age with Redemption and No Anticipated Ret. (in 2067)	68	70

Table 4: Demographic characteristics of graduate workers under alternative retirement scenarios with university years' redemption.

Figure 4 illustrates the evolution of the total lifetime contributions across the considered scenarios. The redemption of university years increases contributions early in the career, allowing these amounts to benefit from a longer revaluation horizon.

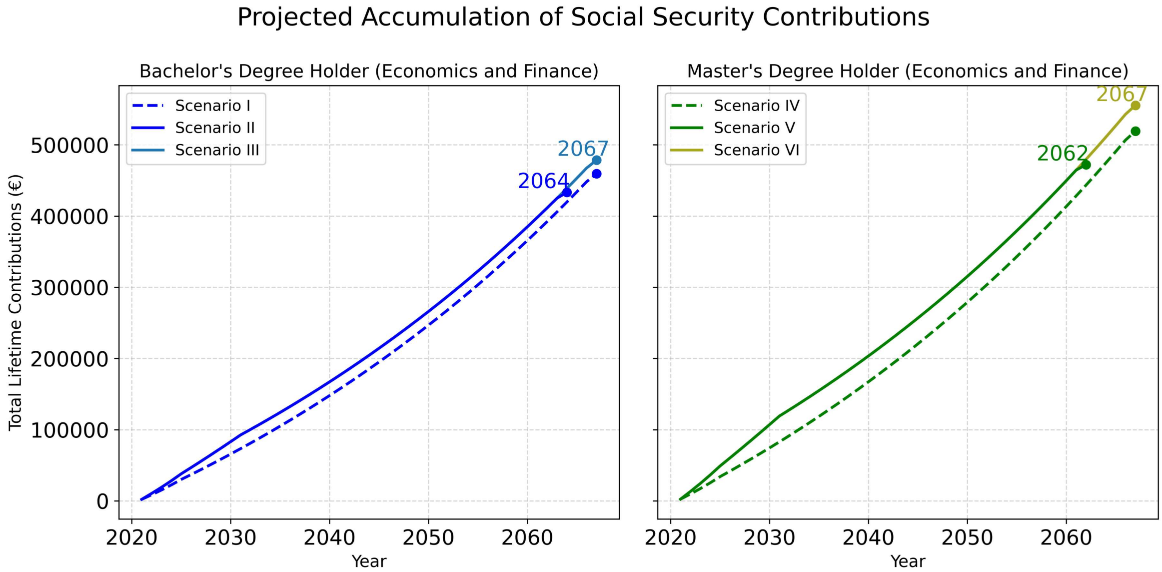

Figure 4: Evolution of Total Lifetime Contributions Across Scenarios

We now compare the scenarios in terms of the adequacy of the pension benefits. To this end, we follow the methodology outlined in Section 3.4 to compute the replacement ratios — both in gross and net terms — for each of the six considered scenarios.

In addition to the calculation of public pension and replacement ratios, we have to calculate also the tax savings associated to university years' redemption. Indeed, the redemption cost can be fully deducted from the taxable income, giving rise to slightly different annual tax credits and, above all, an annual tax saving which depends on the marginal tax rate of the worker. The total savings amount to € 5,740.11 for Bachelor's graduates and € 11,364.26 for Master's graduates. The tax savings provide an additional financial incentive for redeeming university years, as individuals not only improve their contributory position for pension purposes but also benefit from a reduction in taxation during the years in which redemption payments are made.

Table 5 reports all the components for evaluating pension adequacy in the six scenarios considered: gross and net pension benefits, gross and net replacement ratios, and tax savings in the scenarios with redemption.

	I **Bachelor** **No redemption** **Ret. in 2067** **Age 68**	**II** **Bachelor** **Redemption** **Ret. in 2064** **Age 65**	**III** **Bachelor** **Redemption** **Ret. in 2067** **Age 68**	**IV** **Master** **No redemption** **Ret. in 2067** **Age 70**	**V** **Master** **Redemption** **Ret. in 2062** **Age 65**	**VI** **Master** **Redemption** **Ret. in 2067** **Age 70**
Gross Annual Salary at Ret.	€ 44,524.20	€ 42,120.42	€ 44,524.20	€ 50,329.47	€ 45,882.81	€ 50,329.47
Gross Annual Pension	€ 24,707.36	€ 21,585.07	€ 25,742.08	€ 29,876.25	€ 23,552.57	€ 31,961.55
GRR	55.49 %	51.25 %	57.82 %	59.36 %	51.33 %	63.50 %
Net Annual Salary at Ret.	€ 32,372.39	€ 31,824.31	€ 32,372.39	€ 35,043.96	€ 34,517.06	€ 35,043.96
Net Annual Pension	€ 19,235.76	€ 17,141.20	€ 19,979.89	€ 22,559.25	€ 18,461.08	€ 23,798.08
NRR	59.42 %	53.86 %	61.72 %	64.37 %	53.48 %	67.91 %
Tax savings	—	€ 5,740.11	€ 5,740.11	—	€ 11,364.26	€ 11,364.26

Table 5: Annual salaries at retirement, pension benefits, replacement ratios and tax savings across the considered scenarios.

We observe the following:

- For both Bachelor's and Master's graduates, redeeming university years without advancing the retirement date yields the highest replacement ratios. This is followed by the no-redemption scenarios, while the lowest replacement ratios are observed in the cases where redemption is combined with anticipated retirement. In particular, we note that:
  - *Redemption with anticipated retirement vs. no redemption:* these scenarios are not directly comparable, as they involve different retirement ages and working horizons. Nonetheless, the results show that combining redemption with anticipated retirement leads to a reduction in the replacement ratios relative to the no-redemption benchmark. This outcome reflects the structure of the NDC system, in which earlier retirement implies both a shorter contribution period and the application of less favorable transformation coefficients. Although the reduction in the replacement ratios indicates lower pension adequacy, anticipated retirement provides access to pension benefits at a younger age and may therefore improve individual welfare through non-monetary channels, such as increased leisure and a better quality of life. These aspects are not captured by the replacement ratios.

  - *Redemption without anticipated retirement vs. no redemption:* when university years are redeemed without anticipating retirement, the replacement ratios are higher than in the no-redemption case. This result follows directly from the increase in total lifetime contributions, while the transformation coefficient remains unchanged, as retirement occurs at the same age. Consequently, higher accumulated contributions translate into higher pension benefits.

- In the corresponding scenarios, Master's graduates achieve higher replacement ratios than Bachelor's graduates, primarily reflecting their later retirement age. Notably, when redemption is combined with anticipated retirement — so that both individuals retire at the same age of 65 — the replacement ratios are essentially identical.

Therefore, the following conclusions can be drawn.

Redeeming university years with the objective of anticipating retirement leads to a reduction in pension adequacy, as measured by the replacement ratios, relative to the no-redemption scenarios. However, this strategy may still be attractive when non-monetary benefits — such as increased leisure time and earlier exit from the labor market — are taken into account.

By contrast, when university years are redeemed without advancing the retirement date, replacement ratios are higher than in the no-redemption case. Nonetheless, the improvement in pension adequacy remains limited, although tax savings partially offset the financial cost of redemption.

Overall, the results suggest that for individuals who do not intend to retire earlier the redemption of university years leads to increases in the NRR of approximately 2–4%, leaving room for further improvements in pension adequacy. Consequently, alternative strategies — such as participation in supplementary pension schemes or private savings — are explored in the following sections as potential means to improve retirement outcomes.

5 Alternative use of the redemption cost

In the previous section, we found out that redeeming university years without anticipating retirement yields higher NRRs than relying solely on the mandatory public pension. However, this comparison is not entirely balanced, as the redemption scenario involves a cost borne by the worker, whereas the public pension alone does not. Therefore, it remains unclear whether university years' redemption is truly advantageous.

To address this issue, the present section develops a more consistent framework for comparison. Specifically, we compare the decision to redeem university years without anticipating retirement with an alternative scenario in which the worker allocates an equivalent amount to other forms of savings or investment. In particular, we take into account the fact that university years' redemption generates tax savings that are not necessarily available under alternative investment strategies.

In this comparison, we exclude scenarios without university years' redemption and those involving redemption combined with anticipated retirement, as their inclusion would not ensure consistency due to a different payment stream in one case and a different retirement age in the other case. This approach allows us to isolate the role of the allocation choice, holding constant the timing of contributions and the retirement date. The central question can therefore be formulated as follows: *what would be the outcome if, instead of redeeming university years, the worker invested the same financial resources in alternative instruments?*

To evaluate this choice, we consider the following alternative strategies:

- investing an amount equal to the annual redemption instalment in a defined contribution (DC) pension scheme, following the same payment schedule as the redemption plan. The accrued capital at the end of the contribution period (10 years) is then converted into a deferred lifetime annuity, with payments starting at retirement;

- investing in financial markets via an ETF according to an adjusted contribution rule. Specifically, under the ETF strategy, the annual contribution is set equal to the annual redemption instalment RC^d, with $d \in \{\text{Bachelor}, \text{Master}\}$, net of the tax savings that would be generated in the same year through university years' redemption. The accumulated wealth after 10 years is then converted into a deferred lifetime annuity payable from the retirement date onward.

Figure 5 provides a schematic representation of the timing and structure of the three strategies, highlighting the accumulation phase and the subsequent conversion into retirement income.

Notice that, with both alternative strategies, the accumulated capital is annuitized rather than withdrawn as a lump sum, consistently with the aim of maximizing the total replacement ratio.

In the remainder of this section, we outline the assumptions and the stochastic models underlying the two alternative investment strategies. Building on these elements, we then compute via Monte Carlo simulations the resulting retirement outcomes in terms of net replacement ratios, and we evaluate the associated tax advantages.

5.1 Tax considerations and calculation of net annual benefits of the alternative strategies

Before proceeding with the analysis, it is necessary to clarify the fiscal treatment of the two alternative investment strategies considered for allocating the redemption cost: (i) participation in a DC pension

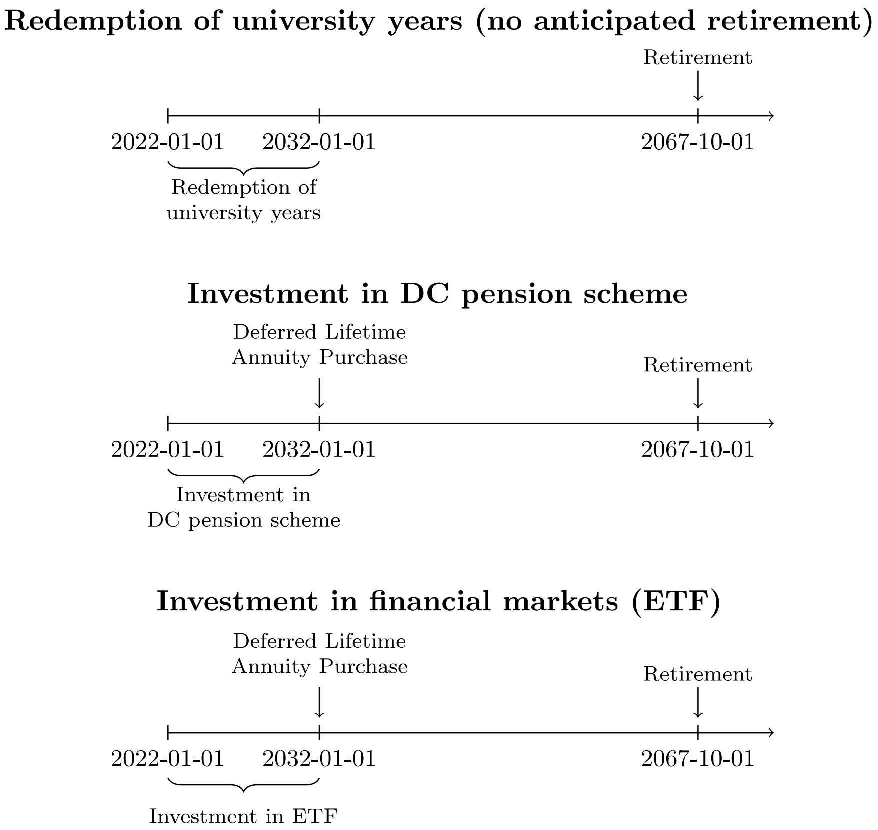

Figure 5: Timeline representation of the three alternative retirement strategies. The months worked in year 2021 are omitted for simplicity.

scheme, and (ii) direct investment in ETFs. These strategies differ along three main dimensions: contributions' tax deductibility, taxation of returns, and taxation of retirement benefits. For simplicity, we do not consider taxation arising from dividends, non-capital-income, as well as transaction costs and management fees.

5.1.1 DC pension schemes

The investment in a DC pension scheme benefits from favorable tax provisions at all stages, under an E-T-T (Exempt-Taxed-Taxed) logic: contributions are deductible from taxable income (within statutory limits); investment returns are taxed annually, at preferential rates relative to standard financial income; pension benefits are taxed upon withdrawal at retirement, at reduced rates compared to the ordinary personal income tax schedule.[12]

Deduction of Pension Fund Contributions. Similarly to INPS payments for the redemption of university years, contributions to individual pension funds are deductible from taxable income up to €5,300.00 annually (threshold valid from 2026). This deduction reduces IRPEF taxable income and therefore generates immediate tax savings. By construction, in the present setting these tax savings coincide to those obtainable through university year redemption, since the annual contributions to the fund match the annual cost of redemption and do not exceed the annual limit. Therefore, the total tax savings over the 10 years considered are €5,740.11 for Bachelor graduate workers and €11,364.26 for Master graduate workers, respectively.

Taxation of Pension Fund Returns. Contributions to the DC pension scheme are invested in financial markets according to the fund's investment policy and generate taxable returns. However, pension funds benefit from preferential taxation: returns accrued by the fund are generally taxed at 20%, compared to the standard 26% applied to most financial investments. Moreover, returns attributable to investments in Italian government bonds and equivalent securities issued by "white list" countries enter the taxable base only for 62.5% of their amount, implying an effective tax rate of 12.5% on that component (i.e., $20\% \cdot 62.5\% = 12.5\%$).

In the model, taxation is incorporated on an annual basis. Let the annual gain be defined as

$$\text{gain}(t) = X(t) - X^*(t-1) - c(t), \qquad t = 1, \ldots, T, \tag{8}$$

[12] For an overview of the Italian tax treatment of DC pension schemes, see *DC Pension Design: the Experience in Italy*, EIOPA 2023 DC Pensions Roundtable. Available at: https://www.eiopa.europa.eu/document/download/6e0de349-2985-4c2a-aeac-469973b7600e_en.

where $X(t)$ denotes the fund value at the end of year t, $X^*(t-1)$ is the tax-adjusted value carried over from the previous year, and $c(t)$ is the contribution made during year t. This quantity can be decomposed as

$$\text{gain}(t) = \text{gain}_s(t) + \text{gain}_{rf}(t), \qquad t = 1, \ldots, T, \tag{9}$$

where $\text{gain}_{rf}(t)$ denotes the component attributable to investments in government bonds and equivalent securities (which we assume to be risk-free assets), and $\text{gain}_s(t)$ the residual component.

The gross tax liability is computed by applying the 20% rate to the corresponding taxable base, i.e.

$$\text{tax}^{\text{gross}}(t) = 0.20\left[\text{gain}_s(t) + 0.625\,\text{gain}_{rf}(t)\right], \qquad t = 1, ..., T. \tag{10}$$

The taxable base may be negative, in which case it generates a tax credit rather than a tax liability. Let $TC(t)$ denote the cumulative tax credits available at the end of year t, evolving according to

$$TC(t) = \max\left\{TC(t-1) - \text{tax}^{\text{gross}}(t),\ 0\right\}, \qquad t = 1, \ldots, T. \tag{11}$$

The tax effectively paid in year t is then given by

$$\text{tax}(t) = \max\left\{0,\ \text{tax}^{\text{gross}}(t) - TC(t-1)\right\}, \qquad t = 1, ..., T. \tag{12}$$

Accordingly, the tax-adjusted fund value evolves as

$$X^*(t) = X(t) - \text{tax}(t), \qquad t = 1, ..., T. \tag{13}$$

Taxation of Final Pension Benefits. Upon retirement, benefits paid by the DC pension scheme are subject to a substitute tax applied only to the portion of accumulated wealth corresponding to previously deducted contributions, which have not been taxed during the accumulation phase. The applicable tax rate is $\phi = 15\%$, lower than the standard IRPEF rates (starting at 23%). This rate is reduced by 0.3 % for each year of participation beyond the fifteenth, down to a minimum of 9% (which can be achieved after a participation of at least 35 years).

After the T-year contribution period, a deferred annuity is purchased, with a deferment period of m years. The net annual pension benefit received at retirement age x is therefore given by

$$\text{Net Annual Benefit}_{\text{DC}} = \frac{X^*(T) - \phi \cdot TRC}{{}_{m|}a_{x-m}},$$

where ${}_{m|}a_{x-m}$ is the cost of a unitary deferred lifetime annuity with deferment period m years issued to an individual aged $x - m$.

In the setting considered in this section, participation in the DC pension scheme spans $T = 10$ years, while $x = 68$ for the Bachelor graduate worker and $x = 70$ for the Master graduate worker. Retirement occurs after $m = 35$ years. Hence, the applicable tax rate remains $\phi = 15\%$, as the reduction applies only after fifteen years of participation. The resulting net annual pension benefits for Bachelor and Master graduates are given by

$$\text{Net Annual Benefit}_{\text{DC}}^{d} = \begin{cases} \dfrac{X^{*d}(10) - 0.15 \cdot TRC^{d}}{{}_{35|}a_{33}}, & d = \text{Bachelor}, \\ \dfrac{X^{*d}(10) - 0.15 \cdot TRC^{d}}{{}_{35|}a_{35}}, & d = \text{Master}. \end{cases} \tag{14}$$

5.1.2 Financial market investments: ETF

In contrast to pension funds, investments in ETFs are not subject to a favorable E-T-T taxation regime. In particular, contributions are not tax-deductible and, therefore, do not generate any intermediate tax savings.

Taxation on Gains. Taxation occurs only upon liquidation. Specifically, capital gains are taxed at a flat rate of 26%, which is less favorable than the 20% rate applied to pension fund returns.

Let T denote the investment horizon. Recalling that, within this alternative strategy, the worker invests the total redemption cost TRC minus the sum of the tax savings $TS(t)$ generated each year t by the other strategies, the post-tax accumulated capital is given by

$$E^*(T) = E(T) - 0.26 \cdot \max\left\{ E(T) - \left(TRC - \sum_{t=1}^{T} TS(t) \right), 0 \right\},$$

where $E(T)$ denotes the terminal value at time T of the investment in an ETF. Similarly to the DC pension fund, the post-tax accumulated capital $E^*(T)$ is then used to buy a deferred annuity with deferment period m years. As a result, the net annual supplementary pension benefit is given by:

$$\text{Net Annual Benefit}_{\text{ETF}} = \frac{E^*(T)}{{}_{m|}a_{x-m}}.$$

As before, in this section the accumulation phase lasts $T = 10$ years and the retirement phase begins after a deferment period of $m = 35$ years. Hence, the net annual supplementary pension benefit is given by:

$$\text{Net Annual Benefit}^{d}_{\text{ETF}} = \begin{cases} \dfrac{E^{*d}(10)}{{}_{35|}a_{33}}, & d = \text{Bachelor}, \\ \dfrac{E^{*d}(10)}{{}_{35|}a_{35}}, & d = \text{Master}. \end{cases} \tag{15}$$

5.2 Assessing the impact of investing in a DC pension fund on retirement outcomes

In this section, we consider a worker who invests the total redemption cost in a DC pension fund, rather than redeeming university years. We assume that contributions are made exclusively by the employee, with no employer participation, and that the accumulated capital is used to purchase a deferred lifetime annuity, providing pension benefits from the retirement date onward.

From an investment perspective, lifecycle considerations play a central role in DC pension design. Standard practice suggests that younger individuals should allocate a larger share of their portfolio to higher-return, higher-risk assets (such as equities), while gradually shifting towards safer assets as retirement approaches, in order to reduce exposure to market downturns close to annuitization. Consistent with this principle, we assume that the pension fund follows a *deterministic lifestyle strategy* (Cairns, Blake, and Dowd, 2006), under which contributions are initially fully invested in equities and, starting ten years before retirement, are progressively reallocated into bonds. By the time of retirement, the portfolio would be entirely invested in low-risk assets, which are then used to purchase a deferred lifetime annuity. This approach is widely adopted in practice due to its simplicity, transparency, and ease of implementation.

5.2.1 The Accumulation Model for the DC pension fund

We introduce a standard general continuous-time framework for the accumulation phase of the DC pension fund. We assume the following:

1. The financial market is described by a Black–Scholes setting with a risk-free asset and a risky asset. Therefore the price of the risk-free asset $G(t)$ evolves according to:

$$dG(t) = rG(t)\,dt,$$

where $r \geq 0$ is the constant risk-free rate, while the price of the risky asset $S(t)$ follows a geometric Brownian motion:

$$dS(t) = \lambda S(t)\,dt + \sigma S(t)\,dW(t),$$

with drift $\lambda > r$ and volatility $\sigma > 0$ and $W(t)$ being a standard Brownian motion.

2. The $d \in \{\text{Bachelor}, \text{Master}\}$ worker enters the fund at time $t = 0$, aged χ^d, with initial wealth $x_0^d \geq 0$, contributes for $T^d \leq \tau^d$ years, and retires at age $\chi^d + \tau^d$.

3. Annual contributions to the DC pension fund $c^d(t)$ are fixed in monetary terms and equal — over the first ten years of the accumulation period — to the annual redemption cost RC^d, i.e.

$$c^d(t) = RC^d, \qquad d \in \{\text{Bachelor}, \text{Master}\}.$$

4. In the period $[0, T^d]$, the value of the fund $X^d(t)$, with $d \in \{\text{Bachelor}, \text{Master}\}$, evolves according to the following stochastic differential equation (SDE):

$$\begin{cases} dX^d(t) = \Big\{X^d(t)\big[(1-\theta^d(t))(\lambda - r) + r\big] + c^d(t)\Big\}dt + X^d(t)(1-\theta^d(t))\sigma\, dW(t), \\ X^d(0) = x_0^d, \end{cases} \tag{16}$$

where $\theta^d(t)$ is the share invested in the risk-free asset. It must be noted that these dynamics describe the *gross evolution* of the fund within each year. At the end of each period, taxes on accrued returns are applied as described in Section 5.1, yielding the after-tax value $X^*(t)$ that is carried forward.

5. The portfolio allocation follows a deterministic lifestyle rule, under which the share invested in the risk-free asset gradually increases during the last ten years before retirement. Let $t_s^d = \tau^d - 10$ denote the switching time at which this gradual reallocation begins. Therefore $\theta^d(t)$ is given by:

$$\theta^d(t) = \begin{cases} 0, & t < t_s^d, \\ \dfrac{t - t_s^d}{10}, & t \geq t_s^d, \end{cases} \qquad d \in \{\text{Bachelor}, \text{Master}\}. \tag{17}$$

6. At the end of the accumulation phase, the amount $X^{*d}(T^d)$ is converted into a deferred lifetime annuity according to (14).

In the setting considered in this section, we have $T^d = 10$ and $\tau^d = 45$ years for both $d \in \{\text{Bachelor}, \text{Master}\}$. Hence $t_s^d = \tau^d - 10 = 35$, so that for all $t \in [0, 10]$ one has $\theta^d(t) = 0$. In other words, throughout the accumulation phase, contributions are invested entirely in the equity component of the pension fund.

Remark 1. *The framework described in points 1–6 above is the stochastic model for evaluating the DC pension investment strategies considered both in the present section and, with proper adjustments, in Section 6.*

5.2.2 Simulation assumptions and outcomes for the DC pension fund

The Monte Carlo simulations are conducted under the following set of assumptions:

- **initial fund:** $x_0^{\text{Bachelor}} = x_0^{\text{Master}} = 0$;
- **financial market parameters:** $r = 2\%$, $\lambda = 4.2\%$, and $\sigma = 6.6\%$, implying a market price of risk $\beta = \frac{\lambda - r}{\sigma} = \frac{1}{3}$;
- **investment horizon:** $T^{\text{Bachelor}} = T^{\text{Master}} = 10$ years;
- **retirement age:** $\chi^{\text{Bachelor}} + \tau^{\text{Bachelor}} = 68$ for Bachelor's degree holders and $\chi^{\text{Master}} + \tau^{\text{Master}} = 70$ for Master's degree holders;
- **annuity factors:** ${}_{35|}a_{33} = 14.55$ and ${}_{35|}a_{35} = 13.51$, computed using a discount rate $i = 1\%$ and mortality table A62D.[13]

Given these assumptions, we perform 10,000 Monte Carlo simulations of the risky asset and the fund evolution for each representative worker, using a monthly discretization scheme. Figure 6 reports the distribution of accumulated fund values at the end of the ten-year investment horizon, prior to the application of taxes on pension benefits.

We see that Master's degree holders systematically accumulate higher levels of wealth than Bachelor's degree holders. This result is driven by the higher total contributions invested in the fund, which mirror the larger redemption cost associated with a longer study period (five years instead of three) and the larger wage. At the same time, the greater level of contributions also translates into higher absolute variability in final outcomes.

To assess the implications for retirement adequacy, we compute the annual pension benefit generated by the accumulated fund. Specifically, applying (14) to the average simulated values of $X^{*d}(10)$, with

[13] The mortality tables A62D and A62I are standard references in the Italian annuity market for deferred and immediate lifetime annuities, respectively. They reflect the characteristics of individuals who are more likely to purchase lifetime annuities — typically those in better health and with higher expected longevity. Cohort-specific age adjustments are applied to capture the characteristics of the relevant cohorts (individuals born in 1999 for Bachelor's graduates and 1997 for Master's graduates). The tables are available at: `https://ordineattuari.it/media/u2ihaw3j/serie_a62_final.xlsx`.

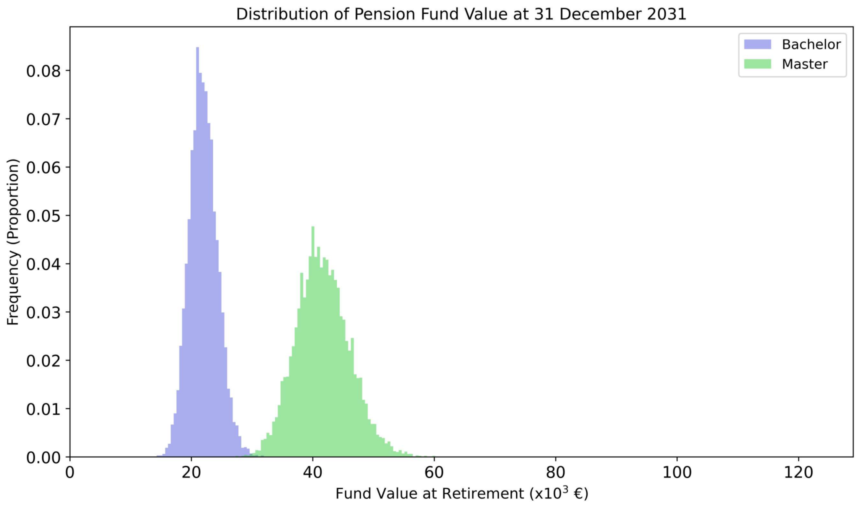

Figure 6: Distribution of accumulated pension fund values at the end of the investment horizon

$d \in \{\text{Bachelor}, \text{Master}\}$, yields:

$$\text{Net Annual Benefit}_{\text{DC}}^{\text{Bachelor}} = €1,332.91, \qquad \text{Net Annual Benefit}_{\text{DC}}^{\text{Master}} = €2,704.36. \tag{18}$$

We then evaluate the overall retirement outcome by combining the supplementary pension income with public pension benefits. In particular, the NRR is computed as the ratio between total net pension income — given by the sum of (i) net public pension benefits without redemption (see Scenarios I and IV in Table 5) and (ii) the net annual benefit from the DC pension fund as in (18) — and the net labor income immediately prior to retirement (see Scenarios I and IV in Table 5).

The resulting NRRs are:

$$NRR_{\text{DC}}^{\text{Bachelor}} = 63.54\%, \qquad NRR_{\text{DC}}^{\text{Master}} = 72.09\%. \tag{19}$$

These results quantify the extent to which investing an amount equal to the total redemption cost in a DC pension fund can enhance retirement income, relative to relying exclusively on the public pension system.

A comparison between these outcomes, the redemption (without anticipated retirement) scenarios reported in Table 5, and the alternative financial market strategy is provided in Section 5.4.

5.3 Assessing the impact of investing in an ETF on retirement outcomes

In this section, we consider a worker who invests an amount equivalent to the total redemption cost in an ETF-based accumulation plan, rather than redeeming university years or investing in a DC pension fund. Due to the fact that the investment in the DC pension fund and the university years' redemption give rise to tax savings — while the ETF investment does not — in order to assure a consistent comparison among these alternatives we assume that the amount invested in the ETF is equal to the total redemption cost minus the tax savings.

We consider a passive investment strategy implemented over the period 2022–32. Specifically, graduate workers invest in an ETF designed to replicate the performance of the FTSE MIB index. At the end of the ten-year accumulation phase, the total wealth is converted into a deferred lifetime annuity, providing retirement income starting in 2067.

5.3.1 The Accumulation Model for the ETF

We formalize the dynamics of the ETF-based accumulation plan as follows.

1. The price of the reference stock market index follows a Geometric Brownian Motion (GBM) with constant parameters. Let $F(t)$ denote the index level at time t. Its dynamics are given by:

$$dF(t) = \mu F(t)\, dt + \rho F(t)\, dW(t),$$

   where $\mu > 0$ is the drift, $\rho > 0$ is the volatility, and $W(t)$ is a standard Brownian motion.

2. The $d \in \{\text{Bachelor}, \text{Master}\}$ worker enters the fund at time $t = 0$, aged χ^d, with initial wealth $e_0^d \geq 0$, contributes for $T \leq \tau$ years, and retires at age $\chi^d + \tau$.

3. The evolution of the worker's accumulated wealth, denoted by $E(t)$ is described by:

$$\begin{cases} dE^d(t) = [\mu E^d(t) + c^d(t)]\, dt + \rho E^d(t)\, dW(t) \\ E^d(0) = e_0^d \end{cases}, \qquad d \in \{\text{Bachelor}, \text{Master}\} \tag{20}$$

   with $c^d(t)$ representing the contribution flow of the d worker. More precisely, $c^d(t)$ is defined as the difference between the annual redemption installment RC^d and the tax savings that would be obtained, in the same year, under the redemption option and the DC pension fund investment:

$$c^d(t) = RC^d - TS^d(t), \qquad d \in \{\text{Bachelor}, \text{Master}\}. \tag{21}$$

4. At the end of the $[0, T]$ accumulation phase, the capital $E(T)$ is converted into a deferred lifetime annuity according to (15), taking into account taxation on accrued returns.

In the setting considered in this section, we have $T = 10$ and $\tau = 45$ years for both workers.

5.3.2 Simulation assumptions and outcomes for the ETF

The simulations are conducted under the following assumptions:

- **initial wealth:** $e_0^{\text{Bachelor}} = e_0^{\text{Master}} = 0$;
- **financial market parameters:** the parameters are calibrated using historical data from Yahoo Finance over the period 2011.01.01–2025.12.31. In particular, the volatility is estimated as $\rho = 23.29\%$, corresponding to the annualized standard deviation of log-returns of the FTSE MIB. Let $\hat{m} = 5.22\%$ denote the annualized mean of log-returns. The drift of the GBM is then given by

$$\mu = \hat{m} + \frac{1}{2}\sigma^2 = 7.93\%,$$

  yielding a Sharpe ratio of approximately $\beta = \frac{\mu - r}{\rho} = \frac{5.93\%}{23.29\%} \approx 0.25$ (assuming $r = 2\%$ as in Section 5.2.2), which ensures consistency between the GBM specification and the empirical log-return dynamics;
- **investment horizon**, **retirement age** and **annuity pricing** are set as in Section 5.2.2.

Figure 7 reports the distribution of terminal wealth at the end of the ten-year investment horizon, prior to the application of taxation on capital gains.

The results highlight a substantially higher degree of dispersion compared to the analogous outcomes for the DC pension fund (Figure 6). This is directly attributable to the higher volatility of the underlying financial asset. At the same time, the role of contributions remains evident: higher contributions for Master's graduates translate into higher expected wealth, although accompanied by greater absolute variability.

Applying (15) to the average simulated values of $E^d(10)$, with $d \in \{\text{Bachelor}, \text{Master}\}$, yields:

$$\text{Net Annual Benefit}_{\text{ETF}}^{\text{Bachelor}} = €1,235.69, \qquad \text{Net Annual Benefit}_{\text{ETF}}^{\text{Master}} = €2,461.86. \tag{22}$$

We then evaluate the overall retirement outcome by combining the supplementary pension income with public pension benefits. In particular, the NRR is computed as the ratio between total net pension

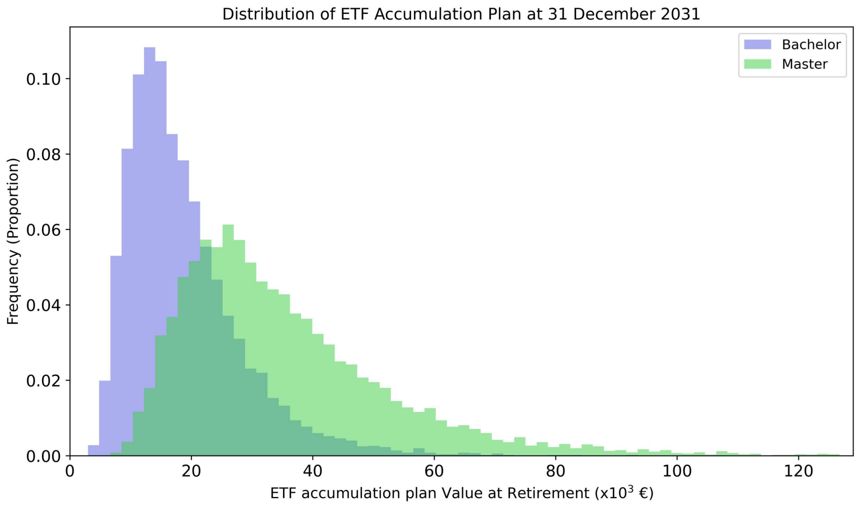

Figure 7: Distribution of ETF-based accumulation plan values at maturity

income — given by the sum of (i) net public pension benefits without redemption (see Scenarios I and IV in Table 5) and (ii) the net annual benefit from the ETF as in (22) — and the net labor income immediately prior to retirement (see Scenarios I and IV in Table 5).

The resulting NRRs are:

$$NRR_{\text{ETF}}^{\text{Bachelor}} = 63.24\%, \qquad NRR_{\text{ETF}}^{\text{Master}} = 71.40\%.$$

Also in this case, investing an amount equivalent to the redemption cost in an ETF can enhance retirement income, relative to relying exclusively on the public pension system.

5.4 Comparison of alternative retirement strategies

Building on the results obtained in Sections 4 and 5.2–5.3, we are finally able to address the following question: *"What are the retirement outcomes if, instead of redeeming university years, the worker allocates the equivalent cost to alternative investment strategies?"*.

To ensure a meaningful comparison, the ETF-based strategy has been defined using an *adjusted contribution rule*. In particular, the annual investment has been set equal to the redemption installment RC^d, net of the tax savings that would be generated under university years' redemption or participation in a DC pension fund. This adjustment places all strategies on a comparable basis in terms of net financial effort of the worker.

We therefore compare the NRRs associated with (i) university years' redemption without anticipated retirement (Scenarios III and VI of Section 4), (ii) participation in a DC pension fund, and (iii) investment in an ETF-based accumulation plan. The results, together with the tax savings accrued during the accumulation phase with redemption and DC pension fund participation and the reduced contributions savings in the ETF investment, are summarized in Table 6.

	University years' redemption		**DC pension fund**		**ETF-based accumulation plan**	
Degree	**Bachelor**	**Master**	**Bachelor**	**Master**	**Bachelor**	**Master**
NRR	61.72 %	67.91 %	63.54 %	72.09 %	63.24 %	71.40 %
Tax savings	€ 5,740.11	€ 11,364.26	€ 5,740.11	€ 11,364.26	—	—
Reduced contribution	—	—	—	—	€ 5,740.11	€ 11,364.26

Table 6: Comparison of average NRRs across alternative retirement strategies

The comparison yields the following insights.

- **Ranking of strategies.** Across both graduate groups, participation in a DC pension fund yields the highest NRRs. The ETF-based strategy performs slightly worse, while university years' redemption without anticipated retirement delivers the lowest outcomes.

- **Magnitude of differences.** For Bachelor's graduates, differences remain relatively contained: NRRs range from 61.72% (redemption) to 63.54% (DC pension fund). For Master's graduates, differences are more pronounced: NRRs range from 67.91% (redemption) to 72.09% (DC pension fund), with the ETF-based strategy slightly underperforming relative to the latter. This suggests that the relative advantage of alternative investment strategies over redemption becomes more relevant at higher income levels, or a longer redeemed period.

- **Role of tax savings.** Both university years' redemption and DC pension schemes benefit from tax deductibility during the contribution phase. To account for this, the ETF strategy is constructed by reducing the invested amount by the tax savings that would arise under the alternative strategies. In other words, the ETF contribution is deliberately reduced to reflect the fact that, under the other two strategies, part of the contribution is effectively returned to the worker in the form of tax savings. It should be noted that the payment streams in the DC pension fund/redemption option and in the ETF strategy are economically equivalent, but not perfectly identical. In the case of DC pension funds and university years' redemption, the associated tax savings are realized in the fiscal year following the contribution payment, whereas in the ETF strategy the contribution is reduced immediately to reflect the absence of such tax advantages.

- **Higher growth does not translate into higher outcomes.** A notable result is that the ETF-based strategy delivers slightly lower outcomes than the DC pension fund, despite being characterized by a higher expected growth rate ($\mu > \lambda$). The reasons are twofold: on the one side, the ETF strategy is financed by lower effective contributions due to the lack of the tax savings, that act as an indirect contribution in the case of the DC pension investment; on the other side, a less favorable tax treatment for the ETF, with capital gains being taxed more heavily at retirement. Further theoretical insight into the comparison between the final accumulated wealth — both before and after taxation — under the DC pension fund and the ETF investment strategies is provided in Section 5.5.

It is also important to note that:

- the results for the university years' redemption strategy are obtained under a prudential assumption on the revaluation of notional contributions, namely that future revaluation coefficients are set to their minimum level (null GDP growth). Incorporating more realistic projections of nominal GDP growth would lead to more favorable outcomes for the redemption option. This aspect will be explored in detail in Section 7;
- the comparison presented in this section is conducted over an investment horizon aligned with the ten-year period over which the redemption cost is paid. This restricts the analysis to a relatively short contribution phase and does not fully capture the effects of long-term participation in alternative strategies. Section 6 relaxes this restriction and extends the analysis to strategies defined over the entire working life.

5.5 Theoretical considerations on the dynamics of the alternative strategies

The results in Section 5.4 show that participation in a DC pension fund yields slightly higher replacement ratios than investment in an ETF-based accumulation plan. This section provides an analytical explanation of these findings by comparing the expected accumulated wealth generated by the two strategies.

For conciseness, we report here only the main analytical results underlying the numerical outcomes, while the complete mathematical derivations are provided in Appendix C.

It can be shown that, given the SDE for the wealth dynamics in the DC pension scheme (16), with $X^d(0) = 0$, $\theta^d(t) = 0$, and $c^d(t) = RC^d$, for $d \in \{\text{Bachelor}, \text{Master}\}$, the expected terminal wealth accumulated in the DC pension fund — temporarily abstracting from the annual taxation of investment returns — is

$$\mathbb{E}[X^d(T)] = RC^d \frac{e^{\lambda T} - 1}{\lambda}, \qquad d \in \{\text{Bachelor}, \text{Master}\}. \tag{23}$$

Similarly, given the SDE for the wealth dynamics in the ETF-based accumulation plan (20), with $E^d(0) = 0$ and $c^d(t) = RC^d - TS^d(t)$, the expected terminal wealth accumulated through the ETF strategy is

$$\mathbb{E}[E^d(T)] = RC^d \frac{e^{\mu T} - 1}{\mu} - \sum_{t=1}^{T} TS^d(t)\, e^{\mu(T-t)} \frac{e^{\mu} - 1}{\mu}, \qquad d \in \{\text{Bachelor}, \text{Master}\}.$$

The comparison between the two strategies must be conducted in terms of *net terminal wealth*, taking into account the different fiscal treatments at retirement. For the ETF strategy, capital gains are taxed at a rate of 26%, so that

$$\mathbb{E}[E^{*d}(T)] = \mathbb{E}[E^d(T)] - 0.26 \cdot \max\left\{\mathbb{E}[E^d(T)] - \left(TRC^d - \sum_{t=1}^{10} TS^d(t)\right), 0\right\}, \tag{24}$$

for $d \in \{\text{Bachelor}, \text{Master}\}$.

For the DC pension fund, taxation on capital returns is applied annually during the accumulation phase. This makes the wealth dynamics path-dependent and reduces the effective growth rate. Denoting by λ^{net} the implied after-tax growth rate, one has $\lambda^{net} \leq \lambda$. Under our simulation assumptions, we find $\lambda^{net} \approx 3.24\%$, i.e.

$$\mathbb{E}[X^{*d}(T)] = RC^d \frac{e^{\lambda^{net} T} - 1}{\lambda^{net}}.$$

DC pension benefits are then taxed at the more favorable rate of 15%, yielding the following post-tax value:

$$\mathbb{E}[X^{*d}(T)] - 0.15 \cdot TRC^d. \tag{25}$$

The relevant comparison is therefore between the two post-tax quantities (29) and (30). The simulation results clearly illustrate the quantitative impact of these adjustments. For Bachelor's graduates,

$$\mathbb{E}[X^{*\text{Bachelor}}(T)] = 22,222.72, \qquad \mathbb{E}[E^{\text{Bachelor}}(T)] = 19,707.39,$$

so that the DC pension fund already dominates before taxation at retirement. After taxation on retirement benefits, we have

$$\mathbb{E}[X^{*\text{Bachelor}}(T)] - 0.15\, TRC^{\text{Bachelor}} = 19,399.54, \qquad \mathbb{E}[E^{*\text{Bachelor}}(T)] = 17,984.55,$$

so that the gap, while still in favor of the DC pension fund, becomes smaller. A similar pattern emerges for Master's graduates:

$$\mathbb{E}[X^{*\text{Master}}(T)] = 41,866.96, \qquad \mathbb{E}[E^{\text{Master}}(T)] = 36,495.04,$$

and, after taxation on retirement benefits,

$$\mathbb{E}[X^{*\text{Master}}(T)] - 0.15\,TRC^{\text{Master}} = 36,548.17, \qquad \mathbb{E}[E^{*\text{Master}}(T)] = 33,270.86,$$

so that the DC pension fund dominates also in net terms.

It should be noted that, even before taxation, the accumulated wealth in the DC pension fund exceeds that obtained under the ETF strategy. This difference arises because the comparison is conducted under equal financial effort for the worker, rather than under equal invested amounts. In the case of the DC pension fund, contributions are tax deductible, so that part of the contribution is effectively financed by the Italian State through the associated tax savings. By contrast, ETF investments do not benefit from any deductibility. Because we want to ensure comparability in terms of effective payments done by the two individuals, we have the unavoidable consequence that the effective cash flow invested in the ETF is approximately 30% lower than the amount invested in the DC pension fund. This is the main reason why the accumulated wealth of the ETF is lower than that of the DC pension fund before taxation on retirement benefits.

After taxation at retirement, the accumulated wealth under the DC pension fund remains higher than the one obtained through the ETF strategy. Taxation on retirement benefits, although less favorable for the ETF strategy, does not drive the ranking of outcomes. Rather, it almost compensates the difference between the two strategies, as the higher tax rate is applied to a lower accumulated amount. Therefore, the DC pension fund dominates the investment in the ETF also in terms of NRRs, but only to a small extent.

6 Investing over the whole working life

In Section 4, we compared the redemption option against the no redemption with and without anticipated retirement, and the need for a coherent comparison between redemption and alternative investment strategies emerged. This comparison has been thoroughly addressed in Section 5. In turn, the ten-year investment horizon considered in Section 5 appears relatively short, particularly in light of the increasing pressure on public pension systems and the corresponding need for more robust retirement planning.

This motivates the analysis of strategies that extend over the entire working life, thereby providing a more realistic and comprehensive framework for long-term pension accumulation. Within this setting, individuals face a fundamental intertemporal choice early in their careers: whether to allocate resources to the redemption of university years and subsequently complement their retirement savings through a DC pension scheme, or to forgo redemption altogether and rely exclusively on private pension accumulation.

6.1 Assumptions

We introduce and compare retirement investment strategies that span the full working life. In particular, graduate workers are assumed to choose among three alternative options, which differ in both the timing and the allocation of contributions:

- **Option A (Redemption, subsequent DC pension fund investment, anticipated retirement).** Graduate workers redeem their university years over the first ten years of their careers. Upon completion of the redemption period, they allocate each year an amount equal to half of the annual redemption cost to a DC pension scheme, continuing until the anticipated retirement date R^{ant} (i.e., 2062 for Master's graduates and 2064 for Bachelor's graduates). At R^{ant}, the accumulated wealth is converted into an immediate lifetime annuity.

- **Option A Bis (Redemption, subsequent DC pension fund investment, standard retirement).** As in Option A, graduate workers redeem their university years during the first ten years of their careers and subsequently invest, on an annual basis, half of the redemption cost in a DC pension scheme. However, in this case, retirement occurs at the statutory date $R = 2067$. The accumulated wealth at R^{ant} is therefore converted into a deferred lifetime annuity, with payments starting at R.

- **Option B (No redemption, only DC pension fund investment, standard retirement).** Graduate workers do not redeem their university years and instead allocate the same financial resources entirely to a DC pension scheme, as in Options A and A Bis. Contributions replicate the redemption payment schedule over the first ten years and are then reduced to half of that amount until R^{ant}. As in Option A Bis, the accumulated wealth is then converted into a deferred lifetime annuity with payments starting at the statutory retirement date $R = 2067$.

To provide a clear representation of the timing and structure of these strategies, Figure 8 illustrates the dynamics of contributions and retirement decisions over the accumulation period.

In the remainder of this section, we outline the modeling assumptions underlying the three alternative investment strategies, where different from what we already presented in the previous sections.

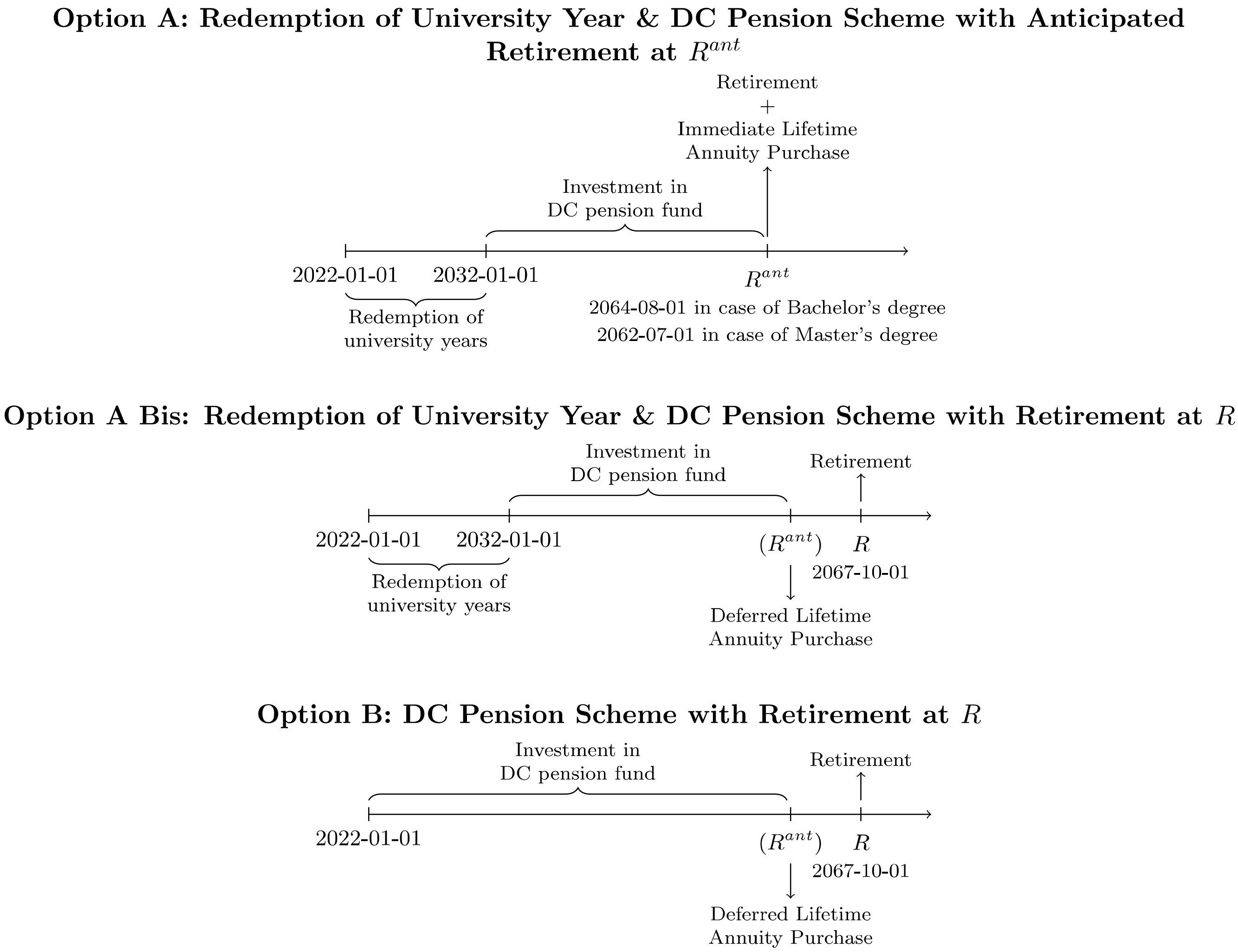

Figure 8: Timeline representation of the three alternative retirement strategies. The months worked in year 2021 are omitted for simplicity.

6.2 Tax considerations and calculation of the net annual benefits

The tax treatment of investments in a DC pension scheme has been described in detail in Section 5.1. Accordingly, Equations (8)–(13) continue to apply. In the present setting, differences across the three options arise only in terms of (i) the length of participation in the pension scheme, (ii) the timing of annuitization, and (iii) the applicable tax rate on pension benefits.

Taxation of pension benefits. Recalling the setting of Section 5.2.1, let T^d be the contribution period in the DC pension scheme for the $d \in \{\text{Bachelor}, \text{Master}\}$ worker. Let ϕ^d denote the tax rate applied to pension benefits for the d worker. As discussed in Section 5.1, this rate depends on the number of years of participation in the pension scheme T^d and is given by

$$\phi^d = \max\left\{0.15 - 0.003 \cdot (T^d - 15),\, 0.09\right\}.$$

Under the three options considered, the length of participation is:

$$T^{\text{Bachelor}} = \begin{cases} 32, & \text{Options A and A Bis,} \\ 42, & \text{Option B,} \end{cases} \qquad T^{\text{Master}} = \begin{cases} 30, & \text{Options A and A Bis,} \\ 40, & \text{Option B.} \end{cases} \tag{26}$$

This implies the following effective tax rates:

$$\phi^{\text{Bachelor}} = \begin{cases} 0.099, & \text{Options A and A Bis,} \\ 0.09, & \text{Option B,} \end{cases} \qquad \phi^{\text{Master}} = \begin{cases} 0.105, & \text{Options A and A Bis,} \\ 0.09, & \text{Option B.} \end{cases} \tag{27}$$

Net pension benefits. Following the framework described in Section 5.1, we compute the net annual pension benefit associated with each of the three options.

- **Option A (immediate annuity).** Retirement occurs at R^{ant}, and the accumulated wealth is converted into an immediate lifetime annuity at age 65. The net annual benefit provided by the DC pension fund is therefore given by

$$\text{Net Annual Benefit}_{\text{A}}^d = \begin{cases} \dfrac{X^{*d}(32) - 0.099 \cdot \frac{RC^d}{2} \cdot 32}{a_{65}}, & d = \text{Bachelor}, \\[2ex] \dfrac{X^{*d}(30) - 0.105 \cdot \frac{RC^d}{2} \cdot 30}{a_{65}}, & d = \text{Master}. \end{cases}$$

- **Option A Bis (deferred annuity).** Retirement occurs at R, and the accumulated wealth is converted into a deferred lifetime annuity at age 65, with payments starting at the statutory retirement date (after 3 years for the Bachelor graduate and after 5 years for the Master graduate). The net annual benefit provided by the DC pension fund is

$$\text{Net Annual Benefit}^d_{\text{A Bis}} = \begin{cases} \dfrac{X^{*d}(32) - 0.099 \cdot \frac{RC^d}{2} \cdot 32}{{}_{3|}a_{65}}, & d = \text{Bachelor}, \\ \dfrac{X^{*d}(30) - 0.105 \cdot \frac{RC^d}{2} \cdot 30}{{}_{5|}a_{65}}, & d = \text{Master}. \end{cases}$$

- **Option B (deferred annuity, no redemption).** Participation in the pension scheme is 10 years longer, leading to the minimum tax rate on benefits. The accumulated wealth is converted into a deferred lifetime annuity at age 65, with payments starting at the statutory retirement date (after 3 years for the Bachelor graduate and after 5 years for the Master graduate). The net annual benefit provided by the DC pension fund is

$$\text{Net Annual Benefit}^d_{\text{B}} = \begin{cases} \dfrac{X^{*d}(42) - 0.09 \cdot \left(TRC^d + \frac{RC^d}{2} \cdot 32\right)}{{}_{3|}a_{65}}, & d = \text{Bachelor}, \\ \dfrac{X^{*d}(40) - 0.09 \cdot \left(TRC^d + \frac{RC^d}{2} \cdot 30\right)}{{}_{5|}a_{65}}, & d = \text{Master}. \end{cases}$$

6.3 Simulation results

The evolution of accumulated wealth in the DC pension fund follows the model described in Section 5.2.1. Simulations are conducted under the same assumptions outlined in Section 5.2.2, with modifications reflecting the specific features of each option. In particular, application of the lifestyle strategy (17) implies that the share invested in the risk-free asset is no longer always null.

Across all options, the Monte Carlo simulation is implemented using 10,000 paths with monthly discretization. Annuities are evaluated at age 65 using the A62I/A62D mortality tables (see Footnote 13) and a discount rate $i = 1\%$. The three strategies differ in terms of investment horizon, contribution profiles, and retirement timing:

- **Option A**
  - **investment horizon:** $T^{\text{Bachelor}} = 32$ years, $T^{\text{Master}} = 30$ years;

- **contribution rule:** $c^d(t) = 0.5 \cdot RC^d(t)$;
- **switching time:** $t_s^{\text{Bachelor}} = 22$, $t_s^{\text{Master}} = 20$;
- **retirement age:** 65 for both workers;
- **annuity type:** immediate lifetime annuity ($a_{65} = 24.03$).

- **Option A Bis**
  - **investment horizon:** $T^{\text{Bachelor}} = 32$ years, $T^{\text{Master}} = 30$ years;
  - **contribution rule:** $c^d(t) = 0.5 \cdot RC^d(t)$;
  - **switching time:** $t_s^{\text{Bachelor}} = t_s^{\text{Master}} = 25$;
  - **retirement age:** 68 (Bachelor) and 70 (Master);
  - **annuity type:** deferred lifetime annuity (${}_{3|}a_{65} = 23.09$ for Bachelor, ${}_{5|}a_{65} = 21.15$ for Master).

- **Option B**
  - **investment horizon:** $T^{\text{Bachelor}} = 42$ years, $T^{\text{Master}} = 40$ years;
  - **contribution rule:**

$$c^d(t) = \begin{cases} RC^d(t), & t \leq 10, \\ 0.5 \cdot RC^d(t), & t > 10, \end{cases} \qquad d \in \{\text{Bachelor}, \text{Master}\};$$

  - **switching time:** $t_s^{\text{Bachelor}} = t_s^{\text{Master}} = 35$;
  - **retirement age** and **annuity type**: as in Option A Bis.

Given these assumptions, the simulations provide the distribution of accumulated wealth and, consequently, the corresponding net annual pension benefits for each option. We focus on the average outcomes across simulations. To assess the adequacy of each strategy, we compute the associated NRRs. The results, together with the tax savings accrued during the accumulation phase, are reported in Table 7.

Since all three strategies are constructed to involve the same total monetary effort and generate essentially identical tax savings during the accumulation phase, differences in outcomes are entirely driven by the timing of retirement and the length of the investment horizon (26), coupled with the different taxation (27) at retirement.

Two main patterns emerge.

	Option A		Option A Bis		Option B	
Degree	**Bachelor**	**Master**	**Bachelor**	**Master**	**Bachelor**	**Master**
NRR	59.63%	62.39%	68.46%	79.56%	74.53%	91.11%
Tax savings	€ 19,217.46	€ 36,935.57	€ 19,239.67	€ 36,836.07	€ 19,239.67	€ 36,836.07

Table 7: Comparison of average NRRs across alternative whole-working-life retirement strategies

- **Anticipated retirement entails a substantial reduction in NRR.** Option A, which allows retirement at age 65, yields significantly lower NRRs compared to the other strategies. Specifically, NRRs amount to 59.63% for Bachelor's graduates and 62.39% for Master's graduates. In contrast, delaying retirement to the statutory age (Options A Bis and B) leads to markedly higher replacement ratios, namely about 68–75% for the Bachelor's and 80–91% for the Master's graduates. Quantitatively, under the redemption option moving from anticipated retirement (Option A) to standard retirement (Option A Bis) increases the NRR by 8.8 percentage points for Bachelor's graduates and more than 17 percentage points for Master's graduates. This highlights the dominant role of the more favorable annuity conversion.

- **Longer contribution horizons to the DC pension fund dominate redemption effects.** Among the strategies that do not involve anticipated retirement, Option B consistently outperforms Option A Bis. For Bachelor's graduates, the NRR increases from 68.46% to 74.53%, while for Master's graduates it rises from 79.56% to 91.11%. This result reflects the longer DC pension fund investment horizon in Option B, which allows for greater capital accumulation and benefits from a more favorable tax rate on pension benefits. The advantage is particularly pronounced for Master's graduates, for whom the gain exceeds 11.5 percentage points.

The results highlight a clear trade-off between retirement timing and pension adequacy. Anticipated retirement (Option A) reduces both the accumulation period in the first pillar and the applicable transformation coefficients both for the public pension and for the supplementary pension benefits, leading to substantially lower pension benefits. Conversely, postponing retirement (Options A Bis and B) allows for longer compounding and more favorable actuarial conditions, leading to higher NRRs.

When focusing on strategies with retirement at the statutory age, Option B yields higher NRRs than Option A Bis. This difference does not arise from a higher overall saving effort, which is the same across the two strategies, but from a different allocation of contributions. Under Option B, all contributions are directed to the DC pension fund over a longer period, allowing a larger share of total contributions to benefit from financial market returns. By contrast, under Option A Bis, part of the resources is allocated to the redemption of university years, whose return depends on the notional revaluation mechanism of the public pension system, that is linked to the GDP growth. In addition, the longer participation in the DC pension scheme under Option B implies a more favorable tax treatment of pension benefits, as the applicable tax rate decreases with the number of years of participation. These two elements jointly contribute to remarkably higher net pension outcomes obtained under Option B.

However, this comparison should be interpreted with caution. The outcomes associated with university years' redemption are computed under a prudential assumption on the revaluation of notional contributions, namely that future revaluation rates are set to the minimum level of 0% GDP growth. This assumption tends to penalize the redemption option, as it effectively removes one of its main sources of return. Relaxing this assumption by incorporating more realistic projections of nominal GDP growth would increase the value of redeemed contributions and, consequently, improve the relative performance of strategies involving redemption. This aspect is further investigated in the next section.

7 Sensitivity analysis

This section examines the sensitivity of the results derived so far to variations in the key assumptions underlying the analysis. To this end, we focus on the main drivers of retirement outcomes. In particular, we consider alternative assumptions on the following parameters: nominal GDP growth, transformation coefficients used to compute public pension benefits, actuarial basis used to price lifetime annuities, financial market parameters governing pension fund dynamics and ETF-based accumulation plan. We evaluate how these variations affect the NRRs associated with the strategies introduced in Sections 5–6.

For expositional clarity, noting that the six strategies considered share many similarities, it is convenient to adopt a consistent terminology across sections. The first strategy presented in Section 5 (see Figure 5, top panel) is almost equal to strategy A Bis of Section 6 (see Figure 8, middle panel), with the only difference that, in the former, no investment takes place from 2032 until retirement. We therefore refer to this strategy as *Short A Bis* and call the longer one *Long A Bis*. By the same logic, the second strategy presented in Section 5 (see Figure 5, middle panel) is almost equal to strategy B of Section 6 (see Figure 8, bottom panel), with the only difference that, in the former, no investment takes place from 2032 until retirement. We therefore refer to this strategy as *Short B* and call the longer one *Long B*. To emphasize the length of the investment horizon, the third strategy of Section 5 (see Figure 5, bottom panel) will be called *Short ETF*, while the first strategy of Section 6 (see Figure 8, top panel) will be called *Long A*. To sum up, the three strategies in Figure 5 are called Short A Bis, Short B and Short ETF, while the three strategies in Figure 8 are called Long A, Long A Bis, and Long B. Clearly, among the six strategies considered, strategy Long A is the only one featuring anticipated retirement at R^{ant}, while strategy Short ETF is the only one that involves an investment in ETF; for this reason, these two strategies are not directly comparable with the others.

Table 8 reports the key parameters that are varied for the sensitivity analysis, together with the alternative values considered in each case. Each parameter is varied individually, holding all others fixed at their baseline levels, in order to isolate its impact on the resulting NRRs.

Table 8: Parameters considered in the sensitivity analysis

Driver	Parameter	Baseline	Min	Max
Nominal GDP	Growth rate	0%	1%	2%
Transformation coefficient	Bachelor, standard retirement: $\hat{\beta}_{68}(2067)$	5.378%	4.878%	5.878%
	Bachelor, anticipated retirement: $\hat{\beta}_{65}(2064)$	4.982%	4.482%	5.482%
	Master, standard retirement: $\hat{\beta}_{70}(2067)$	5.753%	5.253%	6.253%
	Master, anticipated retirement: $\hat{\beta}_{65}(2062)$	4.489%	4.489%	5.489%
Actuarial basis	Technical rate i	1%	0%	2%
Pension fund dynamics	Drift λ	4.2%	4.2%	5%
	Volatility σ	6.6%	10%	6.6%
	Sharpe Ratio	0.33	0.22	0.45
ETF	Drift μ	7.93%	7.93 %	10%
	Volatility ρ	23.29%	28.5 %	23.29%
	Sharpe Ratio	0.25	0.21	0.34

The results of the sensitivity analysis are presented in Table 9 (Short strategies in the top panel and Long strategies in the bottom panel), which highlights in bold the strategies delivering the highest NRRs in each scenario. Clearly, notice that the ETF sensitivity analysis appears only in the Short strategies panel.

We observe the following.

- **Comparison across strategies.** In almost all scenarios, the strategies delivering the highest NRRs are the ones characterized by investment in DC pension funds. In particular, in the set of the Long strategies, strategy Long B is always the best one; in the set of the Short strategies, strategy Short B is almost always the winning one, with the exceptions of strategy Short A Bis with the largest GDP growth value, and strategy Short ETF with the more optimistic ETF parameters. This confirms that the main conclusions of the baseline analysis are robust to parameter uncertainty.

- **Short vs Long strategies.** Short strategies yield NRRs that are lower than Long strategies. This is clearly due to the shorter investment horizon characterizing these strategies.

- **Main drivers of retirement income.** The sensitivity analysis highlights a clear hierarchy in the drivers of retirement outcomes. Nominal GDP growth emerges by far as the most influential factor, immediately followed by the transformation coefficients. The technical rate for annuity pricing also delivers an important impact on the NRRs, while financial market parameters, both for the DC pension fund and for the ETF, play a comparatively limited role, especially over short investment horizons.

Driver		Short A Bis		Short B		Short ETF	
		Bachelor	Master	Bachelor	Master	Bachelor	Master
Baseline		61.72%	67.91%	**63.54%**	**72.09%**	63.24%	71.40%
GDP	**Min**	73.72%	81.66%	**74.91%**	**83.92%**	74.61%	83.23%
	Max	**88.61%**	**99.21%**	88.42%	99.01%	88.12%	98.32%
Transformation	**Min**	56.60%	63.20%	**58.78%**	**67.67%**	58.48%	66.98%
coefficient	**Max**	66.65%	72.62%	**68.45%**	**76.49%**	68.15%	75.80%
i	**Min**	61.72%	67.91%	**61.95%**	**69.15%**	61.76%	68.72%
	Max	61.72%	67.91%	**66.04%**	**76.70%**	65.56%	75.59%
DC p.f.	**Min**	61.72%	67.91%	**63.51%**	**72.03%**	63.24%	71.40%
	Max	61.72%	67.91%	**63.70%**	**72.40%**	63.24%	71.40%
ETF	**Min**	61.72%	67.91%	**63.54%**	**72.09%**	63.23%	71.39%
	Max	61.72%	67.91%	63.54%	72.09%	**63.62%**	**72.11%**

Driver		Long A (Retirement at R^{ant})		Long A Bis		Long B	
		Bachelor	Master	Bachelor	Master	Bachelor	Master
Baseline		59.63%	62.39%	68.46%	79.56%	**74.53%**	**91.11%**
GDP	**Min**	70.29%	72.62%	80.46%	93.31%	**85.90%**	**102.94%**
	Max	82.07%	83.97%	95.34%	110.86%	**99.41%**	**118.03%**
Transformation	**Min**	55.11%	57.87%	63.34%	74.85%	**69.77 %**	**86.70%**
coefficient	**Max**	64.15%	67.05%	73.38%	84.27%	**79.45%**	**95.51%**
i	**Min**	58.74%	61.01%	67.33%	77.5%	**72.00%**	**86.38%**
	Max	60.59%	63.88%	69.72%	81.92%	**77.38%**	**96.53%**
DC p.f.	**Min**	59.59%	62.33%	68.38 %	79.42%	**74.33%**	**90.70%**
	Max	60.29%	63.31%	69.30%	81.00%	**77.58%**	**96.43%**

Table 9: Sensitivity analysis results. Top panel: Short strategies; bottom panel: Long strategies.

- **Role of nominal GDP.** Variations in nominal GDP growth have a remarkable impact. Moving from the baseline (0%) to the highest scenario (2%) leads to very large increases in NRRs, ranging between 22% and 32% across all profiles, and being above 25% in most cases. This reflects the central role of GDP-driven revaluation in the Notional Defined Contribution system: even modest changes in long-run growth rates significantly affect retirement income. Importantly, this effect is pervasive across all strategies, including those based on financial accumulation. Clearly, this reflects the fact that NRRs are ultimately driven by the evolution of the public pension component (affected by GDP), which remains the primary determinant of total retirement income.

- **Role of transformation coefficients.** Variations in the transformation coefficients have a sizable impact on the resulting NRRs, as they govern the conversion of accumulated lifetime contributions into pension income at retirement. Moving from the minimum transformation coefficients to the maximum ones leads to substantial increases in the NRRs, ranging around 9–10% across all profiles.

- **Role of the technical rate.** Changes in the technical rate used for annuity pricing have a moderate effect on the resulting NRRs. A higher technical rate implies more favorable annuity conversion factors, thereby increasing retirement income. Moving from the minimum scenario (0%) to the maximum scenario (2%) leads to non-negligible increases in the NRRs, ranging in general between 2–7%, except for strategy Long B (about 10% for the Master graduate), where a larger share of retirement income derives from annuitized wealth. Strategy Short A Bis is not affected by changes in the technical rate, since it does not depend on private annuity pricing.

- **Role of DC pension fund dynamics parameters.** The impact is clearly null for two out of the six strategies considered (Short A Bis and Short ETF). On the other strategies, variations in the parameters governing pension fund dynamics have a very limited impact on the resulting NRRs, with changes mainly in the order of 1%, with the only exception being strategy Long B.

- **Role of ETF parameters.** In the only strategy affected, i.e. Short ETF, the impact is limited: the resulting changes in NRRs are minimal, in the order of less than 1%. This is primarily due to the short investment horizon, which limits the compounding effect of higher expected returns.

8 Concluding remarks

This work examines the convenience of redeeming university years within the Italian pension system, with the objective of understanding whether such an instrument provides a meaningful advantage for graduate workers. To address this question, we develop a comprehensive framework combining the redemption option with public pension provision, supplementary pension schemes, and financial market investment opportunities. We focus on individuals who graduated in 2021 with either a Bachelor's or a Master's degree and entered the Italian labour market under the current NDC public pension system.

Comparing the positions of two otherwise identical graduates who choose to redeem or not redeem university years is not straightforward, as the decision can be driven by two main conflicting objectives: anticipating retirement and increasing pension benefits. The convenience of redemption depends crucially on the workers' objective, for redemption does not allow to maximize benefit adequacy and anticipate retirement simultaneously. We restrict attention to the pension adequacy objective and adopt the replacement ratio as the relevant measure in the worker's decision-making process. In particular, under identical or equivalent contribution schedules, we analyze three alternative strategies: redeeming university years, investing in a DC pension fund, or investing in an ETF-based accumulation plan. Using stochastic models for the evolution of the DC pension fund's wealth and the ETF investment, and different investment horizons, we perform Monte Carlo simulations and obtain the distribution of the corresponding NRRs. The possibility of anticipated retirement has also been explored.

Our results, whose robustness is confirmed by sensitivity analyses, consistently show that DC pension funds generally provide higher NRRs than university years' redemption and the ETF-based strategy. Such ranking is reversed in the presence of sufficiently high GDP growth, which increases the attractiveness of university years' redemption, or under more favorable ETF return assumptions, which make the ETF-based accumulation strategy slightly outperform DC pension funds. Anticipated retirement, as expected, yields lower NRRs in all scenarios. DC pension funds emerge as highly competitive due to the combination of long-term financial returns and favorable tax treatment during both the accumulation and decumulation phases.

Beyond the specific numerical results, this work makes a novel contribution by proposing a unified framework for comparing university years' redemption with alternative investment opportunities under standard economic assumptions. The analysis also emphasizes the importance of integrating the public pension mechanism, fiscal considerations and retirement timing within the same evaluation framework, rather than considering university years' redemption in isolation. By providing a structured and comprehensive comparison of the alternatives available to the graduate worker, this work aims to offer a useful reference framework in the presence of complex retirement planning decisions.

Despite providing a unified evaluation framework, this work raises more questions than it answers. The comparison exercise developed in this study is necessarily partial, as the range of possible combinations of investment opportunities, contribution patterns, and retirement horizons is simply too broad and inherently complex. For this reason, the analysis has been deliberately restricted to a set of representative accumulation strategies. Clearly, this unified valuation framework makes possible the investigation of potentially any other accumulation strategy.

A notable absence in this study is the case in which the worker places significant value on retiring earlier. If the desire to retire earlier was taken into account, a different ranking among the available options would probably emerge, with the redemption option likely becoming the dominant strategy. In turn, such a result would provide evidence that the availability of the university years' redemption option may enhance individuals' welfare during retirement and ultimately promote well-being at all ages. This outcome would offer potentially relevant policy implications for countries in which similar mechanisms are currently unavailable. This issue is left to future research.

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A The Italian pension system and the redemption mechanism

In this appendix we first review the evolution of the Italian public pension system and then present the procedure used to compute the redemption cost under the earnings-based regime, which is no longer in force.

A.1 The evolution of the Italian pension system

Until the early 1990s, pension benefits in Italy were calculated under an earning-based pay-as-you-go (PAYG) scheme, where current workers' contributions finance the pensions of current retirees. The pension benefit was then determined on the basis of contributory seniority and the wages earned during the final years of employment.[14] Broadly speaking, each year of contributions increased the future pension by about 2% of the reference wage. Therefore, a worker with 40 years of contributions could reach a replacement ratio close to 80% of the final salary.

However, from the mid-1970s onward, economic growth slowed and demographic conditions deteriorated, with declining fertility and increasing life expectancy. Both factors undermined the key conditions required for the proper functioning of the earnings-based PAYG system, which relied on intergenerational balance.

As a result, these developments placed increasing pressure on public finances. Pension expenditure became progressively unsustainable, further aggravated by increases in minimum pensions and the widespread use of so-called *baby-pensions*, that is, retirement at very young ages.

At that point, the need for cost containment and a greater system uniformity could no longer be postponed. As a result, the 1990s marked a period of substantial pension reform.

The Italian pension system underwent a profound transformation during the 1990s, through two major reforms: the Amato Reform (1992) and the Dini Reform (1995). These reforms marked the transition from an earnings-based defined benefit scheme to a notional defined contribution (NDC) framework, fundamentally reshaping the relationship between contributions, retirement age, and pension benefits.

The Amato reform (1992) represented the first substantial intervention aimed at restoring financial sustainability. While it preserved the earnings-based system, it significantly tightened eligibility conditions and reduced future pension generosity. The retirement age was gradually increased (to 60 years old for women and 65 years old for men in the private sector), the minimum contributory requirement was raised from 15 to 20 years, and pension indexation was shifted from real wages to prices (via the Consumer Price Index). The pension formula continued to apply a 2% rate of return per year of contributions, but the reference earnings period was extended, thereby reducing expected benefits, especially for younger cohorts.

[14] The reference earnings were the last monthly salary for public employees and the average of the last 5 or 10 years, respectively, for private employees and the self-employed.

The structural break occurred with the Dini Reform (1995), which introduced the NDC system. Under the NDC scheme, each worker contributes a fixed share of earnings (33% for private-sector employees) to an individual notional account. Contributions are annually capitalized at the five-year moving average of nominal GDP growth. At retirement, the accumulated notional capital is converted into an annuity through actuarial transformation coefficients that depend on retirement age and life expectancy.

The reform strengthened the actuarial link between contributions and benefits and introduced a more explicit mechanism of financial balance. Importantly, the transition was gradual. Workers were classified into three groups based on their contribution history as of 31 December 1995: (i) individuals with at least 18 years of contributions as of 31 December 1995, whose pension continued to be calculated under the earnings-based method; (ii) individuals with less than 18 years of contributions as of 31 December 1995, whose pension combines an earnings-based component for contributions accrued up to 1995 and a contribution-based component thereafter (*pro-rata rule*); and (iii) individuals with no contributions accrued before 1 January 1996, whose pension is entirely calculated under the contribution-based (NDC) method.

The Monti-Fornero reform (2011) accelerated and consolidated the transition to a fully contribution-based regime. From 2012 onward, all workers became subject to the pro-rata contributory method for contributions accrued after 31 December 2011, including those previously fully under the earnings-based regime (see Table 10 for a detailed overview, which provides the English translation of the table reported in Ragioneria Generale dello Stato (2025), Appendix 1, letter B). Retirement ages were raised and harmonized across sectors and genders, and eligibility requirements were subsequently indexed to life expectancy through an automatic adjustment mechanism. The reform thus marked the completion of the structural shift toward a predominantly contribution-based framework.

These reforms generated three main concerns for workers:

1. **Declining replacement ratios.** Compared to the pre-1992 earnings-based regime, the NDC framework generally results in lower pension benefits, reflecting a tighter actuarial link between contributions and entitlements.

2. **Increasing retirement age.** The automatic adjustment of eligibility requirements to life expectancy entails a gradual increase in both statutory and effective retirement ages.

3. **Centrality of contribution continuity.** Under a contribution-based system, pension adequacy depends directly on lifetime contributions. As a result, career interruptions, unemployment, and delayed entry into the labor market have a persistent and cumulative impact on retirement income, more so than under the previous defined benefit scheme.

As a consequence, individuals may seek instruments that mitigate these concerns and improve their retirement prospects. Within this context, the redemption of the university degree (*riscatto del corso di laurea*) represents a tool through which individuals could directly influence either their replacement ratio or their eligibility timing.

A.2 Cost of university years' redemption under the earned-based regime

When the period to be redeemed belongs to the earnings-based system, the cost is determined through an actuarial method based on the so-called *mathematical reserve approach*. The mathematical reserve represents the lump-sum amount that the worker must pay to the mandatory pension fund to which she is affiliated (e.g., INPS for private-sector employees) in order to recognize the additional contributory period within the earnings-related regime.

The mathematical reserve is calculated as follows. The starting point is the difference between two hypothetical annual pension amounts:

$$I_p = P_2 - P_1,$$

where P_1 is the pension computed on the basis of the contribution history accrued at the time of the redemption request, and P_2 is the pension calculated including the period to be redeemed. The difference I_p therefore represents the annual pension increment generated by redemption.

Finally, the redemption cost is obtained by multiplying this increment by an actuarial coefficient:

$$RC = I_p \cdot AC$$

where RC denotes the mathematical reserve (i.e., the redemption cost) and AC is an actuarial coefficient that reflects the present value of one euro of additional annual lifetime pension to be paid from retirement onward. The actuarial coefficient is basically the single premium of a deferred lifetime annuity, and therefore depends mainly on factors such as age, gender and contributory seniority. In other words, the coefficient converts the permanent pension increase I_p into its corresponding expected present value at the time of the request.

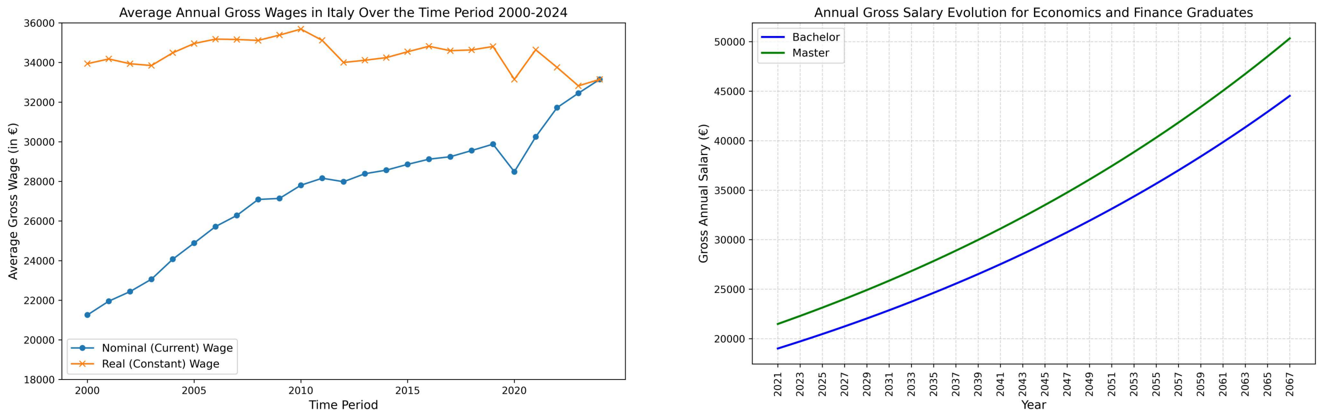
Earnings-based regime	Mixed regime	Contribution-based regime
Eligible workers		
Workers with at least 18 years of contributions as of 31 December 1995 (for pensions granted until 31 December 2011).	Workers with fewer than 18 years of contributions as of 31 December 1995 (for the contributions accrued up to that date) and workers with at least 18 years of contributions as of 31 December 1995 but with pension rights accrued from 1 January 2012 onward (for the portion accrued after that date).	Workers entering the social security system from 1 January 1996 onward.
Pension formula		
The pension P is calculated using the earnings-based method: $P = 2\% \cdot (C^1W^1 + C^2W^2)$ where W^1 and W^2 denote pensionable earnings, and C^1 and C^2 denote years of contribution. For contributions accrued up to 31 December 1992, W^1 is the last monthly wage for public employees and the average of the last 5 or 10 years for private employees and the self-employed. For contributions accrued after 31 December 1992, W^2 is the average wage over the last 10 years for private employees and the average over the last 15 years for public employees and the self-employed.	The pension is obtained as the sum of two components: $P = P_A + P_B$ Component P_A is calculated using the earnings-based method: $P_A = 2\% \cdot (C^1W^1 + C^kW^2)$ where W^1 and W^2 denote pensionable earnings, and C^1 and C^k denote years of contribution. For contributions accrued up to 31 December 1992, W^1 is the last monthly wage for public employees and the average of the last 5 or 10 years for private employees and the self-employed. For contributions accrued between 1 January 1993 and 31 December 1995, W^2 is the average salary over a progressively increasing number of years. For contributions accrued from 1 January 1996 onward, component P_B is calculated under the contribution-based method: $P_B = c_t \cdot M$	The pension is calculated using the contribution-based method: $P = c_t \cdot M$ where c_t denotes the transformation coefficient and M the accumulated contribution amount, i.e. the sum of all accrued contributions capitalized at a rate equal to the five-year moving average of the nominal GDP growth. Transformation coefficients are revised every three years (every two years from 2019 onward) according to changes in life expectancy. For the 2025–2026 period, coefficients range from a minimum of 4.204% at age 57 to a maximum of 6.655% at age 71. The contribution rate applied to pensionable earnings is 33% for employees. For self-employed workers, the statutory rate was 20% until 2011 and was gradually increased to 24% from 2018. For coordinated and continuous collaboration workers, it was 27% for 2012 and 2013, then was progressively increased until reaching 33% in 2018. Contributions are subject to an annual earnings ceiling (equal to €120,607 in 2025).

Table 10: Pension benefit calculation rules under the three pension regimes. Source: Ragioneria Generale dello Stato (2025), Appendix 1, letter B.

B Preliminaries for the analysis of the convenience of the redemption option

This appendix presents the preliminary assumptions and institutional computations that constitute the basis for the subsequent analysis of university years' redemption. In particular, we reconstruct the salary profiles of the representative workers, compute mandatory public pension benefits and replacement ratios, and describe the fiscal framework used throughout the paper to derive net incomes and net replacement ratios from their gross counterparts.

B.1 Assumptions on salaries



(a) Average annual gross wage in Italy, 2000–2024. Source: *OECD*.

(b) Projected evolution of annual gross salaries for Economics and Finance graduates.

Figure 9: Evolution of wages and projected salary dynamics.

B.1.1 From gross to net salaries (and viceversa)

This appendix provides the fiscal computations underlying the salary and pension figures used in the main text. Its purpose is twofold. First, it explains how we recover gross annual salaries from the net salary information reported by AlmaLaurea (2023). Second, it shows how gross salaries and gross pension benefits are converted into their net counterparts, which are needed to compute net replacement ratios.

Throughout the appendix, we maintain the same assumptions adopted in Section 3. In particular, the regulatory and tax framework is assumed to remain constant over time and coincides with the legislation in force in 2026, which is also applied retroactively to earlier years for consistency of comparison.

Since AlmaLaurea (2023) reports average salaries in net monthly terms, reverse calculations are required in order to recover the corresponding gross annual salaries. To perform this step, one must reconstruct the main items affecting payroll taxation. For private-sector employees, these are:

- mandatory social security contributions paid by the employee;
- IRPEF (*Imposta sul Reddito delle Persone Fisiche*), i.e. the Italian tax on personal income;
- regional and municipal surtaxes;
- employee tax credits and other payroll-related relief measures.

Employee social security contributions. The starting point is gross contractual compensation. For simplicity, we assume that lump-sum reimbursements and other non-standard payroll items are equal to zero. The taxable base for social security purposes is therefore proxied by gross labor income, rounded to the nearest euro.

For private-sector employees, the statutory pension contribution rate is equal to 33% of pensionable earnings. Of this amount, only 9.19% is borne directly by the employee and therefore reduces take-home pay; the remaining 23.81% is paid by the employer. Accordingly, employee social security contributions are computed as

$$\text{INPS contributions} = 9.19\% \cdot \text{round}(\text{gross salary earned}).$$

IRPEF. After deducting the employee share of social security contributions, one obtains taxable income for personal income tax purposes. IRPEF is then computed according to the progressive schedule reported in Table 11.

Income Bracket	IRPEF Rate	Yearly Gross Tax
From €0 to €28,000	23%	23% of the income, up to €6,440
From €28,001 to €50,000	33%	€6,440 + 33% of the income exceeding €28,000, up to €13,700
From €50,001	43%	€13,700 + 43% of the income exceeding €50,000

Table 11: IRPEF Rates as of 2026

Regional and municipal surtaxes. In addition to IRPEF, labor income is subject to regional and municipal surtaxes, which depend on the taxpayer's place of residence. The rates are set by the respective municipalities and regions and are published on the website of the Italian Department of Finance.[15] In

[15] For further details, see https://www1.finanze.gov.it/finanze2/dipartimentopolitichefiscali/fiscalitalocale/nuova_addcomirpef/sceltaregione.htm.

line with Assumption iii in Section 3.2, we assume that individuals are fiscally resident in Turin, Piedmont. The corresponding rates are reported in Tables 12 and 13.

Income Bracket	Rate	Yearly Gross Tax
From €0 to €15,000	1.62%	1.62% of the income, up to €243
From €15,001 to €28,000	2.68%	€243 + 2.68% of the income exceeding €15,000, up to €591.40
From €28,001 to €50,000	3.31%	€591.40 + 3.31% of the income exceeding €28,000, up to €1,319.60
From €50,001	3.33%	€1,319.60 + 3.33% of the income exceeding €50,000

Table 12: Regional Surtax – Piedmont (2026)

Income Bracket	Rate	Yearly Gross Tax
From €0 to €11,790	0.0%	tax exemption
From €11,791 to €28,000	0.8%	0.8% of the income, up to €224
From €28,001 to €50,000	1.1%	€224 + 1.1% of the income exceeding €28,000, up to €466
From €50,001	1.2%	€466 + 1.2% of the income exceeding €50,000

Table 13: Municipal Surtax – Turin (2025)

Employee tax credit In general, individuals are entitled to some forms of tax credit. These include, for instance, a 19% tax credit applied to a specific list of expenses, or other tax credit for dependents, persons with disabilities, building restoration interventions, and energy efficiency improvements. However, in our analysis, we focus solely on the employee tax credit, summarized in Table 14, since it is the standard tax relief directly linked to employment income.

Income Bracket	Tax credit
Up to €15,000	€1,955, with a minimum of €690
From €15,001 to €25,000	$€1{,}910 + €1,190 \cdot \frac{28{,}000-\text{income}}{13{,}000}$
From €25,001 to €28,000	$€1{,}910 + €65 + €1,190 \cdot \frac{28{,}000-\text{income}}{13{,}000}$
From €28,001 to €35,000	$€65 + €1,910 \cdot \frac{50{,}000-\text{income}}{22{,}000}$
From €35,001 to €50,000	$€1,910 \cdot \frac{50{,}000-\text{income}}{22{,}000}$
From €50,001	€0

Table 14: Employee tax credit (2026)

Moreover, from 2025 onward, additional reductions in the tax wedge were introduced to replace an INPS contribution relief introduced in 2024, which entailed a 6–7% exemption on social security contributions paid by the worker. For incomes up to €20,000, the measure takes the form of a tax-exempt payroll bonus. For incomes between €20,000 and €40,000, it instead takes the form of an additional tax credit. The relevant schedule is reported in Table 15. All credits and bonuses are computed proportionally to the number of days actually worked during the year.

Income Bracket	Instrument	Amount
Up to €8,500	Bonus	$7.1\% \cdot$ income
From €8,501 to €15,000	Bonus	$5.3\% \cdot$ income
From €15,001 to €20,000	Bonus	$4.8\% \cdot$ income
From €20,001 to €32,000	Tax credit	€1,000
From €32,001 to €40,000	Tax credit	$€1,000 \cdot \frac{40{,}000-\text{income}}{8{,}000}$

Table 15: Additional tax wedge reduction measures (from 2025)

B.1.2 Illustrative payroll reconstruction

We now illustrate how these rules are used in practice to recover gross salaries from the net monthly earnings reported by AlmaLaurea (2023).

We begin with the representative Economics and Finance Bachelor graduate. According to AlmaLaurea (2023), the average monthly net salary one year after graduation is €1,292 for Economics and Finance Bachelor graduates. Under Assumption i in Section 3.2, annual net labor income is obtained by multiplying monthly net earnings by 13, yielding $S_n^{\text{Bachelor}}(2022) = €16{,}796$. We then recover the corresponding gross annual salary by reverse engineering the payroll, obtaining $S_g^{\text{Bachelor}}(2022) = €19{,}366.27$. Table 16 reports the detailed computation.

The same computations are performed for the representative Economics and Finance Master graduate in Table 17, obtaining annual net and gross salaries equal to, respectively, $S_n^{\text{Master}}(2022) = €18{,}382$ and $S_g^{\text{Master}}(2022) = €21{,}891.34$.

Once the 2022 gross salary has been identified, the salary path for all other years follows from the deterministic exponential rule introduced in Section 3.3. For example,

$$S_g^{\text{Bachelor}}(2021) = S_g^{\text{Bachelor}}(2022) \cdot e^{-\gamma} = 19{,}366.27 \cdot e^{-1.85\%} = 19{,}011.29.$$

B.1.3 Salaries in the retirement year

For the computation of the replacement ratios, we also need gross and net labor income in the retirement year. Under the assumptions of Section 3.4, individuals starting to work in September 2021 satisfy the contribution requirement for early retirement during 2067 and, after the three-month waiting period, begin receiving pension benefits on October 1$^{\text{st}}$, 2067. As a result, the salary in 2067 is earned only for the first nine months of the year, plus the corresponding accrued share of the thirteenth monthly installment.

Using the salary projection rule

$$S_g^d(t) = S_g^d(2022) \cdot e^{\gamma(t-2022)}, \qquad \gamma = 1.85\%, \quad d \in \{\text{Bachelor}, \text{Master}\}, \quad t = 2021, 2022, ...,$$

gross annual salaries in 2067 are

$$S_g^{\text{Bachelor}}(2067) = S_g^{\text{Bachelor}}(2022)e^{\gamma(2067-2022)} = €44{,}524.20,$$

for the representative Bachelor graduate worker, and

$$S_g^{\text{Master}}(2067) = S_g^{\text{Master}}(2022)e^{\gamma(2067-2022)} = €50{,}329.47.$$

for the Master graduate worker, respectively. Tables 18 and 19 report the corresponding payroll computations for the retirement year, taking into account that only nine months of work are effectively performed.

Description	**Partial**	**Total**
Gross annual income		**19,366.27**
Lump-sum expense reimbursements	—	
Gross taxable earnings (for social security purposes)		19,366.27
INPS contribution (9.19% of 19,366.00)	-1,779.74	
Gross taxable income		17,586.53
Gross IRPEF withholdings		
First bracket: 23% of 17,586.53	-4,044.90	
Regional surtax (Piedmont)		
First bracket: 1.62% of 15,000	-243.00	
Second bracket: 2.68% of (17,586.53 - 15,000)	-69.32	
Municipal surtax (Turin)		
Second bracket: 0.8% of 17,586.53	-140.69	
Employee Tax Credit		
$1{,}910 + 1{,}190 \cdot \frac{28{,}000-17{,}586.53}{13{,}000}$	2,863.23	
Additional Tax Wedge Bonus		
4.8% of 17,586.53	844.15	
Annual Net Income		**16,796.00**

Table 16: Economics and Finance, 2021 Bachelor graduate – 2022 payroll (2026 regulations retroactively applied)

Description	Partial	Total
Gross annual income		**21,891.34**
Lump-sum expense reimbursements	—	
Gross taxable earnings (for social security purposes)		21,891.34
INPS contribution (9.19% of 21,891.00)	-2,011.78	
Gross taxable income		19,879.56
Gross IRPEF withholdings		
First bracket: 23% of 19,879.56	-4,572.30	
Regional surtax (Piedmont)		
First bracket: 1.62% of 15,000	-243.00	
Second bracket: 2.68% of (19,879.56 - 15,000)	-130.77	
Municipal surtax (Turin)		
Second bracket: 0.8% of 19,879.56	-159.04	
Employee Tax Credit		
$1{,}910 + 1{,}190 \cdot \frac{28{,}000 - 19{,}879.56}{13{,}000}$	2,653.33	
Additional Tax Wedge Bonus		
4.8% of 19,879.56	954.22	
Annual Net Income		**18,382.00**

Table 17: Economics and Finance, 2021 Master graduate – 2022 payroll (2026 regulations retroactively applied)

Description	Partial	Total
Gross annual income		**44,524.20**
Months worked: 9 months		
Income effectively earned: $\frac{44{,}524.20}{13}\left(9+\frac{9}{12}\right)=33,393.15$		
Lump-sum expense reimbursements	—	
Gross taxable earnings (for social security purposes)		33,393.15
INPS Contribution (9.19% of 33,393.00)	-3,068.82	
Gross taxable income		30,324.33
Gross IRPEF withholdings		
First bracket: 23% of 28,000	-6,440.00	
Second bracket: 33% of (30,324.33-28,000)	-767.03	
Regional surtax (Piedmont)		
First bracket: 1.62% of 15,000	-243.00	
Second bracket: 2.68% of (28,000-15,000)	-348.40	
Third bracket: 3.31% of (30,324.33-28,000)	-76.94	
Municipal surtax (Turin)		
Second bracket: 0.8% of 28,000	-224.00	
Third bracket: 1.1% of (30,324.33-28,000)	-25.57	
Employee tax credit		
$\left(65+1,910\cdot\frac{50{,}000-30{,}324.33}{22{,}000}\right)\cdot\frac{9}{12}$	1,329.90	
Additional tax wedge credit		
$1,000\cdot\frac{9}{12}$	750.00	
Net Income		**24,279.29**
Annual Net Income		**32,372.39**

Table 18: Economics and Finance, 2021 Bachelor graduate – 2067 payroll (2026 regulations apply)

Description	Partial	Total
Gross annual income		**50,329.47**
Months worked: 9 months		
Income effectively earned: $\frac{50{,}329.47}{13}\left(9+\frac{9}{12}\right)=37,747.10$		
Lump-sum expense reimbursements	—	
Gross taxable earnings (for social security purposes)		37,747.10
INPS Contribution (9.19% of 37,747.00)	-3,468.95	
Gross taxable income		34,278.15
Gross IRPEF withholdings		
First bracket: 23% of 28,000	-6,440.00	
Second bracket: 33% of (34,278.15-28,000)	-2,071.79	
Regional surtax (Piedmont)		
First bracket: 1.62% of 15,000	-243.00	
Second bracket: 2.68% of (28,000-15,000)	-348.40	
Third bracket: 3.31% of (34,278.15-28,000)	-207.81	
Municipal surtax (Turin)		
Second bracket: 0.8% of 28,000	-224.00	
Third bracket: 1.1% of (34,278.15-28,000)	-69.06	
Employee tax credit		
$\left(65+1,910\cdot\frac{50{,}000-34{,}278.15}{22{,}000}\right)\cdot\frac{9}{12}$	1,072.46	
Additional tax wedge credit		
$1,000\cdot\frac{40{,}000-34{,}278.15}{8{,}000}\cdot\frac{9}{12}$	536.42	
Net Income		**26,282.97**
Annual Net Income		**35,043.96**

Table 19: Economics and Finance, 2021 Master graduate – 2067 payroll (2026 regulations apply)

B.2 Mandatory public pension and replacement ratios

The gross annual pension benefit for the Bachelor graduate is computed as

$$P_g^{\text{Bachelor}} = \hat{\beta}_{68}(2067) \cdot TLC^{\text{Bachelor}}(2067) = 5.378\% \cdot € \, 459{,}415.41 = € \, 24{,}707.36,$$

where $\hat{\beta}_{68}(2067)$ denotes the projected transformation coefficient in 2067 for an individual retiring at age 68, and $TLC^{\text{Bachelor}}(2067)$ represents the total lifetime contributions accumulated by the representative Bachelor graduate up to retirement.

Similarly, the gross annual pension benefit for the Master graduate is given by

$$P_g^{\text{Master}} = \hat{\beta}_{70}(2067) \cdot TLC^{\text{Master}}(2067) = 5.753\% \cdot € \, 519{,}315.93 = € \, 29{,}876.25,$$

where $\hat{\beta}_{70}(2067)$ is the projected transformation coefficient in 2067 for an individual retiring at age 70, and $TLC^{\text{Master}}(2067)$ denotes the corresponding total lifetime contributions accumulated by the representative Master graduate.

To compute the net pension income, gross annual pension benefits must be adjusted for personal income taxation. Pension income is subject to IRPEF and to the same regional and municipal surtaxes considered above. However, unlike labor income, it benefits from a specific pension tax credit, summarized in Table 20. Clearly, no employee social security contributions apply at this stage.

Applying these rules yields the following net annual pension benefits:

$$P_n^{\text{Bachelor}} = €19,235.76, \qquad P_n^{\text{Master}} = €22{,}559.25.$$

The detailed calculations (including the inclusion of the applicable tax credit from Table 20) are reported in Tables 21 and 22.

Finally, net replacement ratios are defined as

$$NRR^d = \frac{P_n^d}{S_n^d(2067)}, \qquad d \in \{\text{Bachelor}, \text{Master}\}.$$

Using the net labor incomes reconstructed for 2067, we obtain

$$NRR^{\text{Bachelor}} = \frac{€19,235.76}{€32{,}372.39} = 59.42\%,$$

$$NRR^{\text{Master}} = \frac{€22{,}559.25}{€35{,}043.96} = 64.37\%.$$

Income Bracket	Tax credit
Up to €8,500	€1,955, with a minimum of €713
From €8,501 to €25,000	€700 + €$1,255 \cdot \frac{28{,}000-\text{income}}{19{,}500}$
From €25,001 to €28,000	€700 + €50 + €$1,255 \cdot \frac{28{,}000-\text{income}}{19{,}500}$
From €28,001 to €29,000	€50 + €$700 \cdot \frac{50{,}000-\text{income}}{22{,}000}$
From €29,001 to €50,000	€$700 \cdot \frac{50{,}000-\text{income}}{22{,}000}$
From €50,001	€0

Table 20: Pension tax credit (2026)

Description	Partial	Total
Gross annual pension		**24,707.36**
Gross taxable income		24,707.36
Gross IRPEF withholdings		
First bracket: 23% of 24,707.36	-5,682.69	
Regional surtax (Piedmont)		
First bracket: 1.62% of 15,000	-243.00	
Second bracket: 2.68% of (24,707.36-15,000)	-260.16	
Municipal surtax (Turin)		
Second bracket: 0.8% of 24,707.36	-197.66	
Pension tax credit		
$700 + 1,255 \cdot \frac{28{,}000-24{,}707.36}{19{,}500}$	911.91	
Net annual pension		**19,235.76**

Table 21: Economics and Finance, 2021 Bachelor graduate – Pension payroll (2026 regulations apply)

Description	Partial	Total
Gross annual pension		**29,876.25**
Gross taxable income		29,876.25
Gross IRPEF withholdings		
First bracket: 23% of 28,000	-6,440.00	
Second bracket: 33% of (29,876.25-28,000)	-619.16	
Regional surtax (Piedmont)		
First bracket: 1.62% of 15,000	-243.00	
Second bracket: 2.68% of (28,000-15,000)	-348.40	
Third bracket: 3.31% of (29,876.25-28,000)	-62.10	
Municipal surtax (Turin)		
Second bracket: 0.8% of 28,000	-224.00	
Third bracket: 1.1% of (29,876.25-28,000)	-20.64	
Pension tax credit		
$700 \cdot \frac{50{,}000-29{,}876.25}{22{,}000}$	640.30	
Net annual pension		**22,559.25**

Table 22: Economics and Finance, 2021 Master graduate – Pension payroll (2026 regulations apply)

C Theoretical considerations on the dynamics of the alternative strategies

The results in Section 5.4 show that participation in a DC pension fund yields slightly higher replacement ratios than investment in an ETF-based accumulation plan. This section provides an analytical explanation of these findings by comparing the expected accumulated wealth generated by the two strategies. In doing so, we also account for the role of taxation, which interacts with the accumulation dynamics and contributes to shaping the relative performance of the two investment options.

Dynamics of the DC pension fund during the contribution period. During the ten-year contribution period, the portfolio share invested in the risky asset is equal to one, since the de-risking phase of the deterministic lifestyle strategy starts only later. Moreover, contributions are constant and equal to the annual redemption installment RC^d, with $d \in \{\text{Bachelor}, \text{Master}\}$. Hence, abstracting temporarily from the annual taxation of investment returns, the DC pension fund wealth satisfies

$$dX^d(t) = \left(\lambda X^d(t) + RC^d\right) dt + \sigma X^d(t)\, dW(t), \qquad X^d(0) = 0, \qquad d \in \{\text{Bachelor}, \text{Master}\}.$$

Multiplying $X^d(t)$ by the integrating factor

$$Y(t) = \exp\left\{-\left(\lambda - \frac{\sigma^2}{2}\right) t - \sigma W(t)\right\},$$

which satisfies the following SDE:

$$dY(t) = -(\lambda - \sigma^2)Y(t)dt - \sigma Y(t)dW(t), \qquad Y(0) = 1$$

we can apply Itô's formula to $f(X^d(t), Y(t)) = X^d(t)Y(t)$, obtaining

$$\begin{aligned}
d\left(X^d(t)Y(t)\right) &= Y(t)dX^d(t) + X^d(t)dY(t) + dX^d(t)dY(t) \\
&= Y(t)\left[\left(\lambda X^d(t) + RC^d\right) dt + \sigma X^d(t)\, dW(t)\right] + X^d(t)\left[-(\lambda - \sigma^2)Y(t)dt - \sigma Y(t)dW(t)\right] \\
&\quad - \sigma^2 X^d(t)Y(t)dt \\
&= RC^d\, Y(t)\, dt, \qquad d \in \{\text{Bachelor}, \text{Master}\}.
\end{aligned}$$

Therefore,

$$X^d(t)\,Y(t) = RC^d \int_0^t Y(s)\,ds.$$

As a consequence, the closed-form solution for $X^d(t)$, with $d \in \{\text{Bachelor}, \text{Master}\}$, is

$$X^d(t) = RC^d \int_0^t \frac{Y(s)}{Y(t)}\,ds, \qquad d \in \{\text{Bachelor}, \text{Master}\}.$$

Equivalently,

$$X^d(t) = RC^d \int_0^t e^{\left(\lambda - \frac{\sigma^2}{2}\right)(t-s) + \sigma(W(t)-W(s))}\,ds, \qquad d \in \{\text{Bachelor}, \text{Master}\}.$$

Taking expectations, using Fubini and recalling that $W(t) - W(s) \sim \mathcal{N}(0, t-s)$, we obtain

$$\begin{aligned}
\mathbb{E}[X^d(t)] &= RC^d \int_0^t e^{\left(\lambda - \frac{\sigma^2}{2}\right)(t-s)}\,\mathbb{E}\left[e^{\sigma(W(t)-W(s))}\right]\,ds \\
&= RC^d \int_0^t e^{\left(\lambda - \frac{\sigma^2}{2}\right)(t-s) + \frac{\sigma^2}{2}(t-s)}\,ds \\
&= RC^d \int_0^t e^{\lambda(t-s)}\,ds = RC^d \cdot \frac{e^{\lambda t} - 1}{\lambda}, \qquad d \in \{\text{Bachelor}, \text{Master}\}.
\end{aligned}$$

Therefore, under the simplifying assumption that no annual taxation is applied to capital returns, the expected terminal wealth accumulated in the DC pension fund is given by

$$\mathbb{E}[X^d(T)] = RC^d\,\frac{e^{\lambda T} - 1}{\lambda}, \qquad d \in \{\text{Bachelor}, \text{Master}\}. \tag{28}$$

Dynamics of the ETF-based accumulation plan. The ETF-based accumulation plan follows

$$dE^d(t) = \left(\mu E^d(t) + c^d(t)\right)dt + \rho E^d(t)\,dW(t), \qquad E^d(0) = 0, \qquad d \in \{\text{Bachelor}, \text{Master}\},$$

where μ and ρ denote the drift and volatility of the ETF. The contribution flow is adjusted in order to account for the fact that direct financial investment does not generate the tax savings associated with university years' redemption or DC pension fund contributions. Hence,

$$c^d(t) = RC^d - \text{TS}^d(t), \qquad d \in \{\text{Bachelor}, \text{Master}\},$$

where $\mathrm{TS}^d(t)$ denotes the tax savings generated in year t under both DC pension fund participation and university years' redemption for a worker of type d.

Applying the same integrating factor argument used for the DC pension fund wealth, the solution can be written as

$$E^d(T) = \int_0^T c^d(s) e^{(\mu - \frac{1}{2}\rho^2)(T-s) + \rho(W(T)-W(s))} \, ds, \qquad d \in \{\text{Bachelor}, \text{Master}\}.$$

Under the assumption that the tax saving is constant within each year, i.e. $\mathrm{TS}(s) = \mathrm{TS}(t),\ s \in (t-1, t]$, we can write

$$E^d(T) = RC^d \int_0^T e^{(\mu - \frac{1}{2}\rho^2)(T-s) + \rho(W(T)-W(s))} \, ds - \sum_{t=1}^{T} \mathrm{TS}^d(t) \int_{t-1}^{t} e^{(\mu - \frac{1}{2}\rho^2)(T-s) + \rho(W(T)-W(s))} \, ds,$$

for $d \in \{\text{Bachelor}, \text{Master}\}$. Taking expectations gives

$$\begin{aligned}
\mathbb{E}[E^d(T)] &= RC^d \int_0^T e^{\mu(T-s)} \, ds - \sum_{t=1}^{T} \mathrm{TS}^d(t) \int_{t-1}^{t} e^{\mu(T-s)} \, ds \\
&= RC^d \cdot \frac{e^{\mu T} - 1}{\mu} - \sum_{t=1}^{T} \mathrm{TS}^d(t) \cdot e^{\mu(T-t)} \frac{e^{\mu} - 1}{\mu}, \qquad d \in \{\text{Bachelor}, \text{Master}\}.
\end{aligned}$$

Comparison of the two expected accumulated values. Under the simulation assumptions adopted in this section, the ETF is characterized by a higher drift than the DC pension fund, that is, $\mu > \lambda$. Since the function

$$f(x) = \frac{e^{xT} - 1}{x}$$

is strictly increasing for $x > 0$, it follows that

$$\frac{e^{\lambda T} - 1}{\lambda} < \frac{e^{\mu T} - 1}{\mu}.$$

Indeed,

$$f'(x) = \frac{xTe^{xT} - e^{xT} + 1}{x^2} = \frac{e^{xT}(xT - 1) + 1}{x^2}.$$

Let

$$g(x) = e^{xT}(xT - 1) + 1.$$

Then $g(0) = 0$ and

$$g'(x) = T^2 x e^{xT} > 0 \qquad \text{for } x > 0.$$

Hence $g(x) > 0$ for all $x > 0$, and therefore $f'(x) > 0$.

Consequently, if both strategies were financed by the same contribution flow and in the absence of taxation, the ETF strategy would yield a higher expected accumulated value:

$$RC^d \frac{e^{\lambda T} - 1}{\lambda} < RC^d \frac{e^{\mu T} - 1}{\mu}, \qquad d \in \{\text{Bachelor}, \text{Master}\}.$$

However, this comparison is only partial, as the two strategies differ along three key dimensions: (i) the effective contribution invested, (ii) the taxation of returns during the accumulation phase, and (iii) the taxation of benefits at retirement.

First, the ETF strategy is not financed by the full redemption installment RC^d, but by the reduced contribution $RC^d - \text{TS}^d(t)$, since tax savings obtained from the other two strategies are not invested. This mechanically lowers the amount accumulated in financial markets.

Second, the analytical expression for the DC pension fund's wealth (28) abstracts from the annual taxation of returns. In the simulation, positive returns are taxed yearly, while tax credits generated by negative performance are carried forward and used to offset future gains. This makes the accumulation path-dependent and reduces the effective growth rate. Denoting by λ^{net} the implied after-tax rate, one has $\lambda^{net} \leq \lambda$. Under our simulation, $\lambda^{net} \approx 3.24\%$, so that

$$\mathbb{E}[X^{*d}(T)] = RC^d \frac{e^{\lambda^{net} T} - 1}{\lambda^{net}}.$$

Third, and crucially, the comparison must be conducted in terms of *net terminal wealth*, taking into account the different tax treatments at retirement. For the ETF strategy, capital gains are taxed at a rate of 26%, so that

$$\mathbb{E}[E^{*d}(T)] = \mathbb{E}[E^d(T)] - 0.26 \cdot \max\left\{\mathbb{E}[E^d(T)] - \left(TRC^d - \sum_{t=1}^{10} \text{TS}^d(t)\right), 0\right\}, \tag{29}$$

for $d \in \{\text{Bachelor}, \text{Master}\}$. By contrast, DC pension benefits are taxed at the more favorable rate of 15%, yielding as post-tax value

$$\mathbb{E}[X^{*d}(T)] - 0.15 \cdot TRC^d. \tag{30}$$

The relevant comparison is therefore between the two post-tax quantities (29) and (30). The simulation results clearly illustrate the quantitative importance of these adjustments. For Bachelor's graduates,

$$\mathbb{E}[X^{*\text{Bachelor}}(T)] = 22,222.72, \qquad \mathbb{E}[E^{\text{Bachelor}}(T)] = 19,707.39,$$

so that the DC pension fund already dominates before taxation at retirement. After taxation on retirement benefits, we have

$$\mathbb{E}[X^{*\text{Bachelor}}(T)] - 0.15\, TRC^{\text{Bachelor}} = 19,399.54, \qquad \mathbb{E}[E^{*\text{Bachelor}}(T)] = 17,984.55,$$

so that the gap, while still in favor of the DC pension fund, becomes smaller. A similar pattern emerges for Master's graduates:

$$\mathbb{E}[X^{*\text{Master}}(T)] = 41,866.96, \qquad \mathbb{E}[E^{\text{Master}}(T)] = 36,495.04,$$

and, after taxation on retirement benefits,

$$\mathbb{E}[X^{*\text{Master}}(T)] - 0.15\, TRC^{\text{Master}} = 36,548.17, \qquad \mathbb{E}[E^{*\text{Master}}(T)] = 33,270.86,$$

so that the DC pension fund dominates also in net terms.

We stress again that, even before taxation, the accumulated wealth in the DC pension fund exceeds that obtained under the ETF strategy. This difference arises because the comparison is conducted under equal financial effort for the worker, rather than under equal invested amounts. In the case of the DC pension fund, contributions are tax deductible, so that part of the contribution is effectively financed by the Italian State through the associated tax savings. By contrast, ETF investments do not benefit from any deductibility. Because we want to ensure comparability in terms of effective payments done by the two individuals, we have the unavoidable consequence that the effective cash flow invested in the ETF is approximately 30% lower than the amount invested in the DC pension fund. This is the main reason why the accumulated wealth of the ETF is lower than that of the DC pension fund before taxation on retirement benefits.

After taxation at retirement, the accumulated wealth under the DC pension fund remains higher than the one obtained through the ETF strategy. Taxation on retirement benefits, although less favorable for the ETF strategy, does not drive the ranking of outcomes. Rather, it almost compensates the difference between the two strategies, as the higher tax rate is applied to a lower accumulated amount. Therefore, the DC pension fund dominates the investment in the ETF in terms of net replacement ratios, but only to a small extent.