Apr, 2026
GRINS DISCUSSION PAPER SERIES DP N° 102/2026 ISSN 3035-5576

GRINS

Integrating Long-Term Care into the Italian Retirement Pension System

DP N° 102/2026

Authors:
Adnan Abdulaziz Shahir, Luca Vincenzo Ballestra, Carlo Mazzaferro, Marcello Morciano

Apr, 2026
GRINS DISCUSSION PAPER SERIES DP N° 102/2026 ISSN 3035-5576

Integrating Long-Term Care into the Italian Retirement Pension System

Adnan Abdulaziz Shahir, Luca Vincenzo Ballestra, Carlo Mazzaferro, Marcello Morciano

KEYWORDS

long-term care | notional defined contribution | survivor dividend | fiscal sustainability | pension adequacy | Italy

JEL CODE

H55, I13, J26

ACKNOWLEDGEMENTS

This study was funded by the European Union - NextGenerationEU, in the framework of the GRINS - Growing Resilient, INclusive and Sustainable project (GRINS PE00000018). The views and opinions expressed are solely those of the authors and do not necessarily reflect those of the European Union, nor can the European Union be held responsible for them.

CITE THIS WORK

Author(s): Adnan Abdulaziz Shahir, Luca Vincenzo Ballestra, Carlo Mazzaferro, Marcello Morciano. Title: Integrating Long-Term Care into the Italian Retirement Pension System. Publication Date: 2026.

Population aging is rapidly increasing long-term care (LTC) needs and putting growing pressure on public welfare systems. In Italy, the publicly funded LTC system remains structurally underfinanced despite rising demand.
This paper assesses the financial feasibility of integrating comprehensive LTC coverage into the Italian Notional Defined Contribution (NDC) pension system. Using an extended multistate actuarial framework calibrated to Italian administrative data, we evaluate two alternative integration designs: Enhanced Pension Annuities (EPA) and Life Care Annuities (LCA), under different allocation rules for the net Survivor Dividend (SD), defined as the notional capital released by contributors who die before retirement, net of survivor protection.
We show that financing total LTC expenditure within the NDC framework requires an additional contribution rate of between 3.48 and 4.59 percentage points under LCA, depending on the SD allocation rule and on whether system balance is assessed at the cohort or macro level.
Under EPA, by contrast, the financing burden is shifted from contribution rates to pension adequacy. The net SD is sizable and comparable in magnitude to current public expenditure on home-based LTC in Italy.
Its allocation to LTC financing mitigates, but does not eliminate, the trade-off between higher contribution rates under LCA and lower pension adequacy under EPA, with relevant inter- and intra-generational distributional implications.

Integrating Long-Term Care into the Italian Retirement Pension System*

Adnan Abdulaziz Shahir[a], Luca Vincenzo Ballestra[a], Carlo Mazzaferro[a], Marcello Morciano[b,*]

[a] *Department of Statistical Sciences, University of Bologna, Bologna, Italy*
[b] *Department of Economics, University of Modena and Reggio Emilia, Modena, Italy*

Abstract

Population aging is rapidly increasing long-term care (LTC) needs and putting growing pressure on public welfare systems. In Italy, the publicly funded LTC system remains structurally underfinanced despite rising demand. This paper assesses the financial feasibility of integrating comprehensive LTC coverage into the Italian Notional Defined Contribution (NDC) pension system. Using an extended multistate actuarial framework calibrated to Italian administrative data, we evaluate two alternative integration designs, Enhanced Pension Annuities (EPA) and Life Care Annuities (LCA), under different allocation rules for the net Survivor Dividend (SD), defined as the notional capital released by contributors who die before retirement, net of survivor protection. We show that financing total LTC expenditure within the NDC framework requires an additional contribution rate of between 3.48 and 4.59 percentage points under LCA, depending on the SD allocation rule and on whether system balance is assessed at the cohort or macro level. Under EPA, by contrast, the financing burden is shifted from contribution rates to pension adequacy. The net SD is sizable and comparable in magnitude to current public

*The authors acknowledge funding from the European Union — NextGenerationEU, in the framework of the "GRINS — Growing Resilient, INclusive and Sustainable" project (PNRR—M4C2—I1.3—PE00000018—CUP J33C22002910001). We also thank participants for helpful comments on early versions of this work at the Italian National Social Security Institute (INPS, 22/07/2025) and at the Joint Research Centre of the European Commission (JRC, 28/01/2026). The views and opinions expressed are solely those of the authors and do not necessarily reflect those of the European Union, nor can the European Union be held responsible for them.

*Corresponding author. Emails: adnan.shahir2@unibo.it; luca.ballestra@unibo.it; carlo.mazzaferro@unibo.it; marcello.morciano@unimore.it.

expenditure on home-based LTC in Italy. Its allocation to LTC financing mitigates, but does not eliminate, the trade-off between higher contribution rates under LCA and lower pension adequacy under EPA, with relevant inter- and intra-generational distributional implications.

Keywords: long-term care, notional defined contribution, survivor dividend, fiscal sustainability, pension adequacy, Italy.

JEL Codes: H55, I13, J26.

1. Introduction

Worldwide, demand for long-term care (LTC) is intensifying rapidly due to population aging, increasing longevity often accompanied by frailty, and the weakening of traditional family-based support. Public LTC systems therefore face growing pressure to secure stable and equitable financing for LTC without compromising fiscal sustainability. Across OECD countries, around 1.5% of GDP is currently devoted to LTC, but this share is projected to increase 2.5 times by 2050, and could even quadruple if benefit adequacy is strengthened, an option many countries are actively considering (OECD, 2020).

Financing this expansion remains a major policy challenge. Countries rely on a wide mix of instruments, including general taxation, private provision through life or group insurance products, and mandatory social insurance schemes, either dedicated to LTC or integrated within broader health or pension pillars (de Biase and Dougherty, 2023; Costa-Font and Raut, 2022).

Given that most LTC recipients are well beyond retirement age, scholars have explored retirement products that combine lifetime annuities with LTC benefits. Costa-Font et al. (2015) argue that LTC financing should be considered as part of a comprehensive retirement strategy, even if the objectives of consumption smoothing (retirement) and insurance against dependency (LTC) can be analytically distinguished. Examples include Enhanced Pension Annuities (EPA) and Life Care Annuities (LCA) (Pitacco, 2013, 2014).

In parallel, many countries have adopted Notional Defined Contribution (NDC) pension frameworks within pay-as-you-go (PAYG) systems (Hindriks and Cetin (2025); OECD (2025)). NDC schemes mimic the logic of financial defined contribution plans where the present value of lifetime benefits corresponds to the notional capital accumulated at retirement. Sweden, Italy, Latvia, and Poland offer prominent examples (OECD, 2025; EPC, 2024; Marano et al., 2012; Börsch-Supan, 2005). Building on this architecture, scholars examined how LTC-linked annuities can be embedded within existing NDC pension designs (Pla-Porcel et al., 2016; Vidal-Meliá et al., 2020). We aim to contribute to this literature along three distinct dimensions.

Embedding LTC within the pension system can yield diversification gains and intra-generational distributive effects. Longevity and dependency risks tend to move in opposite directions, creating a form of *natural hedging* that may support overall system sustainability (Rickayzen, 2007; Levantesi and Menzietti, 2018). At the same time, such integration can entail redistributive consequences within the same cohorts: wealthier individuals generally live longer (Mazzaferro et al., 2012) and face a lower probability of severe LTC needs (Lera et al., 2021), while poorer individuals tend to have shorter lifespans but higher dependency risks. One contribution of this paper is to compare how two alternative LTC-integration schemes, LCA versus an EPA, within an NDC framework affect this natural hedge and the resulting redistributive outcomes.

Within this context, the Survivor Dividend (SD), namely the accumulated capital of a deceased person, when the death occurs prior to its use, represents a potential lever for financing additional social protection components. Pla-Porcel et al. (2016) examined how LTC benefits can be embedded within NDC-based pension annuity designs for the Swedish and Japanese settings, while Arnold-Gaille et al. (2024) analysed the use of the SD to strengthen minimum pensions in France. However, institutional differences matter directly for the SD. In the Swedish NDC design, the SD is explicitly redistributed within the same birth cohort as a contingent return, acting as an intra-generational (and regressive) stabilizer. In other NDC schemes, the SD is absorbed into the general financing of the system, generating a positive imbalance used for broader institutional purposes.[1]

The Italian case, which is the empirical focus of our analysis, differs markedly from other NDC settings in the institutional treatment of the SD. Although an SD is mechanically generated within the Italian NDC accounts, only a fraction of the associated death-related capital is potentially available for intra-cohort redistribution, as a substantial share is absorbed by survivor protection mechanisms.[2] Crucially, this implies that the SD relevant for

[1]Differences in "*actuarial purity*" are well known. Sweden preserves transparency and financial sustainability in the old-age pillar by managing disability and survivor protection through separate instruments, while others (e.g. Italy) internalize these social risks within the core contributory framework (see Gronchi and Nistico 2003). Beyond the treatment of social risks, European NDC schemes also differ in other key design features, including the way indexation is implemented and how annuities are converted. See, e.g., EPC (2024) for details.

[2]In practice, Italy internalizes survivor protection within the NDC mechanism through two channels. First, transformation coefficients are structurally kept lower to incorporate the expected continuation of payments to a surviving spouse, embedding the cost of survivor protection ex ante in the annuity. Second, if death occurs before retirement, the accumulated notional capital constitutes an SD that is not redistributed within the cohort but is instead converted into an annuity paid to the surviving spouse or heirs.

redistribution or alternative financing purposes must be defined *net* of the actuarial cost of survivor pensions. In other words, in contrast to NDC systems where the SD can serve as a contingent return to surviving cohort members, enhance intra-cohort risk-sharing, and partially offset longevity–dependency imbalances, the Italian design prevents the full use of the gross SD for stabilising or financing purposes beyond survivor pensions. In this respect, the Italian NDC framework resembles many defined benefit pension systems in Europe, where survivor and longevity risks are internalized within the core pension scheme rather than managed through explicit redistribution mechanisms. Another contribution of this paper is therefore to quantify the SD generated within the Italian NDC system *after accounting for survivor protection*, and to assess the extent to which the resulting net SD can be used to offset the financing pressure generated by late-life LTC risks.

Specifically, we focus on Italy and assess the fiscal implications of a hypothetical reform that integrates all or part of the public LTC expenditures into its NDC pension system, under alternative SD^{net} allocation scenarios. Introduced in 1995, Italy's NDC framework features automatic actuarial adjustments and risk-sharing mechanisms that support fiscal transparency and long-run sustainability (Devolder et al., 2021; Levantesi et al., 2024). By contrast, the Italian LTC system is widely regarded as inadequate and fragmented (Santini et al., 2025; Audino et al., 2024; Brugiavini et al., 2023; Gori et al., 2015; Norton, 2017), and past reform proposals have repeatedly stalled due to the absence of a dedicated and sustainable funding channel.

In addition to the *status quo*, we simulate two alternative allocation rules for the net survivor dividend (SD^{net}), each corresponding to a distinct institutional arrangement and policy interpretation. Under the first rule, the full SD^{net} accumulated by a cohort is redistributed among the surviving retirees of the same cohort by increasing their pensions. This allocation closely mirrors the logic of the Swedish NDC system, here extended to a framework that explicitly incorporates survivor protection. In this scenario, all residual death-related capital is used to increase old-age pensions. Since higher retirement pensions mechanically translate into higher survivor pensions during the retirement phase, this rule also indirectly strengthens post-retirement survivor benefits. Importantly, no share of SD^{net} is earmarked for LTC financing. The alternative rule assigns a fundamentally different role to SD^{net}. Rather than enhancing the retirement pensions of surviving cohort members, SD^{net} is used to offset the financial burden generated by the integration of LTC into the pension system. In this case, SD^{net} acts as a partial natural hedge against longevity and LTC risks, supporting the financing of LTC expenditures without increasing pension entitlements.

Methodologically, we also extend the framework of Pla-Porcel et al. (2016) by integrating LTC without relying on hard-to-obtain prevalence or incidence data. Instead, we combine publicly available age-specific per-capita LTC expenditure profiles by type of service with official survival probabilities and Italian administrative earnings data, and convert these age-specific LTC costs into annuity-equivalent values within an NDC setting. This makes the framework readily portable to other institutional contexts. We also extend Arnold-Gaille et al. (2024) by allowing the *net* SD to be allocated under alternative scenarios and by evaluating balance both at the retirement-date cohort level and under annual macro-balance. For the Italian case, the paper goes beyond Levantesi et al. (2024), who focus on integrating only the *Indennità di Accompagnamento*[3]; by contrast, we consider the full System of Health Accounts (SHA) LTC expenditure structure (home-based care, residential and semi-residential services, and cash benefits) and explicitly account for contributor mortality as well as for the fiscal implications of financing either total LTC expenditure or selected LTC components.

Accordingly, this paper makes three main contributions. First, it develops an actuarially consistent framework to integrate LTC expenditure into an NDC pension system while preserving the conceptual distinction between EPA and LCA financing designs and explicitly accounting for survivor protection within an NDC system. Second, it quantifies the survivor dividend in the Italian case and shows how its current institutional absorption through survivor protection constrains its potential role in financing LTC. Third, using Italian administrative data and age-specific LTC expenditure profiles, it estimates the contribution-rate implications of financing alternative LTC components under different allocation rules of the *net SD*, and clarifies the associated trade-off between contribution increases under LCA and pension adequacy under EPA.

We find that financing the full set of public LTC expenditures across all macro-functions in Italy requires a substantial additional contribution under the LCA design. At the cohort level, the total contribution rate rises from

[3]The *Indennità di Accompagnamento* is the main non–means-tested LTC cash benefit in Italy, accounting in 2024 for about €15.7 billion (0.7% of GDP) and the largest share of total LTC spending (RGS, 2025).

29.00% to between 32.48% and 33.57%, depending on the SD allocation rule. Under annual macro-balance, the corresponding total rate ranges from 32.57% to 33.59%. Under EPA, by contrast, the contribution rate remains unchanged at the cohort level, but the adjustment occurs through lower pensions rather than higher contributions. For total LTC expenditure, the implied reduction in the initial pension at the cohort level is about 17.1%, 16.5%, and 13.0% under, respectively, no redistribution of SD^{net}, full SD^{net} redistribution, and the LTC-related SD^{net} rule. Under macro-balance, EPA may still require a modest contribution adjustment, up to 1.02 percentage points. Overall, the net SD can therefore mitigate the financing burden of the LTC integration, but its effectiveness depends critically on the balance criterion and on its allocation between pensions and LTC. More broadly, integrating pensions and LTC within a unified actuarial NDC framework improves allocative efficiency by allowing the system to better exploit the natural hedging between longevity and LTC risks.

The remainder of the paper proceeds as follows. Section 2 presents the methodological framework used to model demographic and actuarial conditions and to assess system balance. Section 3 describes the Italian calibration and reports the main numerical results. Section 4 concludes.[4]

2. Methodology

The methodological framework is organized into sequential blocks. We first introduce the demographic and economic foundations of the model and the age profile of LTC expenditure. We then define the actuarial transformation rules, accumulated notional capital, pre- and post-retirement survivor-protection blocks, and the net survivor dividend. On this basis, we derive the retirement pension under the alternative LTC-integration designs, and finally analyse balance conditions both at the cohort level, at the retirement date, and at the aggregate level, in a generic calendar year t.

[4]Additional material, including an illustrative synthetic application, a comparison with previous findings, calibration data, and the proof of the main proposition are reported in the Appendices.

2.1. Demographic and Economic Foundations

We begin by characterising the distribution of contributors and wages across the population.

Following previous studies Boado-Penas and Vidal-Meliá (2014); Pla-Porcel et al. (2016); Vidal-Meliá and Boado-Penas (2013), we define the key variables and parameters as follows. Individuals enter the labour market at age x_e and contribute for A years, retiring at age $x_e + A$. Let $l_{(x_e+k,t)}$ denote the number of contributors aged $x_e + k$ in calendar year t, where $k = 0, 1, \ldots, A-1$ represents the number of years elapsed since labour market entry. Thus, the term $x_e + k$ identifies the biological age of the contributor cohort at time t.

We assume a stable population in which the relative sizes of successive cohorts remain constant over time. Under a constant annual growth rate, γ, the size of each working-age cohort evolves proportionally across calendar years. Specifically, cohort sizes scale according to

$$l_{(x_e+k,t)} = l_{(x_e+k,1)}(1+\gamma)^{t-1}. \tag{1}$$

Average age-specific wages, $y_{(x_e+k,t)}$, describe the earnings profile of contributors. We assume that wages grow at a constant real rate g, such that

$$y_{(x_e+k,t)} = y_{(x_e+k,1)}(1+g)^{t-1}. \tag{2}$$

Throughout, inflation is assumed to be zero, so that all monetary quantities are expressed in real terms. Consequently, the age–wage profile scales proportionally over time. The parameter g denotes the constant real rate of wage growth.

We assume that, following labour-market entry, death is the only source of exit from contributory status prior to retirement. The stable-growth parameter γ therefore governs the scale of entrant cohorts across calendar years, whereas, within a given birth cohort, the transition from age $x_e + k$ at time t to age $x_e + k + 1$ at time $t + 1$ is determined solely by one-year survival:

$$l_{(x_e+k+1,t+1)} = l_{(x_e+k,t)}\ {}_1p_{x_e+k}, \qquad k = 0, \ldots, A-2. \tag{3}$$

Accordingly, the number of contributors in that cohort who die between ages $x_e + k$ and $x_e + k + 1$ is

$$d_{(x_e+k,t)} = l_{(x_e+k,t)} - l_{(x_e+k+1,t+1)} = l_{(x_e+k,t)}\ {}_1q_{x_e+k}, \tag{4}$$

where ${}_1q_{x_e+k} = 1 - {}_1p_{x_e+k}$. This recursion links adjacent ages and calendar years within the same birth cohort.

2.2. LTC Contingencies

We model LTC expenditure as the product of two separable components: an age-specific benefit schedule and a common time-indexation rule. Let $C^{LTC}_{(x,1)}$ denote the LTC cash benefit associated with age x in the base year $t = 1$. The base-year schedule captures the fact that care needs, and hence LTC expenditure, increase with age.

For expositional convenience, we first introduce the LTC schedule relevant for the retirement block of the model, where direct LTC payments arise from retirement age onward. A later subsection extends the same indexed schedule to eligible survivors of contributors who die before retirement. All benefits, including pensions and LTC benefits, are assumed to be indexed at the constant rate α. Thus, for each age $x \in \{x_e + A, \ldots, \omega\}$ and calendar year t,

$$C^{LTC}_{(x,t)} = C^{LTC}_{(x,1)}(1 + \alpha)^{t-1}. \tag{5}$$

Equation 5 implies that the cross-sectional age profile of LTC expenditure is fixed in real terms in the base year and subsequently indexed at rate α. Hence, for a cohort retiring in year t, $C^{LTC}_{(x_e+A+n,t)}$ is the age-specific LTC cash amount in year-t prices, while the amount actually paid in year $t + n$ is

$$C^{LTC}_{(x_e+A+n,t+n)} = C^{LTC}_{(x_e+A+n,t)}(1 + \alpha)^n.$$

2.3. Actuarial Transformation

To convert accumulated notional capital into a lifetime annuity, we apply an actuarial divisor, denoted by AF, which reflects the expected duration of benefit payments. The divisor is constructed from cumulative survival probabilities ${}_np_{x_e+A}$, discounted by the factor $F = (1 + \alpha)/(1 + G)$, where G is the notional rate of return and α is the benefit indexation rate.

For a generic starting age x, we define the retiree-only annuity divisor as

$$AF_x = \sum_{n=0}^{\omega-x} {}_np_x \, F^n. \tag{6}$$

In particular, at retirement age $x_e + A$ this becomes

$$AF_{x_e+A} = \sum_{n=0}^{\omega-(x_e+A)} {}_np_{x_e+A} \, F^n. \tag{7}$$

For completeness, the survivor-specific annuity divisor used in the pre-retirement survivor block is defined, for a generic age x, as

$$AF_x^S = \sum_{n=0}^{\omega-x} {}_np_x^S \, F^n, \tag{8}$$

where ${}_np_x^S$ denotes the n-year continuation probability of the relevant survivor benefit.

2.4. Accumulated Notional Capital and Survivor Dividend

Following Arnold-Gaille et al. (2024) and Pla-Porcel et al. (2016), the accumulation phase can be analysed from two complementary perspectives: a cohort-based perspective, which tracks the notional capital credited to all contributors in a birth cohort, and an individual-based perspective, which isolates the capital ultimately attributable to contributors who survive until retirement.

A central point in our framework is that the notional capital released by contributors who die before retirement is not entirely available to finance additional benefits. In particular, part of this capital must be used to finance survivor pensions for eligible spouses. Therefore, only the residual component, net of pre-retirement survivor protection, can be treated as a potential source of financing for LTC expenditure.

The total notional capital accumulated by a birth cohort (K^{acT}) accounts for all contributions credited at the rate θ_α, capitalized at the system rate $G = (1+\gamma)(1+g) - 1$:

$$K^{acT}_{(x_e+A,t)} = \theta_\alpha \sum_{k=0}^{A-1} \left[l_{(x_e+k,k+t-A)} y_{(x_e+k,k+t-A)} (1+G)^{A-k} \right]. \tag{9}$$

In contrast, K^{ac} represents the capital restricted to individuals who survive until retirement age $x_e + A$:

$$K^{ac}_{(x_e+A,t)} = \theta_\alpha l_{(x_e+A,t)} \sum_{k=0}^{A-1} \left[y_{(x_e+k,k+t-A)} (1+G)^{A-k} \right]. \tag{10}$$

To account for survivor pensions attached to contributors who die before retirement, we define the individual notional capital accumulated up to age $x_e + k$ as

$$K^{ind}_{(x_e+k,\, k+t-A)} = \theta_\alpha \sum_{j=0}^{k} \left[y_{(x_e+j,\, j+t-A)} (1+G)^{k-j} \right], \qquad k = 0, \dots, A-1. \tag{11}$$

Let

$$d_{(x_e+k,\,k+t-A)} = l_{(x_e+k,\,k+t-A)} - l_{(x_e+k+1,\,k+t-A+1)} \tag{12}$$

denote the number of contributors who die between ages $x_e + k$ and $x_e + k + 1$.

We then define the actuarial value of survivor pensions generated by pre-retirement deaths as

$$SK_{(x_e+A,t)} = \sum_{k=0}^{A-1} \left[d_{(x_e+k,\,k+t-A)}\, \phi_{x_e+k}\, K^{ind}_{(x_e+k,\,k+t-A)} (1+G)^{A-k} \right], \tag{13}$$

where $\phi_{x_e+k} \in [0, 1]$ is a reduced-form actuarial coefficient, defined below, summarising at each pre-retirement age the incidence of an eligible survivor and the conversion of the deceased contributor's notional capital into a survivor annuity. Hence, $SK_{(x_e+A,t)}$ measures the portion of death-related capital absorbed by survivor protection and therefore not available to finance LTC expenditure.

Equation 13 values the cost of pre-retirement survivor protection in retirement-date equivalent capital units. For this reason, the notional capital accumulated at the age of death is projected forward to retirement through the factor $(1 + G)^{A-k}$ before entering the definition of $SK_{(x_e+A,t)}$.

$SK_{(x_e+A,t)}$ measures the retirement-date equivalent capital absorbed by pre-retirement survivor protection. Since the macro-balance is formulated in annual cash-flow terms, we also define the corresponding expenditure flow.

In particular, we account for the expenditure associated with survivor pensions and benefits paid to the eligible survivors of deceased workers, as described in the next subsection.

2.5. Pre-Retirement Survivor Benefits

In the Italian system, when an insured worker dies before retirement, eligible survivors may receive an indirect pension from the first day of the month following death, rather than from the date at which the worker would otherwise have retired. The benefit is equal to a fraction ρ of the pension that would have been payable to the deceased worker. We therefore define

$$\phi_{x_e+k} = c^{pre}_{x_e+k} \rho \frac{AF^S_{x_e+k}}{AF_{x_e+k}}, \tag{14}$$

where $c^{pre}_{x_e+k}$ denotes the probability that a contributor dying at age $x_e + k$ leaves eligible survivors, ρ is the statutory survivor-pension replacement rate, and the ratio of annuity factors reflects the difference between the expected duration of survivor benefits and that of the worker's own pension.

Let ${}_n p^S_{x_e+k}$ denote the n-year continuation probability of benefits payable to eligible survivors following a death at age $x_e + k$. Under the simplifying assumptions adopted here, we approximate this continuation probability by the survival probability of an individual aged x_{e+k}, namely,

$$ {}_n p^S_{x_e+k} = {}_n p_{x_e+k}. $$

Consider contributors aged $x_e + k$ who die in calendar year $t - n$. Each such death generates survivor benefits linked to the notional capital accumulated up to the age of death, $K^{ind}_{(x_e+k,t-n)}$. The portion of that capital absorbed by survivor protection is $\phi_{x_e+k} K^{ind}_{(x_e+k,t-n)}$. Dividing by the survivor-specific annuity factor $AF^S_{x_e+k}$ yields the initial annual survivor pension generated by a death at age $x_e + k$ in year $t - n$:

$$ \frac{\phi_{x_e+k} K^{ind}_{(x_e+k,t-n)}}{AF^S_{x_e+k}}. $$

Aggregating across ages at death and past durations yields the annual pre-retirement survivor-pension expenditure:

$$ B^{pre}_t = \sum_{k=0}^{A-1} \sum_{n=0}^{\omega-(x_e+k)} d_{(x_e+k,\,t-n)} \left(\frac{\phi_{x_e+k}\, K^{ind}_{(x_e+k,\,t-n)}}{AF^S_{x_e+k}} \right) {}_n p^S_{x_e+k}\, (1+\alpha)^n. \quad (15) $$

Equation 15 is the annual cash-flow counterpart of Equation 13: while $SK_{(x_e+A,t)}$ measures the retirement-date equivalent capital absorbed by pre-retirement survivor protection, B^{pre}_t measures the aggregate expenditure in calendar year t on survivor benefits generated by deaths occurring during the contributory period.

In this pre-retirement survivor block, we use the same age-indexed LTC schedule introduced above, but we evaluate it from the age at death onward rather than from the retirement age onward. We next extend the same block to LTC benefits paid to eligible survivors of contributors who die before retirement. For a death occurring at age $x_e + k$ in calendar year u, define the present value at the age of death of the associated LTC cash schedule as

$$ PV^{pre,LTC}_{(x_e+k,u)} = \sum_{m=0}^{\omega-(x_e+k)} {}_m p^S_{x_e+k}\, C^{LTC}_{(x_e+k+m,u)} F^m, \quad (16) $$

where m denotes the number of years elapsed since death.

The corresponding annuity-equivalent LTC charge embedded in the pre-retirement survivor annuity is

$$c^{pre,LTC}_{(x_e+k,u)} = \frac{PV^{pre,LTC}_{(x_e+k,u)}}{AF^S_{x_e+k}}. \tag{17}$$

Under EPA, the initial pre-retirement survivor annuity net of the LTC charge is therefore

$$\bar{b}^{pre,LTC}_{(x_e+k,u)} = \frac{\phi_{x_e+k} K^{ind}_{(x_e+k,u)}}{AF^S_{x_e+k}} - c^{pre,LTC}_{(x_e+k,u)}. \tag{18}$$

Equation 18 is defined for a single death at age $x_e + k$ in year u. Setting $u = t - n$ and aggregating over all working ages k and past durations n, the LTC cash expenditure paid in calendar year t to survivors of workers is

$$B^{pre,LTC}_t = \sum_{k=0}^{A-1} \sum_{n=0}^{\omega-(x_e+k)} d_{(x_e+k,\,t-n)}\, {}_np^S_{x_e+k}\, C^{LTC}_{(x_e+k+n,t)}. \tag{19}$$

Under EPA, the total pre-retirement expenditure block becomes

$$B^{pre,EPA}_t = \sum_{k=0}^{A-1} \sum_{n=0}^{\omega-(x_e+k)} d_{(x_e+k,\,t-n)} \left[\bar{b}^{pre,LTC}_{(x_e+k,t-n)}(1+\alpha)^n + C^{LTC}_{(x_e+k+n,t)}\right] {}_np^S_{x_e+k}, \tag{20}$$

whereas under LCA the pre-retirement survivor pension remains unchanged and the LTC cash term is added separately:

$$B^{pre,LCA}_t = B^{pre}_t + B^{pre,LTC}_t. \tag{21}$$

By construction, the additional LCA contribution finances $B^{pre,LTC}_t$ but is not credited to notional pension capital.

This block should be interpreted as a tractable reduced-form actuarial approximation rather than as a fully granular institutional valuation. A more exact treatment would require additional information on household composition, age differences between spouses, and detailed eligibility rules. In the present framework, these features are summarised by the single age-specific coefficient ϕ_{x_e+k}.

To compute the annuity-factor ratio in Equation (14), we assume, for simplicity, that eligible survivors, most commonly, a surviving spouse, are of the same age as the insured individual. This is consistent with the structure of the model, which uses a single set of life tables for the population as a whole. Under this assumption,

$$AF^S_{x_e+k} = AF_{x_e+k}, \tag{22}$$

so that

$$\phi_{x_e+k} = c^{pre}_{x_e+k}\rho. \tag{23}$$

The difference between the aggregate capital of the full cohort and that of contributors surviving to retirement is interpreted as a *gross* survivor dividend:

$$SD^{gross}_{(x_e+A,t)} = K^{acT}_{(x_e+A,t)} - K^{ac}_{(x_e+A,t)}. \tag{24}$$

The amount effectively available for redistribution within the cohort is the *net* survivor dividend, obtained after deducting the actuarial value of survivor pensions attached to pre-retirement deaths:

$$SD^{net}_{(x_e+A,t)} = SD^{gross}_{(x_e+A,t)} - SK_{(x_e+A,t)}. \tag{25}$$

Hence, unlike in the standard NDC framework, only SD^{net} can be redistributed within the cohort or allocated to LTC financing. The corresponding *Dividend Effect* is

$$D_e = \frac{SD^{net}}{K^{ac}}.$$

2.6. Post-Retirement Survivor Benefits

To account for survivor pensions paid after the death of a pensioner, we modify the standard actuarial framework by introducing equivalent payment survival probabilities that reflect the continuation of a reduced benefit to the surviving spouse.

Let c_{x_e+A} be the probability that the pensioner has eligible survivors at retirement. Note that the parameters $c^{pre}_{x_e+k}$ and c_{x_e+A} capture related but distinct demographic probabilities. In general, these two quantities need not coincide, although they may be set equal in simplified calibrations.

For tractability, we impose the following simplifying assumptions: (i) the eligible survivor to whom the pension reverts, typically a surviving spouse, is of the same age as the pensioner at retirement; (ii) the lifetimes of the pensioner and the survivor are independent; and (iii) both follow the same mortality law.

Let ${}_np_x$ denote the n-year survival probability of an individual aged x, and ${}_1q_x = 1 - {}_1p_x$ the corresponding one-year death probability. For $n \geq 1$, the expected payment at duration n from retirement can be decomposed into two mutually exclusive components: (i) the pensioner is alive at time n, in which case the full pension is paid; and (ii) the pensioner dies during the year $(s, s+1]$ for some $s = 0, \ldots, n-1$, while the eligible survivor survives until time n, in which case a reduced pension equal to a fraction r of the original benefit is paid.

Under the above assumptions, the probability that the pensioner survives s years, dies during the following year, and that the spouse remains alive until time n is

$$ {}_sp_{x_e+A} \cdot {}_1q_{x_e+A+s} \cdot {}_np_{x_e+A}. $$

Summing over all possible years of death of the pensioner before n, and weighting by the probability of having an eligible spouse and by the benefit reduction factor r, we obtain the equivalent payment survival probability:

$$ \begin{aligned} {}_n\tilde{p}_{x_e+A} &= {}_np_{x_e+A} + r\, c_{x_e+A} \sum_{s=0}^{n-1} {}_sp_{x_e+A}\ {}_1q_{x_e+A+s}\ {}_np_{x_e+A}, \qquad n \geq 1 \\ &= {}_np_{x_e+A} \left[1 + r\, c_{x_e+A} \sum_{s=0}^{n-1} {}_sp_{x_e+A}\ {}_1q_{x_e+A+s} \right]. \end{aligned} \tag{26} $$

Under the same assumptions, the summation term is the probability that the pensioner dies within the first n years after retirement, namely

$$ \sum_{s=0}^{n-1} {}_sp_{x_e+A}\, {}_1q_{x_e+A+s} = 1 - {}_np_{x_e+A}. $$

Hence Equation 26 can also be written as

$$ {}_n\tilde{p}_{x_e+A} = {}_np_{x_e+A} \left[1 + r\, c_{x_e+A} \left(1 - {}_np_{x_e+A} \right) \right], \qquad n \geq 1. $$

By convention, the equivalent payment survival probability at retirement is

$$ {}_0\tilde{p}_{x_e+A} = 1. $$

We use these adjusted survival probabilities in place of the standard survival probability in the definition of the pension annuity divisor, ensuring that the present value of pension benefits correctly reflects the presence of survivor benefits. The pension annuity divisor is therefore replaced by

$$AF^{SP}_{x_e+A} = \sum_{n=0}^{\omega-(x_e+A)} {}_n\tilde{p}_{x_e+A}\, F^n. \tag{27}$$

Because we now allow the eligible survivors of a pensioner to receive the LTC cash benefit C^{LTC} as well, it is useful to distinguish the pension-payment probability from the LTC-payment probability. For $n \geq 1$, let

$${}_n s_{x_e+A} = c_{x_e+A} \sum_{s=0}^{n-1} {}_s p_{x_e+A}\, {}_1 q_{x_e+A+s}\, {}_n p_{x_e+A} = c_{x_e+A}\, {}_n p_{x_e+A} \Big(1 - {}_n p_{x_e+A}\Big)$$

denote the probability that the pensioner has died before duration n and that an eligible survivor is still alive at that duration. We then define the LTC-payment probability by

$${}_n\pi^{LTC}_{x_e+A} = {}_n p_{x_e+A} + {}_n s_{x_e+A} = {}_n p_{x_e+A} \left[1 + c_{x_e+A}\Big(1 - {}_n p_{x_e+A}\Big)\right], \qquad n \geq 1, \tag{28}$$

with ${}_0\pi^{LTC}_{x_e+A} = 1$ by convention. Thus, ${}_n\pi^{LTC}_{x_e+A}$ captures the expected incidence of the LTC cash payment at duration n, irrespective of whether the payment is made to the retiree or, after the retiree's death, to an eligible survivor.

2.7. Estimating the Initial Pension Benefit

Once notional capital has been accumulated, it is converted into a lifetime annuity using the adjusted annuity divisor AF^{SP} in Equation 27, which incorporates survivor pensions paid after the death of the pensioner. We begin by defining the retirement pension in the absence of LTC under the *cohort-based* and *individual-based* approaches. We then consider two alternative LTC integration designs. Under Enhanced Pension Annuities (EPA), LTC is financed through an annuity-equivalent deduction from the pension paid while the retiree is alive. Under Life Care Annuities (LCA), by contrast, LTC is financed through an additional contribution rate, leaving the retirement pension formula unchanged.

2.7.1. Retirement Pension without LTC

Under the cohort-based approach, we pool the capital accumulated by contributors surviving to retirement together with the redistributable *net* survivor dividend and distribute it among retirees who are alive at retirement.

In the notation that follows, the superscript a refers to the state in which the retiree is alive and directly receives the retirement pension:

$$\bar{p}^{(a,co)}_{(x_e+A,t)} = \frac{K^{ac}_{(x_e+A,t)} + SD^{net}_{(x_e+A,t)}}{l_{(x_e+A,t)} AF^{SP}_{x_e+A}} = \frac{K^{acT}_{(x_e+A,t)} - SK_{(x_e+A,t)}}{l_{(x_e+A,t)} AF^{SP}_{x_e+A}}. \tag{29}$$

Conversely, the individual-based approach determines the pension benefit solely from the capital accumulated by survivors (K^{ac}), excluding any intra-cohort redistribution:

$$\bar{p}^{(a,ind)}_{(x_e+A,t)} = \frac{K^{ac}_{(x_e+A,t)}}{l_{(x_e+A,t)} AF^{SP}_{x_e+A}}. \tag{30}$$

In this framework, only the net survivor dividend defined in Equation 25 represents the amount of capital that can be redistributed within the surviving cohort.

2.7.2. LTC integration under EPA

Under EPA, LTC is integrated directly into the pension annuity through an actuarial deduction from the initial pension benefit. Hence, unlike LCA, the financing of LTC operates through a lower pension paid while the retiree is alive rather than through an additional contribution rate.

The present value of expected LTC expenditures for a retiree who enters retirement in year t is obtained by weighting the age-specific LTC benefit profile by the LTC-payment probabilities in Equation 28 and discounting using the factor F:

$$PV^{LTC}_t = \sum_{n=0}^{\omega-(x_e+A)} {}_n\pi^{LTC}_{x_e+A} C^{LTC}_{(x_e+A+n,t)} F^n. \tag{31}$$

Equivalently, using Equation 5, one may write

$$PV^{LTC}_t = \sum_{n=0}^{\omega-(x_e+A)} {}_n\pi^{LTC}_{x_e+A} \frac{C^{LTC}_{(x_e+A+n,t+n)}}{(1+G)^n}.$$

The annuity-equivalent LTC amount is therefore derived as

$$c^{LTC}_t = \frac{PV^{LTC}_t}{AF_{x_e+A}}.$$

Thus, the annuity conversion continues to use the retiree-only divisor AF_{x_e+A}, because under EPA the LTC charge is deducted from the pension paid while the retiree is alive, even though the underlying present value PV_t^{LTC} now internalizes the LTC cash benefits paid both to the retiree and to the surviving spouse of a pensioner.

Under the EPA scheme, the initial pension that integrates LTC for an individual who is retired and alive (a), computed using the cohort-based approach, is denoted as $\bar{p}_{(x_e+A,t)}^{(a,LTC,co)}$. It is defined as the difference between the cohort-based retirement-only pension (Equation 29) and the annuity-equivalent LTC cost, c_t^{LTC}:

$$\bar{p}_{(x_e+A,t)}^{(a,LTC,co)} = \bar{p}_{(x_e+A,t)}^{(a,co)} - c_t^{LTC}. \tag{32}$$

The initial pension that incorporates LTC for retired individuals alive at age $x_e + A$, derived under the individual-based approach, is defined as $\bar{p}_{(x_e+A,t)}^{(a,LTC,ind)}$. It is obtained by subtracting the annuity-equivalent LTC cost, c_t^{LTC}, from the individual-based retirement-only pension (Equation 30):

$$\bar{p}_{(x_e+A,t)}^{(a,LTC,ind)} = \bar{p}_{(x_e+A,t)}^{(a,ind)} - c_t^{LTC}. \tag{33}$$

Under this specification, the LTC deduction continues to apply only to pension payments made while the retiree is alive. If the retiree dies and an eligible spouse survives, the survivor pension continues to be computed as a fraction r of the retirement-only pension defined in Equation 29 or Equation 30; it is therefore not reduced by the LTC deduction c_t^{LTC}. However, the calibration of c_t^{LTC} now internalizes the expected LTC cash benefit paid both to the retiree and, after the retiree's death, to the surviving spouse through Equation 28.

Under the individual-based approach, the net survivor dividend SD^{net} is not automatically redistributed across retirees. Instead, after deducting the actuarial cost of pre-retirement survivor pensions through SK, the residual amount (SD^{net}) can be allocated to LTC financing during retirement.

Accordingly, the share of the survivor dividend attributable to LTC integration is defined as the proportion of the total SD^{net} that can be used to offset the additional contribution burden implied by the LTC financing scheme. Formally,

$$SD_{(x_e+A,t)}^{\mathrm{LTC}} = \begin{cases} \min\left\{1,\ \dfrac{PV_t^{\mathrm{LTC}}\, l_{(x_e+A,t)}}{SD_{(x_e+A,t)}^{net}}\right\}, & \text{if } SD_{(x_e+A,t)}^{net} > 0, \\ 0, & \text{if } SD_{(x_e+A,t)}^{net} \leq 0. \end{cases} \tag{34}$$

This definition ensures that the portion of the survivor dividend allocated to LTC financing cannot exceed the total SD^{net}, while allowing for partial coverage when LTC costs are lower than the available SD^{net}. If SD^{net} is non-positive, no LTC financing can be attributed to it.

If LTC is entirely financed by SD^{net}, the average initial pension without LTC under the SD-related specification coincides with the individual-based retirement-only pension, namely

$$\bar{p}^{(a,ind,SD)}_{(x_e+A,t)} = \bar{p}^{(a,ind)}_{(x_e+A,t)}.$$

When LTC is integrated under the LTC-related SD specification, the initial pension payable while the retiree is alive is obtained by adding to $\bar{p}^{(a,LTC,ind)}_{(x_e+A,t)}$ the annuity-equivalent value of the survivor dividend allocated to LTC coverage:

$$\bar{p}^{(a,LTC,ind,SD)}_{(x_e+A,t)} = \bar{p}^{(a,ind)}_{(x_e+A,t)} - c^{LTC}_t + \frac{SD^{\mathrm{LTC}}_{(x_e+A,t)} SD^{net}_{(x_e+A,t)}}{l_{(x_e+A,t)} AF_{x_e+A}}. \tag{35}$$

The denominator in Equation 35 remains AF_{x_e+A} rather than $AF^{SP}_{x_e+A}$ because this term converts survivor-dividend resources into a retiree-only annuity equivalent that offsets LTC expenditure during periods in which the retiree is alive; it is not intended to finance post-death survivor-pension payments. Consistently with the previous paragraph, this LTC-related adjustment does not modify the survivor pension that may continue after the retiree's death.

For notational convenience, we classify the alternative average pension measures into two groups. The notation $\bar{p}^{(a,\cdot)}_{(x_e+A,t)}$ denotes initial pension measures in the absence of LTC, including $\bar{p}^{(a,co)}_{(x_e+A,t)}$, $\bar{p}^{(a,ind)}_{(x_e+A,t)}$, and $\bar{p}^{(a,ind,SD)}_{(x_e+A,t)}$. Conversely, $\bar{p}^{(a,LTC,\cdot)}_{(x_e+A,t)}$ refers to initial pension measures that incorporate LTC, namely $\bar{p}^{(a,LTC,co)}_{(x_e+A,t)}$, $\bar{p}^{(a,LTC,ind)}_{(x_e+A,t)}$, and $\bar{p}^{(a,LTC,ind,SD)}_{(x_e+A,t)}$.

2.7.3. LTC integration under LCA

Under LCA, LTC is financed through a dedicated contribution add-on and not through a reduction in the pension benefit. Accordingly, the base retirement pension remains exactly the same as in the benchmark without LTC and continues to be determined exclusively by the pension contribution credited to the notional account. In other words, under LCA the integration of LTC does not modify the pension formula: it introduces a separate financing component for LTC while leaving the retirement pension unchanged.

We then calculate the LTC contribution rate θ_α^{LTC} by adjusting the baseline contribution rate θ_α according to the coverage ratio (CR), defined as the ratio between the retirement-only pension and its LTC-adjusted actuarial counterpart used solely to measure the LTC financing requirement. The value of CR varies according to the average pension estimation approach adopted. To cover all specifications, let

$$\delta_{(x_e+A,t)}^{LTC} = \bar{p}_{(x_e+A,t)}^{(a,\cdot)} - \bar{p}_{(x_e+A,t)}^{(a,LTC,\cdot)}$$

denote the uncovered retiree-only annuity component that must be financed through the additional LCA contribution under the relevant specification. Under the no-SD and full-SD specifications, this reduces to $\delta_{(x_e+A,t)}^{LTC} = c_t^{LTC}$, while under the LTC-related SD specification it becomes

$$\delta_{(x_e+A,t)}^{LTC} = c_t^{LTC} - \frac{SD_{(x_e+A,t)}^{\text{LTC}} SD_{(x_e+A,t)}^{net}}{l_{(x_e+A,t)} AF_{x_e+A}}.$$

In all cases,

$$\frac{\delta_{(x_e+A,t)}^{LTC}}{\bar{p}_{(x_e+A,t)}^{(a,\cdot)}} = \frac{CR-1}{CR}.$$

Note that, under the LCA design, $\delta_{(x_e+A,t)}^{LTC}$ should be interpreted only as an actuarial measure of the LTC component to be financed through the additional contribution. It does not represent a reduction in the pension actually paid under LCA. Unlike EPA, where LTC is internalized through a lower initial pension, LCA preserves the retirement pension and finances LTC through a separate contribution flow.

Because the pension benefit itself is obtained by converting accumulated capital with divisor $AF_{x_e+A}^{SP}$, whereas the additional LCA contribution finances a retiree-only annuity converted with AF_{x_e+A}, the required contribution-rate adjustment is

$$\theta_\alpha^{LTC} = \theta_\alpha \left(1 + \frac{CR-1}{CR} \frac{AF_{x_e+A}}{AF_{x_e+A}^{SP}}\right) \tag{36}$$

which reduces, in the special case $AF_{x_e+A} = AF_{x_e+A}^{SP}$, to $\theta_\alpha^{LTC} = \theta_\alpha \left(1 + \frac{CR-1}{CR}\right)$.

Equation 36 determines the total contribution rate required to finance LTC under LCA. Importantly, it does not alter the pension benefit formula. The retirement pension remains the benchmark pension determined by θ_α, while the difference $\theta_\alpha^{LTC} - \theta_\alpha$ identifies the separate contribution needed to finance LTC expenditure.

For the LCA design, the total contribution rate can be decomposed as

$$\theta_\alpha^{LTC} = \theta_\alpha + \eta_\alpha^{LTC},$$

where θ_α is the pension contribution credited to notional accounts and η_α^{LTC} is a separate LTC contribution. Only θ_α enters the accumulation formulas K^{acT}, K^{ac}, and K^{ind}, the pre-retirement survivor annuity in Equation 15, and the pension formulas in Equations 29 and 30. By construction, η_α^{LTC} does not generate additional pension rights and does not modify either direct pensions or survivor pensions. It finances only the LTC expenditure explicitly modelled in the framework. Crucially, the LTC contribution add-on is not credited to notional pension capital and therefore must not mechanically increase either the pension base or the survivor-pension base through a higher contribution rate.

For LCA purposes, the coverage ratio is only a valuation device used to map the LTC annuity-equivalent into an additional contribution requirement; it does not define the pension actually paid under LCA. In the cohort-based specification, the coverage ratio is computed as

$$CR = \frac{\bar{p}_{(x_e+A,t)}^{(a,co)}}{\bar{p}_{(x_e+A,t)}^{(a,LTC,co)}},$$

while in the individual-based specification the same expression applies with the superscript *co* replaced by *ind*.

Under the LTC-related SD specification, the denominator additionally incorporates the annuity-equivalent survivor-dividend component allocated to LTC (Equation 35), so that CR is defined consistently with the SD-adjusted pension measure. Accordingly, $(CR - 1)/CR$ captures the fraction of the retirement-only pension corresponding to the residual LTC annuity that remains to be financed after the SD allocation. Since pre-retirement survivor protection reduces the redistributable amount from SD^{gross} to SD^{net}, the LCA adjustment required to finance LTC is likewise computed net of the actuarial cost of survivor pensions attached to deceased workers.

2.8. Cohort Equilibrium at the Retirement Date

Two notions of balance are relevant in this framework. The first is *cohort balance*, evaluated at the date on which a given birth cohort reaches retirement; it compares the total notional capital generated by that cohort with the retirement-date equivalent value of all benefits generated by the same cohort, including survivor-related LTC extensions. The second is *macro-balance*, evaluated for a given calendar year t; it compares the contributions collected in that year from all working cohorts with the pension, survivor-pension, and LTC expenditure paid in that same year to all cohorts simultaneously present in the system. We first consider cohort balance and then turn to macro-balance in the next subsection.

In the present subsection, t denotes the calendar year in which the cohort reaches retirement age $x_e + A$. The relevant accounting object is therefore an *intertemporal cohort balance* written at the retirement date. On the revenue side stands the total notional capital generated by the cohort and capitalized to age $x_e + A$, namely $K^{acT}_{(x_e+A,t)}$. On the expenditure side stand all benefits generated by that same cohort, evaluated at the same date.

2.8.1. Baseline Cohort Balance

Because Equation 29 implies

$$l_{(x_e+A,t)}\, \bar{p}^{(a,co)}_{(x_e+A,t)}\, AF^{SP}_{x_e+A} = K^{acT}_{(x_e+A,t)} - SK_{(x_e+A,t)},$$

the retirement-date equivalent value of direct pensions and post-retirement survivor pensions is exactly the residual cohort capital left after financing pre-retirement survivor protection. Hence the baseline cohort balance can be written as

$$K^{acT}_{(x_e+A,t)} = SK_{(x_e+A,t)} + l_{(x_e+A,t)}\, \bar{p}^{(a,co)}_{(x_e+A,t)}\, AF^{SP}_{x_e+A}. \tag{37}$$

Equation 37 states that, once all flows are valued at the retirement date, the total capital collected from the cohort is exactly equal to the total pension expenditure generated by that cohort, inclusive of survivor pensions before and after retirement.

2.8.2. Cohort Balance under EPA

Under EPA, a key feature is that the pre-retirement LTC benefit paid to eligible survivors of deceased workers is financed within the same death-contingent capital block that generates the pre-retirement survivor annuity. Hence its retirement-date equivalent value is already embedded in $SK_{(x_e+A,t)}$ and must not be added separately to the cohort balance.

Indeed, for a death occurring at age $x_e + k$ in year u, Equations 18 and 16 imply

$$\bar{b}^{pre,LTC}_{(x_e+k,u)} AF^{S}_{x_e+k} + PV^{pre,LTC}_{(x_e+k,u)} = \phi_{x_e+k} K^{ind}_{(x_e+k,u)}.$$

Thus the same death-contingent capital block $\phi_{x_e+k} K^{ind}_{(x_e+k,u)}$ finances both the pre-retirement survivor annuity net of LTC and the associated LTC cash schedule. Aggregating across deaths and projecting to age $x_e + A$ yields exactly $SK_{(x_e+A,t)}$. This is why no separate pre-retirement LTC term appears in Equation 37 or in the EPA decomposition below.

When LTC is integrated through the EPA design, the same identity can be decomposed so as to display separately the three post-retirement expenditure channels. Let AF_{x_e+A} denote the retiree-only annuity factor in Equation 7. Then the present value at retirement of direct pensions paid while the retiree is alive is $l_{(x_e+A,t)}\, \bar{p}^{(a,LTC,co)}_{(x_e+A,t)} AF_{x_e+A}$, the value of survivor pensions paid after the retiree's death is $l_{(x_e+A,t)}\, \bar{p}^{(a,co)}_{(x_e+A,t)} \Big(AF^{SP}_{x_e+A} - AF_{x_e+A} \Big)$, and the value of LTC expenditure paid either to the retiree or, after the retiree's death, to the surviving spouse is $l_{(x_e+A,t)} PV^{LTC}_t$. Therefore,

$$K^{acT}_{(x_e+A,t)} = SK_{(x_e+A,t)} + l_{(x_e+A,t)} \Big[\bar{p}^{(a,LTC,co)}_{(x_e+A,t)} AF_{x_e+A} + \bar{p}^{(a,co)}_{(x_e+A,t)} \Big(AF^{SP}_{x_e+A} - AF_{x_e+A} \Big) + PV^{LTC}_t \Big]. \quad (38)$$

Now substitute Equation 32, namely

$$\bar{p}^{(a,LTC,co)}_{(x_e+A,t)} = \bar{p}^{(a,co)}_{(x_e+A,t)} - c^{LTC}_t,$$

and the identity $PV^{LTC}_t = c^{LTC}_t AF_{x_e+A}$. The bracketed term in Equation 38 becomes

$$\begin{aligned}
&\bar{p}^{(a,LTC,co)}_{(x_e+A,t)} AF_{x_e+A} + \bar{p}^{(a,co)}_{(x_e+A,t)} \Big(AF^{SP}_{x_e+A} - AF_{x_e+A} \Big) + PV^{LTC}_t \\
&= \Big(\bar{p}^{(a,co)}_{(x_e+A,t)} - c^{LTC}_t \Big) AF_{x_e+A} + \bar{p}^{(a,co)}_{(x_e+A,t)} \Big(AF^{SP}_{x_e+A} - AF_{x_e+A} \Big) + c^{LTC}_t AF_{x_e+A} \\
&= \bar{p}^{(a,co)}_{(x_e+A,t)} AF_{x_e+A} - c^{LTC}_t AF_{x_e+A} + \bar{p}^{(a,co)}_{(x_e+A,t)} \Big(AF^{SP}_{x_e+A} - AF_{x_e+A} \Big) + c^{LTC}_t AF_{x_e+A} \\
&= \bar{p}^{(a,co)}_{(x_e+A,t)} AF^{SP}_{x_e+A}.
\end{aligned}$$

Hence Equation 38 becomes

$$K^{acT}_{(x_e+A,t)} = SK_{(x_e+A,t)} + l_{(x_e+A,t)}\, \bar{p}^{(a,co)}_{(x_e+A,t)} AF^{SP}_{x_e+A},$$

which is exactly Equation 37. Thus, under EPA, the total amount collected from the cohort and capitalized at retirement is exactly equal to the total amount paid to that cohort in the form of direct pensions, survivor pensions, and LTC.

2.8.3. Cohort Balance under LCA

Under LCA, the retirement-only pension remains $\bar{p}^{(a,co)}_{(x_e+A,t)}$, and LTC is financed through an additional contribution component rather than through a deduction from the pension annuity. Accordingly, cohort balance is restored only after adding to the revenue side the retirement-date equivalent value of the dedicated LTC contributions financing all LTC obligations generated by the cohort, namely both the post-retirement LTC schedule and the LTC schedule associated with deaths before retirement. The substantive conclusion is nonetheless the same under both designs: once the financing source is aligned with the institutional mechanism (an internal annuity deduction under EPA and a dedicated LTC contribution under LCA) cohort-level accounting remains actuarially closed. More specifically, under LCA the cohort pension balance itself is unchanged relative to the no-LTC benchmark: what changes is that an additional LTC financing layer is added to cover the LTC expenditure generated by the same cohort. Thus, balance is restored through an extra contribution component, not through a modification of the pension formula.

2.9. Macro-Balance in a Generic Calendar Year

In this subsection, t denotes a generic calendar year. Let us define $R = x_e + A$ and $N = \omega - R$. Macro-balance is formulated as an *annual cash-flow identity* across all working and retired cohorts simultaneously present in year t. We first introduce the common cash-flow structure and the benchmark identity without LTC, and then distinguish between the EPA and LCA designs, which differ in how LTC expenditure is financed at the aggregate level. For the cohort that retired in year $t - n$, the indexed pension paid in year t is $\bar{p}_{t-n}(1 + \alpha)^n$, whereas LTC expenditure is measured through the age-specific cash amount $C^{LTC}_{(R+n,t)}$.

The macro-balance expressions below are written for the cohort-based pension specification, hence the superscript *co*. The same cash-flow logic applies to the alternative pension specifications after replacing *co* by the appropriate pension measure in the relevant retirement-pension terms, namely *ind* under the individual-based approach and ind, SD under the LTC-related SD specification when applicable. In particular, the post-retirement survivor-pension term must remain linked to the retirement-only pension base of the chosen specification, whereas any LTC deduction or SD-based LTC offset affects only the pension paid while the retiree is alive. By contrast, the LTC cash amount C^{LTC} is paid both in the retiree-alive state and in the eligible-survivor state, so the corresponding macro-balance term must be weighted by ${}_n\pi_R^{LTC}$ rather than by ${}_np_R$ alone.

Let

$$W_t = \sum_{k=0}^{A-1} l_{(x_e+k,t)}\, y_{(x_e+k,t)}$$

denote aggregate contributory payroll in year t.

In the benchmark economy, macro-balance is interpreted as a maintained calibration condition: the contribution rate in force is assumed to coincide with the macro-balancing rate implied by the expenditure side of the model. Under this interpretation, macro-balance holds with $\theta_t = \theta_\alpha$ only if the benchmark contribution rate is calibrated so that aggregate revenues equal aggregate expenditures.

Since contributions finance all benefits actually paid in year t, the expenditure side must include four components: (i) pension payments to retirees alive in year t; (ii) survivor pensions paid after the death of a pensioner; (iii) LTC benefits paid either to retirees alive or to eligible survivors of pensioners in year t; and (iv) the pre-retirement survivor block generated by deaths before retirement. Under EPA this last component is denoted by $B_t^{pre,EPA}$ in Equation 20, whereas under LCA it is denoted by $B_t^{pre,LCA}$ in Equation 21.

2.9.1. Benchmark Macro-Balance without LTC Integration

In the benchmark without LTC, but allowing for post-retirement survivor pensions through $\tilde{p}$, macro-balance at contribution rate θ_α requires that, for every calendar year t,

$$\theta_\alpha W_t = \sum_{n=0}^{N} \left[\bar{p}_{t-n}^{(a,co)}(1+\alpha)^n\, {}_np_R + \bar{p}_{t-n}^{(a,co)}(1+\alpha)^n \left({}_n\tilde{p}_R - {}_np_R\right)\right] l_{(R,t-n)} + B_t^{pre}. \quad (39)$$

This benchmark identity provides the reference point for the EPA result stated below.

2.9.2. EPA Macro-Balance

Under EPA, the pension paid while the retiree is alive is reduced at retirement by the annuity-equivalent LTC charge, but annual macro-balance must still record the actual LTC cash expenditure profile, including LTC benefits paid to eligible survivors of both pensioners and workers. The corresponding annual cash-flow identity is therefore:

$$\theta_t W_t = \sum_{n=0}^{N} \Big[\bar{p}_{t-n}^{(a,LTC,co)} (1+\alpha)^n \, {}_n p_R + \bar{p}_{t-n}^{(a,co)} (1+\alpha)^n \left({}_n\tilde{p}_R - {}_n p_R \right) + C_{(R+n,t)}^{LTC} \, {}_n\pi_R^{LTC} \Big] l_{(R,t-n)} + B_t^{pre,EPA}. \tag{40}$$

The first term captures pension payments made while the retiree is alive, the second term captures survivor-pension payments after the retiree's death, the third term captures LTC expenditure actually paid in year t either to the retiree or to an eligible survivor of a pensioner, and $B_t^{pre,EPA}$ captures the pre-retirement survivor block generated by deaths before retirement, inclusive of survivor-related LTC expenditure.

Unlike the annuity-equivalent representation, Equation 40 cannot in general be collapsed into a single retirement-pension term based on ${}_n\tilde{p}_R$. The reason is twofold. First, the annual LTC cash outlay $C_{(R+n,t)}^{LTC}$ need not coincide, year by year, with the indexed annuity deduction embedded in $\bar{p}_{t-n}^{(a,LTC,co)}$. Second, LTC incidence is governed by ${}_n\pi_R^{LTC}$ rather than by the pension-payment probability ${}_n\tilde{p}_R$. Thus EPA preserves actuarial equivalence over the retirement horizon, but not necessarily equality of every calendar-year cash flow.

The corresponding EPA system imbalance under the cash-flow convention is defined as

$$\Delta_t^{EPA} = \theta_t W_t - \sum_{n=0}^{N} \Big[\bar{p}_{t-n}^{(a,LTC,co)} (1+\alpha)^n \, {}_n p_R + \bar{p}_{t-n}^{(a,co)} (1+\alpha)^n \left({}_n\tilde{p}_R - {}_n p_R \right) + C_{(R+n,t)}^{LTC} \, {}_n\pi_R^{LTC} \Big] l_{(R,t-n)} - B_t^{pre,EPA}. \tag{41}$$

Hence $\Delta_t^{EPA} = 0$ denotes macro-balance, $\Delta_t^{EPA} > 0$ a surplus, and $\Delta_t^{EPA} < 0$ a deficit under the EPA design.

The following proposition shows that, under $\alpha = g$, this imbalance differs from zero only when the contribution rate applied in year t differs from the benchmark rate θ_α.

Proposition 1 (EPA macro-balance under $\alpha = g$)**.** *Assume that Equation 39 holds and that $\alpha = g$. Then, for every calendar year t,*

$$\Delta_t^{EPA} = (\theta_t - \theta_\alpha) W_t. \tag{42}$$

Consequently, if $\theta_t = \theta_\alpha$, then $\Delta_t^{EPA} = 0$ for every t [5].

No analogous invariance result generally holds under LCA, because LTC is financed through an explicit contribution add-on rather than through an internal annuity deduction.

2.9.3. LCA Macro-Balance

Under LCA, by contrast, the retirement-only pension continues to coincide with the benchmark pension without LTC, while LTC expenditure appears as an additional cash outlay in calendar year t financed by the contribution add-on η_α^{LTC}. The corresponding annual system imbalance is therefore

$$\begin{aligned}\Delta_t^{LCA} = \theta_t\, W_t - \sum_{n=0}^{N} \Big[\bar{p}_{t-n}^{(a,co)}(1+\alpha)^n\, {}_n p_R + \bar{p}_{t-n}^{(a,co)}(1+\alpha)^n \left({}_n\tilde{p}_R - {}_n p_R \right) \\ + C_{(R+n,t)}^{LTC}\, {}_n\pi_R^{LTC} \Big]\, l_{(R,t-n)} - B_t^{pre,LCA}.\end{aligned} \tag{43}$$

Hence $\Delta_t^{LCA} = 0$ denotes macro-balance, $\Delta_t^{LCA} > 0$ a surplus, and $\Delta_t^{LCA} < 0$ a deficit under the LCA design. In this case, maintaining balance generally requires a contribution rate above the benchmark level, captured by $\theta_\alpha^{LTC} = \theta_\alpha + \eta_\alpha^{LTC}$. The add-on η_α^{LTC} finances LTC only and must therefore not be credited either to the pension base of workers or to the survivor pensions generated by workers who die before retirement.

Finally, with pre-retirement survivor pensions, annual macro-balance must include the expenditure term B_t^{pre} in addition to the year-t retirement, survivor, and LTC outlays defined above, while the capital available for redistribution within the working cohort is reduced from SD^{gross} to SD^{net} by the term $SK_{(x_e+A,t)}$. Accordingly, any comparison between scenarios with and without survivor-dividend redistribution should be understood as referring to the redistribution of SD^{net}, rather than of the full gross capital released by pre-retirement deaths.

3. Results

This section presents the calibration and main numerical results for the Italian case. For validation and transparency, Appendix A reports an illustrative application of the model to a synthetic population and shows that

[5] A formal derivation is provided in Section Appendix D.

the resulting patterns are consistent with those documented in the literature. Here, we present results from the model calibrated to Italian administrative data to quantify the fiscal implications of integrating LTC into the NDC pension system under alternative SD allocation rules.

3.1. Model Calibration and Data Inputs

As in Pla-Porcel et al. (2016) and Boado-Penas and Vidal-Meliá (2014), we construct a stable cross-section of contributors by age. Our starting population consists of 257,845 workers – private employees, public employees, and the self-employed – drawn from administrative records of the Italian National Social Security Institute (INPS), who entered the labour market at the official average entry age, $x_e = 22$ in 2025.[6]

Equation 1 is then used to project this population up to retirement, set at $x_e + A = 65$.[7] In the baseline calibration, we set $\gamma = 0$ and use the latest official cumulative survival probabilities for 2024 provided by the Italian National Institute of Statistics, ISTAT (2024). These probabilities are used both to project cohort survival up to retirement and to convert accumulated contributions into pension annuities.

The cross-sectional age–wage distribution observed in 2025 from administrative INPS data is used as the baseline earnings profile.[8] Wages are assumed to grow annually at $g = 0.7\%$, consistent with the long-term real GDP growth assumptions adopted in the latest projections by the Italian Ministry of Economy and Finance (RGS, 2025) and the European Commission's Ageing Working Group (EPC, 2024). Inflation α is set to zero, so all monetary values are expressed in constant real terms, and each age-specific wage is projected forward by applying cumulative real growth.

[6]Italy shows a markedly late transition from education to employment. Although some international literature uses 16 as a theoretical entry age, this benchmark does not reflect Italian labour-market behaviour. Official data indicate that young people in Italy start working significantly later. For these reasons, we adopt 22 as a realistic assumption and consider sensitivity checks of ± 2 years.

[7]According to the most recent INPS Annual Report (INPS, 2024), the average effective retirement age in Italy is about 64.8 years. This value reflects a weighted average of old-age and early-retirement pathways and therefore captures the actual exit age rather than statutory requirements. The effective retirement age has been gradually increasing and is expected to continue rising.

[8]See Appendix C for details.

We next calibrate the pre-retirement survivor-protection component of the model, that is, the indirect pension rights generated when an insured worker dies before retirement and leaves eligible survivors. In the Italian benchmark, this component is mapped into the case of a surviving spouse. This choice is consistent with the institutional structure of survivor pensions, in which the spouse is the primary reference beneficiary, and with the statutory replacement rate of 60% applying to the case of spouse only. We proxy $c^{pre}_{x_e+k}$ using official data from the Italian National Institute of Statistics (ISTAT, 2024). For simplicity, we adopt a constant benchmark value that does not vary with age. To avoid understating the probability of leaving an eligible survivor, the calibration is based on central working ages rather than on the full contributory span beginning at labour-market entry, since marriage rates are markedly lower at younger ages. Aggregating the 35–64 age classes in the 2024 downloadable files yields a married-to-total ratio of approximately 64.8%. Accordingly, we set

$$c^{pre}_{x_e+k} = c^{pre} = 0.65.$$

Substituting these benchmark values into Equation (23) yields

$$\phi_{x_e+k} \approx 0.65 \times 0.60 \approx 0.39.$$

Furthermore, for the fraction of the pension payable to survivors of a deceased pensioner, we set

$$r = 0.6,$$

consistently with the institutional features of the Italian pension system. This is the benchmark replacement rate for a surviving spouse in the absence of dependent children. Although actual survivor benefits may vary with household composition and income conditions, this value provides a reasonable approximation in a simplified actuarial framework.

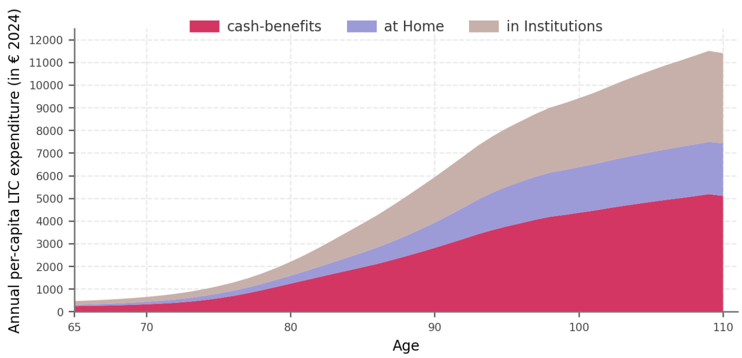
Finally, for simplicity, the probability that a retiree has eligible survivors at retirement is set equal to its pre-retirement counterpart:

$$c_{x_e+A} = c^{pre} = 0.65.$$

Contribution rate θ_α is set at 29.00%, which reflects the weighted average of the effective social-security contribution rate across the main worker categories in Italy.[9]

[9]The statutory contribution rate for private and public sectors employees is 33.00%.

Figure 1: Annual per-capita LTC expenditure (in € 2024) by age and LTC macro-functions



The figure shows the 2024 LTC age gradients by SHA macro-functions. LTC spending rises gradually after age 65 and accelerates sharply from around age 80, mirroring the steep increase in LTC needs at advanced ages. Cash benefits constitute the largest component of LTC expenditure, reflecting the Italian system's strong reliance on cash-based support, while institutional care spending is heavily concentrated at the oldest ages.
Source: Authors' elaboration based on gender-specific RGS 2025 data (Figure 4.7), smoothed (bandwidth = 0.1) and aggregated with age- and gender-weighted ISTAT 2024 population profiles.

Within this scenario, we integrate the LTC system into the NDC pension system. Figure 1 displays annual per-capita LTC spending by age, $C^{LTC}_{(x_e+A,t)}$, drawn from regularly updated Italian official statistics (RGS, 2025) and publicly available in many countries (see Table I.AIII.1 in (EPC, 2024)). These follow the internationally adopted System of Health Accounts (SHA) classification, which distinguishes three LTC macro-functions: home-based services (H), residential and semi-residential care (I), and cash transfers (C). In 2024, LTC spending among 65+ amounted to approximately €8.8 billion for institutional care, €14.3 billion for cash benefits, and €4.9 billion for home-based services, for a total of about €28 billion ($\approx$ 1.3% of Italy's GDP).[10] LTC expenditures are assumed to grow over time at the same rate

Other categories face lower rates: self-employed workers (lavoratori autonomi) contribute between 24.00% and 26.00%, while professionals in the separate scheme (gestione separata) contribute between 25.00% and 33.00%, depending on their coverage. Agricultural, domestic, and other special categories follow specific schedules.

[10]Among total LTC expenditures, the 65+ population accounts for about 65% of institutional care spending, 84% of cash benefits, and 92% of home-based services; overall,

of wages,[11] ensuring consistency between the evolution of labour incomes and the LTC costs.

3.2. Alternative Allocation Rules for Net Survivor Dividends

We consider three alternative allocations of the net survivor dividend (SD^{net}) under both the EPA and LCA designs. We begin from the benchmark case in which SD^{net} is not redistributed within the cohort, which mirrors the current Italian institutional setting. We then consider two alternative allocation rules for SD^{net}, corresponding to two distinct institutional and policy interpretations. Under the "*Full SD^{net} redistribution*" scenario we redistribute the entire SD^{net} generated within a cohort among the surviving retirees of the same cohort, after financing pre-retirement survivor protection. This allocation closely mirrors the logic of the Swedish NDC system, here extended to a setting that also accounts for survivor protection. In this case, all residual death-related capital is used to increase retirement pensions. Since higher old-age pensions also imply higher survivor pensions during the retirement phase, this rule indirectly strengthens post-retirement survivor benefits as well. Notably, no portion of SD^{net} is earmarked for LTC financing.[12]

By contrast, the "*LTC-related SD^{net}*" rule assigns a different role to the net survivor dividend. In this scenario, retirement pensions do not benefit from additional redistribution. Instead, the share of SD^{net} allocated to LTC is the amount needed to offset LTC expenditure, up to a maximum equal to the full available SD^{net}. Thus, if LTC expenditure is lower than SD^{net}, only part of the dividend is used for LTC; if it is higher, the entire available SD^{net} is absorbed and a residual financing gap remains. In this case, SD^{net}

individuals aged 65+ represent roughly 78% of total LTC expenditure.

[11]This assumption is also in line with past evidence: over previous decades, the increase in the number of beneficiaries was partly offset by a relatively subdued growth in average expenditure levels, reflecting the limited transparency and rigidity of indexation rules. Anchoring future LTC costs to wage dynamics therefore provides a coherent benchmark that avoids mechanically extrapolating historically muted growth driven by institutional features unlikely to persist.

[12]This scenario should be interpreted primarily as an analytical benchmark rather than as the most institutionally plausible reform for Italy. It arises naturally from the comparison between the cohort-based approach, in which the redistributable net survivor dividend is pooled within the cohort, and the individual-based approach, in which it is excluded. For this reason, we retain it in the analysis both to make the contrast between the two accounting approaches transparent and to provide a reference point for the more policy-relevant LTC-related SD^{net} scenario.

is diverted away from pension redistribution and instead acts as a partial natural hedge against the joint financing pressure generated by longevity and LTC risks, supporting LTC financing without increasing pension entitlements.

3.3. Main Results

Table 1 reports cohort-level balance at the retirement date, whereas Table 2 reports the contribution rates required to satisfy annual macro-balance across all cohorts present in a generic calendar year t. In the no-redistribution benchmark, the dividend effect is $D_e = 3.75\%$. The retiree-only annuity divisor is 21.36, while the adjusted divisor that incorporates survivor benefits rises to 23.20.[13]

At the cohort level (Table 1), the baseline contribution rate in the absence of LTC is 29% across all specifications. Under the EPA design, this rate remains unchanged, as LTC costs are fully internalized through a reduction in pension benefits rather than additional contributions. Unchanged contribution rates under EPA should therefore not be interpreted as the absence of an LTC financing burden. Rather, under EPA the cost is shifted from contributions to pension adequacy through a lower initial pension. The tables therefore report primarily the contribution-side implications of LTC integration. Under EPA, the corresponding pension-adequacy effect is not shown directly in Table 1, but it can be derived from the implied coverage ratio in Equation (36). For total LTC expenditure, the cohort-level EPA design implies an actuarial reduction in the initial pension of about 17.1%, 16.5%, and 13.0% under, respectively, no redistribution of SD^{net}, full SD^{net} redistribution, and the LTC-related SD^{net} scenario.

By contrast, under the LCA design, LTC is financed via an explicit contribution add-on, leading to higher contribution rates. For total LTC expenditure (C+H+I), the required rate increases to 33.57% in the absence of SD^{net} redistribution, corresponding to an add-on of 4.57 percentage points (p.p.). This burden is partially mitigated when the SD^{net} is redistributed: the required contribution rate declines to 33.40% under full SD^{net} redistribution to enhance the retirement pension within the cohort, and to 32.48% when only

[13] When computed using the gross survivor dividend $SD^{gross}_{(x_e+A,t)}$, the dividend effect rises to 6.14%, closer to the estimates reported for Sweden—7.39% in Vidal-Meliá et al. (2016) and 7.02% in Boado-Penas and Vidal-Meliá (2014) (see Table B1). The annuity divisor remains somewhat higher than those reported in both the illustrative case and Vidal-Meliá et al. (2016), reflecting differences in wage growth considered.

the LTC-related component of SD^{net} is allocated. This comparison shows that directing SD^{net} to LTC financing is more effective in reducing the LCA burden than redistributing it to pensions. Under full redistribution, the dividend is used mainly to increase pension entitlements; under the LTC-related rule, it is used instead to absorb part of LTC expenditure directly.

Across LTC categories, cash benefits account for the largest share of the increase, followed by institutional care, while home-based care has a comparatively modest impact. Notably, home-based care (H) under the LTC-related SD^{net} scenario can be financed without any additional contribution, reflecting its relatively low cost relative to the available SD^{net}.

Table 1: Cohort-level contribution rates (%) under alternative net survivor-dividend (SD^{net}) allocation, with explicit theta decomposition, by LTC category: Italian case

LTC category	**Scenario**	$\theta^{\text{No LTC}}$	θ^{EPA}	θ^{LCA}	$\eta^{\text{LCA\|No LTC}}$	$\eta^{\text{LCA\|EPA}}$	$\eta^{\text{EPA\|No LTC}}$
Cash (C)	No SD^{net}	29.00	29.00	31.30	2.30	2.30	0.00
	Full SD^{net} redistribution	29.00	29.00	31.21	2.21	2.21	0.00
	LTC-related SD^{net}	29.00	29.00	30.21	1.21	1.21	0.00
Home (H)	No SD^{net}	29.00	29.00	29.82	0.82	0.82	0.00
	Full SD^{net} redistribution	29.00	29.00	29.79	0.79	0.79	0.00
	LTC-related SD^{net}	29.00	29.00	29.00	0.00	0.00	0.00
Institution (I)	No SD^{net}	29.00	29.00	30.45	1.45	1.45	0.00
	Full SD^{net} redistribution	29.00	29.00	30.40	1.40	1.40	0.00
	LTC-related SD^{net}	29.00	29.00	29.37	0.37	0.37	0.00
Total (C+H+I)	No SD^{net}	29.00	29.00	33.57	4.57	4.57	0.00
	Full SD^{net} redistribution	29.00	29.00	33.40	4.40	4.40	0.00
	LTC-related SD^{net}	29.00	29.00	32.48	3.48	3.48	0.00

Notes: Entries report cohort-level contribution rates and their implied decomposition in percentage points. The first three rate columns reproduce the underlying cohort table. The decomposition columns are computed mechanically as $\eta^{\text{LCA|No LTC}} = \theta^{\text{LCA}} - \theta^{\text{No LTC}}$, $\eta^{\text{LCA|EPA}} = \theta^{\text{LCA}} - \theta^{\text{EPA}}$, and $\eta^{\text{EPA|No LTC}} = \theta^{\text{EPA}} - \theta^{\text{No LTC}}$. Scenario considered: ($i$) no redistribution of SD^{net} within the cohort (*"No SD^{net}"*), (ii) full redistribution of the entire SD^{net} (*"Full SD^{net} redistribution"*), and (iii) redistribution limited to the SD^{net} generated by LTC integration (*"LTC-related SD^{net}"*). Common parameters: entry age $x_e = 22$, retirement age $x_e + A = 65$, retiree-only divisor $AF_{(x_e+A)} = 21.36$, adjusted pension divisor $AF^{SP}_{(x_e+A)} = 23.20$, and dividend effect $D_e = 3.75\%$.

The macro-balanced results in Table 2 introduce an additional layer of adjustment, as contribution rates must satisfy annual cash-flow equilibrium across cohorts at time t. In this setting, the baseline contribution rate in the absence of LTC is lower (27.98%) under scenarios without redistribution, reflecting the role of undistributed SD^{net} in relaxing aggregate financing constraints. Under full redistribution, the macro-balanced contribution rate converges to the cohort benchmark (29.00%), as the survivor dividend is entirely reallocated to pension benefits. For total LTC expenditure, this also implies that full SD^{net} redistribution does not lower the total LCA contribution rate relative to the no-redistribution benchmark under macro-balance. On the contrary, the required total rate rises from 32.57% to 33.59%, because full redistribution simultaneously restores the no-LTC benchmark contribution rate from 27.98% to 29.00%.

Under the EPA design, macro-balanced contribution rates may deviate from the no-LTC benchmark, particularly in the LTC-related SD^{net} scenario, where a positive adjustment arises (e.g. 1.02 p.p. for total LTC). This reflects the fact that, while EPA preserves actuarial balance at the cohort level, this equivalence does not generally hold under period-by-period budget constraints, as the system simultaneously finances retirement and survivor pensions alongside LTC expenditures for surviving pensioners and spouses at time t. The difference in total balancing rates across the two tables reflects the different accounting perspective: cohort balance abstracts from inter-cohort cash-flow interactions, whereas macro-balance imposes annual equilibrium across all cohorts simultaneously present in year t.

A particularly sharp result emerges for home-based care (H) under the LTC-related SD^{net} scenario: the macro-balanced contribution rates under EPA and LCA become almost identical (28.75% and 28.80%, respectively), indicating that for this LTC component the choice between the two financing designs has only a minimal effect on the aggregate contribution rate [14].

Under the LCA design, the total contribution rate required to finance LTC is higher, although its decomposition varies across scenarios. In particular, the contribution add-on relative to EPA, $\eta^{\text{LCA|EPA}}$, declines when part of LTC expenditure is absorbed by SD^{net}, falling from 4.59 to 3.57 p.p. in the total LTC case. This mitigation, however, should be interpreted with caution. Under macro-balance, the LTC-related SD^{net} allocation does not reduce the total LCA contribution rate for total LTC relative to the no-redistribution benchmark: in both cases, the required rate is 32.57%. What

[14] This near coincidence reflects the small size of the home-based care component in the Italian calibration. Once part of that expenditure is absorbed by the LTC-related SD^{net}, the residual difference between the EPA annuity deduction and the LCA contribution add-on becomes very small at the macro level.

changes is the gap between LCA and EPA, not the total LCA rate itself. The role of the survivor dividend is therefore better understood as partially narrowing the contribution gap between the two financing designs, rather than as systematically lowering the total LCA contribution rate.

Overall, the comparison between Tables 1 and 2 highlights two key points. First, the financing implications of LTC integration depend critically on the accounting framework: cohort-level balance abstracts from inter-cohort cash-flow interactions, whereas macro-balance incorporates them explicitly. Second, the allocation of SD^{net} affects the financing burden, but its impact differs markedly across accounting frameworks. At the cohort level, reallocating part of the survivor dividend to LTC can substantially reduce the additional LCA contribution. Under macro-balance, by contrast, the effect is weaker and operates mainly through changes in the benchmark rate and in the gap between EPA and LCA, rather than through a systematic reduction in the total LCA contribution rate. From a policy perspective, the two balance concepts answer different questions. Cohort-level balance asks whether a given generation finances, in present-value terms, the full set of benefits it generates over its lifetime. Macro-balance instead asks whether the system can meet its obligations year by year when workers, retirees, survivors, and LTC beneficiaries coexist in the same calendar period. The former is therefore more informative about long-run actuarial fairness across cohorts, whereas the latter is more directly relevant for short-run budget sustainability and annual contribution-setting.

Table 2: Macro-balanced contribution rates (%) under alternative net survivor-dividend (SD^{net}) allocation, with explicit theta decomposition, by LTC category: Italian case

LTC category	**Scenario**	$\theta^{\text{No LTC}}$	θ^{EPA}	θ^{LCA}	$\eta^{\text{LCA}\vert\text{No LTC}}$	$\eta^{\text{LCA}\vert\text{EPA}}$	$\eta^{\text{EPA}\vert\text{No LTC}}$
Cash (C)	No SD^{net}	27.98	27.98	30.28	2.31	2.31	0.00
	Full SD^{net} redistribution	29.00	29.00	31.31	2.31	2.31	0.00
	LTC-related SD^{net}	27.98	29.00	30.28	2.31	1.28	1.02
Home (H)	No SD^{net}	27.98	27.98	28.80	0.82	0.82	0.00
	Full SD^{net} redistribution	29.00	29.00	29.82	0.82	0.82	0.00
	LTC-related SD^{net}	27.98	28.75	28.80	0.82	0.05	0.77
Institution (I)	No SD^{net}	27.98	27.98	29.44	1.46	1.46	0.00
	Full SD^{net} redistribution	29.00	29.00	30.46	1.46	1.46	0.00
	LTC-related SD^{net}	27.98	29.00	29.44	1.46	0.44	1.02
Total (C+H+I)	No SD^{net}	27.98	27.98	32.57	4.59	4.59	0.00
	Full SD^{net} redistribution	29.00	29.00	33.59	4.59	4.59	0.00
	LTC-related SD^{net}	27.98	29.00	32.57	4.59	3.57	1.02

Notes: Entries report macro-balanced contribution rates and their implied decomposition in percentage points. The first three rate columns reproduce the underlying macro-balanced table. The decomposition columns are computed as $\eta^{\text{LCA}|\text{No LTC}} = \theta^{\text{LCA}} - \theta^{\text{No LTC}}$, $\eta^{\text{LCA}|\text{EPA}} = \theta^{\text{LCA}} - \theta^{\text{EPA}}$, and $\eta^{\text{EPA}|\text{No LTC}} = \theta^{\text{EPA}} - \theta^{\text{No LTC}}$. Scenario considered: (*i*) no redistribution of SD^{net} within the cohort (*"No SD^{net}"*), (*ii*) full redistribution of the entire SD^{net} (*"Full SD^{net} redistribution"*), and (*iii*) redistribution limited to the SD^{net} generated by LTC integration (*"LTC-related SD^{net}"*). Common parameters: entry age $x_e = 22$, retirement age $x_e + A = 65$, retiree-only divisor $AF_{(x_e+A)} = 21.36$, adjusted pension divisor $AF^{SP}_{(x_e+A)} = 23.20$, and dividend effect $D_e = 3.75\%$.

Overall, the numerical results show that LTC integration into the Italian NDC framework is financially feasible, but only through explicit trade-offs across contribution rates, pension adequacy, and the institutional use of the survivor dividend. They also show that these trade-offs depend materially on whether balance is evaluated at the cohort level or under annual macro-balance.

4. Conclusion

This study evaluates the financial implications and feasible funding arrangements for integrating long-term care (LTC) into the Italian NDC pension system. Using a multi-state framework with pre- and post-retirement survivor protection, we illustrate how cohort balance and macro-balance evolve in a multi-generational setting where contributors and pensioners coexist. We also quantify the survivor dividend and assess its capacity to partially finance LTC provision while continuing to support survivor pensions.

The main findings can be summarized as follows. First, in the no-redistribution benchmark the net survivor dividend implies a dividend effect of 3.75%. Second, at the cohort level, financing total LTC under LCA requires total contribution rates of 33.57%, 33.40%, and 32.48% under, respectively, no redistribution of SD^{net}, full SD^{net} redistribution, and LTC-related SD^{net} redistribution. Third, under macro-balance, the corresponding total contribution rates are 32.57%, 33.59%, and 32.57%. Fourth, for total LTC expenditure, under EPA the cohort-level contribution rate remains at the benchmark in all scenarios, while under macro-balance it equals the benchmark in the no-redistribution and full-redistribution scenarios and rises from 27.98% to 29.00% in the LTC-related SD^{net} scenario. This shows that EPA mainly shifts the financing burden from contribution increases to pension adequacy, although under annual macro-balance a positive contribution adjustment may still arise.

In more accessible terms, the results point to a clear policy trade-off. LTC can be integrated into the pension system, but not without shifting costs across contributions, pensions, or both. EPA keeps contribution rates closer to current levels, but does so by lowering pension adequacy. LCA preserves pension adequacy, but requires higher contributions during working life. The survivor dividend can soften this trade-off, yet only partially, and its effect depends on whether it is used to raise pensions or to absorb part of LTC expenditure directly.

Overall, integrating LTC into the NDC framework is financially feasible, but it requires explicit trade-offs between contribution rates, pension adequacy, and the institutional use of the survivor dividend.

Beyond financial sustainability, our results highlight important differences across allocation rules in terms of efficiency, risk sharing, and redistribution. The distinction between EPA and LCA has important policy implications. Under an EPA design, resources are primarily collected within cohorts that are close to LTC risk. In this setting, the financing burden is largely borne by retirees, and the reallocation of the survivor dividend also operates over a relatively short horizon between accumulation and use. This proximity enhances the effectiveness of the survivor dividend as a natural hedge, while limiting its impact on labor costs and, therefore, on economic competitiveness. By contrast, an LCA design extends the temporal distance between the accumulation of resources and their eventual use for LTC financing. Contributions are collected in the working life, increasing the cost of labor and potentially affecting employment and international competitiveness, while the benefits materialize only decades later. Although this approach allows for broader intertemporal risk pooling, it weakens the direct link between death-related capital and LTC needs, and reduces the immediacy of the natural hedging mechanism. These differences suggest that, even abstracting from distributional outcomes, the choice between EPA and LCA reflects a fundamental trade-off between timing, efficiency, and the macroeconomic incidence of LTC protection.

When the net survivor dividend is fully redistributed to surviving retirees, the system closely resembles a more traditional NDC design and primarily enhances pension adequacy, including survivor benefits during retirement. While this approach preserves the contributory logic of the pension system, it forgoes the potential efficiency gains from using death-related capital to hedge against longevity- and LTC risks. By contrast, reallocating the LTC-related component of the net survivor dividend to finance LTC expenditures introduces a form of natural hedging within the social insurance system. In this case, death-related capital is used to offset the fiscal pressure generated by rising care needs, improving allocative efficiency by better aligning resources with age-related risks, without increasing pension entitlements.

Finally, the choice between these allocation rules has non-neutral redistributive implications. Full redistribution of the survivor dividend favors longer-lived individuals and cohorts with higher pension entitlements, whereas the LTC-related allocation strengthens insurance against late-life LTC risks, with potentially stronger redistributive effects across individuals with heterogeneous longevity and LTC needs. These findings suggest that the institutional design of survivor dividend allocation is a central policy lever for both efficiency and redistributive properties of an integrated pension and LTC system.

References

Arnold-Gaille, S., Boado-Penas, M.C., Song, Z., 2024. The survivor dividend as a tool to improve pension adequacy in nonfinancial defined contribution schemes. Scandinavian Actuarial Journal 2025, 433–455. doi:10.1080/03461238.2024.2430551.

Audino, M., Mazzaferro, C., Morciano, M., 2024. Non autosufficienza: il nodo dell'indennità di accompagnamento. LaVoce.it. URL: https://lavoce.info/archives/103848/non-autosufficienza-il-nodo-dellindennita-di-accompagnamento/.

de Biase, P., Dougherty, S., 2023. From Local to National: Delivering and Financing Effective Long-Term Care. Technical Report 45. OECD Publishing. Paris. doi:10.1787/578b296f-en.

Boado-Penas, M.d.C., Vidal-Meliá, C., 2014. Nonfinancial defined contribution pension schemes: is a survivor dividend necessary to make the system balanced? Applied Economics Letters 21, 242–247. doi:10.1080/13504851.2013.851767.

Börsch-Supan, A., 2005. From traditional db to notional dc systems: The pension reform process in Sweden, Italy, and Germany. Journal of the European Economic Association 3, 458–465. doi:10.1162/jeea.2005.3.2-3.458.

Brugiavini, A., Carrino, L., Pasini, G., 2023. Long-Term Care in Italy. Technical Report c14914. National Bureau of Economic Research.

Costa-Font, J., Courbage, C., Swartz, K., 2015. Financing long-term care: Ex ante, ex post or both? Health Economics 24, 45–57. doi:10.1002/hec.3152.

Costa-Font, J., Raut, N., 2022. Global Report on Long-Term Care Financing. Technical Report. World Health Organization. URL: https://www.lse.ac.uk/business/consulting/assets/documents/WHO-Global-Report-on-Long-Term-Care-Financing-Final-Report.pdf. report prepared for the World Health Organization.

Devolder, P., Levantesi, S., Menzietti, M., 2021. Automatic balance mechanisms for notional defined contribution pension systems guaranteeing social adequacy and financial sustainability: an application to the

Italian pension system. Annals of Operations Research 299, 765–795. doi:10.1007/s10479-020-03819-x.

EPC, 2024. The 2024 ageing report: Economic and budgetary projections for the EU member states (2022-2070). Publications Office of the European Union.

Gori, C., Fernandez, J.L., Wittenberg, R. (Eds.), 2015. Long-Term Care Reforms in OECD Countries. Policy Press, Bristol. doi:10.1332/policypress/9781447305057.001.0001.

Gronchi, S., Nistico, S., 2003. Fair and sustainable pay-as-you-go pension systems: Theoretical models and practical realizations. Draft Report (Università degli studi di Roma 'La Sapienza', Facoltà di Economia) .

Hindriks, J., Cetin, S., 2025. Sustainability of pension reforms: An EU-wide political stress test. Journal of Pension Economics and Finance , 1–27doi:10.1017/S1474747225100103.

INPS, 2024. Rapporto Annuale. Technical Report. Istituto Nazionale della Previdenza Sociale. Rome. URL: https://www.inps.it. annual Report.

ISTAT, 2024. Resident population by age, sex and marital status. Italian National Institute of Statistics (ISTAT), Demographic Statistics database. URL: https://demo.istat.it/app/?i=POS&l=en. resident population on 1st January, years 2019–2026; accessed 5 April 2026.

Lera, J., Pascual-Sáez, M., Cantarero-Prieto, D., 2021. Socioeconomic inequality in the use of long-term care among european older adults: An empirical approach using the share survey. International Journal of Environmental Research and Public Health 18, 20.

Levantesi, S., Menzietti, M., 2018. Natural hedging in long-term care insurance. ASTIN Bulletin 48, 233–274.

Levantesi, S., Menzietti, M., Fratoni, L., 2024. Financial sustainability and automatic balance mechanisms for ndc pension systems with disability benefits. Annals of Operations Research , 1–23.

Marano, A., Mazzaferro, C., Morciano, M., 2012. The strengths and failures of incentive mechanisms in notional defined contribution pension systems. Giornale degli Economisti e Annali di Economia , 33–70.

Mazzaferro, C., Morciano, M., Savegnago, M., 2012. Differential mortality and redistribution in the Italian notional defined contribution system. Journal of Pension Economics and Finance 11, 500–530.

Norton, E.C., 2017. Long-term care reforms in OECD countries. Cristiano Gori, Jose-Luis Fernandez and Raphael Wittenberg (eds). Policy Press, 2016, ISBN: 978-1447310716, 306 pages. Journal of Pension Economics and Finance 16, 266–267. doi:10.1017/S1474747217000063.

OECD, 2020. Spending on long-term care. URL: https://www.oecd.org/en/publications/spending-on-long-term-care_e1f00970-en.html.

OECD, 2025. Pensions at a Glance 2025: OECD and G20 Indicators. OECD Publishing, Paris. URL: https://doi.org/10.1787/e40274c1-en, doi:10.1787/e40274c1-en.

Pitacco, E., 2013. Biometric risk transfers in life annuities and pension products: A survey. Technical Report 2013/25. CEPAR. URL: http://www.cepar.edu.au/media/123434/25%20biometric%20risk%20transfers%20in%20life%20annuities%20and%20pension%20products.pdf.

Pitacco, E., 2014. Health Insurance: Basic Actuarial Models. EAA Series, Springer.

Pla-Porcel, J., Ventura-Marco, M., Vidal-Meliá, C., 2016. Life care annuities (lca) embedded in a notional defined contribution (ndc) framework. ASTIN Bulletin 46, 331–363. doi:10.1017/asb.2015.27.

RGS, 2025. Rapporto n. 26 – Attività di previsione: La spesa sociale. Technical Report 26. Ministero dell'Economia e delle Finanze. Rome. URL: https://www.rgs.mef.gov.it/_Documenti/VERSIONE-I/Attivit--i/Spesa-soci/Attivita_di_previsione_RGS/2025/Rapporto-2025-n.26.pdf. accessed 2025.

Rickayzen, B.D., 2007. An analysis of disability-linked annuities. Technical Report. Cass Business School.

Santini, S., Busilacchi, G., Lamura, G., Sofritti, F., Pacifico, A., Bongelli, R., Guarascio, C., 2025. Reforming Italy's long-term care system: the role of barriers to and drivers of the use of services at the local level. Frontiers in Public Health 13, 1575330.

Vidal-Meliá, C., Boado-Penas, M.d.C., 2013. Compiling the actuarial balance for pay-as-you-go pension systems. is it better to use the hidden asset or the contribution asset? Applied Economics 45, 1303–1320. doi:10.1080/00036846.2011.615733.

Vidal-Meliá, C., Boado-Penas, M.D.C., Navarro-Cabo, F., 2016. Notional defined contribution pension schemes: why does only Sweden distribute the survivor dividend? Journal of Economic Policy Reform 19, 200–220. doi:10.1080/17487870.2015.1028547.

Vidal-Meliá, C., Ventura-Marco, M., Pla-Porcel, J., 2020. An NDC approach to helping pensioners cope with the cost of long-term care. Journal of Pension Economics and Finance 19, 80–108. doi:10.1017/S1474747218000070.

Appendix A. Illustrative Synthetic Population

To illustrate the mechanics of the model, we begin with a stylized synthetic population, assumed stationary ($\gamma = 0\%$) over time. The representative individual of a cohort of 10,000 workers enters the labour market at age $x_e = 16$ with an initial wage of €20,000, growing at a constant annual rate of $g = 1.6\%$ (the 10-year average real GDP growth rate). Contributions, θ_α, are paid at a fixed rate centred at 16% (varied by ± 10 percentage points in sensitivity analysis), and the statutory retirement age is set at $x_e + A = 65$ (varied by ± 5 years in sensitivity analysis).

Pensions are indexed annually at $\alpha = 0\%$. Mortality follows a simplified Gompertz law with hazard

$$\lambda_x = ae^{bx},$$

and corresponding age-specific one-year death probability

$$m_x = 1 - \exp(-\lambda_x) = 1 - \exp(-ae^{bx}).$$

The parameters $a = 0.0000351$ and $b = 0.093$ generate an age–mortality profile consistent with the Italian life expectancy at birth of approximately 84 years. In the simulations, the associated one-year survival probability is therefore computed as ${}_1p_x = 1 - m_x$, and cumulative survival probabilities are obtained recursively as

$${}_np_x = \prod_{s=0}^{n-1} (1 - m_{x+s}).$$

To construct interval estimates around the mean realisation, we draw repeated stochastic mortality paths from a Beta distribution centred on this bounded one-year death probability m_x, namely $\mathrm{Beta}(\kappa m_x,\ \kappa(1 - m_x))$, with the concentration parameter κ set equal to 5,000 to control dispersion around the expected value. We generate 100 Monte Carlo replications, each consisting of a full simulated mortality path, and compute illustrative 95% empirical percentile intervals from the resulting simulated distribution.

The LTC component is similarly modelled through an age-dependent profile built from an underlying Gompertz-type exponential age gradient, with variability introduced through Beta-distributed stochastic realisations centred on its deterministic schedule. More precisely, we first define the positive age-specific LTC intensity index

$$\tau_x^{\mathrm{LTC}} = a_{\mathrm{LTC}} e^{b_{\mathrm{LTC}} x},$$

where τ_x^{LTC} is a latent age profile governing the growth of care needs with age. It is not itself a probability or a share, and therefore it cannot be used directly as the mean of a Beta distribution. To obtain a bounded object in $(0,1)$, we map this intensity into the operative age-specific LTC share

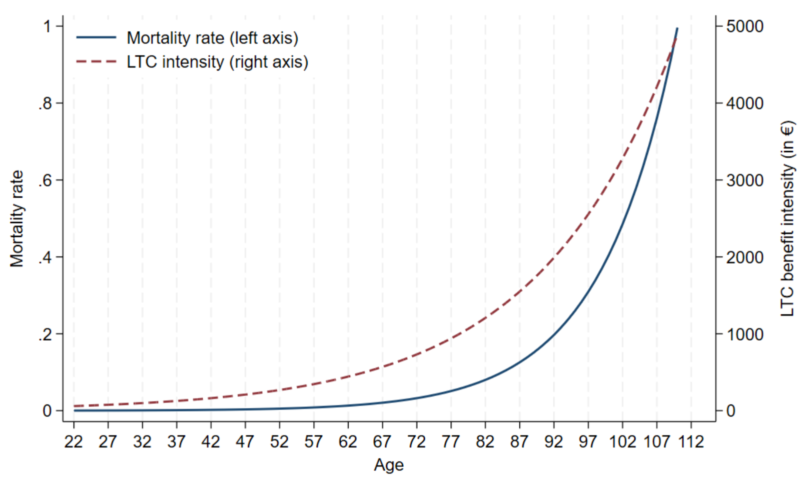
$$\tilde{\tau}_x^{\mathrm{LTC}} = \frac{\tau_x^{\mathrm{LTC}}}{1+\tau_x^{\mathrm{LTC}}}.$$

This share is interpreted as the model-implied fraction of the unit LTC cost paid, on average, at age x in the base year. Parameters were chosen to reflect a more gradual increase in care needs. Specifically, we set $a_{\mathrm{LTC}} = 0.0039$ and $b_{\mathrm{LTC}} = 0.053$. The deterministic base-year LTC cash schedule is then defined as $C_{(x,1)}^{LTC} = 5000\,\tilde{\tau}_x^{\mathrm{LTC}}$. In the stochastic simulations, the bounded LTC share at age x is drawn from

$$\tilde{\tau}_x^{\mathrm{LTC},*} \sim \mathrm{Beta}\Big(\kappa\tilde{\tau}_x^{\mathrm{LTC}},\ \kappa\left(1-\tilde{\tau}_x^{\mathrm{LTC}}\right)\Big),$$

so that the corresponding stochastic base-year LTC cash amount is $C_{(x,1)}^{LTC,*} = 5000\,\tilde{\tau}_x^{\mathrm{LTC},*}$. Thus both the deterministic benchmark and the stochastic realisations are defined on the same support and are directly comparable. Figure A1 synthesises these two deterministic profiles.

Figure A1: Illustrative synthetic profiles by age



Source: Authors' assumptions.

Table A.3 reports the contribution rates required to finance LTC under alternative SD^{net} allocation rules, distinguishing between cohort-level accounting (Panel A) and macro-balanced outcomes (Panel B), and presenting both mean estimates and stochastic confidence intervals. The analysis identifies a non-negligible dividend effect, which can be deployed either to enhance retirement pensions or to partially finance LTC expenditures.

Focusing first on the cohort-level results (Panel A), the contribution rate in the absence of LTC is fixed at 16.00% across all scenarios, reflecting the imposed actuarial balance within cohorts. Under the EPA design, the introduction of LTC leaves this rate unchanged, as financing is achieved through a reduction in pension benefits. By contrast, under the LCA design, LTC integration requires an increase in the contribution rate, the magnitude of which depends on the allocation of SD^{net}. In the absence of redistribution, the rate rises by 1.48 percentage points (p.p.), while full redistribution slightly reduces the increase to 1.38 p.p. The smallest adjustment arises under the LTC-related SD^{net} scenario (0.30 p.p.), indicating that reallocating only the LTC-induced component of the survivor dividend (Equation 34) can substantially mitigate the required contribution add-on.

Panel B shows that imposing macro-balance introduces non-trivial adjustments relative to the cohort perspective. In particular, the baseline contribution rate in the absence of LTC is lower (14.95%) in scenarios without redistribution, reflecting the role of undistributed SD^{net} in easing aggregate financing requirements. When LTC is introduced under the EPA design, the baseline contribution rate remains unchanged in most cases, except in the LTC-related SD^{net} scenario, where it increases by 1.05 percentage points (p.p.). Under the LCA design, mean contribution rates rise in all scenarios by about 1.51–1.52 p.p., with point estimates ranging from 16.46% to 17.52% and 95% confidence intervals spanning 16.40% to 17.54%. This pattern highlights the interaction between benefit adjustments and system-wide cash-flow constraints under macro-balance.

Overall, the results show that SD^{net} redistribution can mitigate the financing burden associated with LTC integration, although its effectiveness depends on both the allocation rule and the accounting framework adopted.

Although based on a stylized framework, our results are broadly consistent with the existing literature (see Appendix B). As reported in Table B1, the annuity divisor in our setting (18.70) is close to the estimate in Vidal-Meliá et al. (2016). Similarly, the estimated dividend effect of 7.38% lies within the range documented in previous studies—7.02% in Boado-Penas and Vidal-

Meliá (2014), 7.39% in Vidal-Meliá et al. (2016), and 10.93% in Pla-Porcel et al. (2016). The macro-balanced LCA add-on of about 1.52 percentage points is also comparable to the 1.72 percentage points reported in Pla-Porcel et al. (2016).

Table A.3: Cohort-level and macro-balanced contribution rates under alternative net survivor-dividend (SD^{net}) allocation, with and without LTC integration: mean estimates and 95% confidence intervals, illustrative case

Scenario	Without LTC	With LTC: EPA	With LTC: LCA
Panel A. Cohort-level contribution rate			
No SD^{net}	16.00 [16.00, 16.00]	16.00 [16.00, 16.00]	17.48 [17.46, 17.50]
Full SD^{net} redistribution	16.00 [16.00, 16.00]	16.00 [16.00, 16.00]	17.38 [17.36, 17.40]
LTC-related SD^{net}	16.00 [16.00, 16.00]	16.00 [16.00, 16.00]	16.30 [16.22, 16.37]
Panel B. Macro-balanced contribution rate			
No SD^{net}	14.95 [14.89, 15.00]	14.95 [14.89, 15.00]	16.46 [16.40, 16.52]
Full SD^{net} redistribution	16.00 [16.00, 16.00]	16.00 [16.00, 16.00]	17.52 [17.50, 17.54]
LTC-related SD^{net}	14.95 [14.89, 15.00]	16.00 [16.00, 16.00]	16.46 [16.40, 16.52]

Notes: Entries report mean estimates, with 95% confidence intervals in brackets. Scenarios considered are: (*i*) no redistribution of SD^{net} within the cohort; (*ii*) full redistribution of the entire SD^{net}; and (*iii*) redistribution limited to the SD^{net} associated with LTC integration. EPA and LCA denote the two LTC integration mechanisms described in the text. Common parameters: entry age $x_e = 16$, retirement age $x_e + A = 65$, retiree-only divisor $AF_{(x_e+A)} = 18.70$, adjusted pension divisor $AF^{SP}_{(x_e+A)} = 20.70$, dividend effect $D_e = 7.38\%$, and the dividend effect based on $SD^{gross}_{(x_e+A,t)}$ is 12.10%.

Appendix B. Related Literature and Comparison with Previous Findings

Pla-Porcel et al. (2016) develop a multi-state overlapping generations (MOLG) model to examine the integration of LTC into a pension system, reporting key actuarial outcomes under low, medium, and high LTC cost assumptions. Their calibration combines a Swedish earnings profile with Japanese mortality rates.

Vidal-Meliá et al. (2020) extend this framework by introducing multiple health states, including five levels of dependency, and incorporating a minimum pension scheme. Using LTC transition probabilities based on Robinson's (1996) care transition framework, they show that, in the absence of a minimum pension, LTC integration raises the contribution rate from 16% to 18.38%, generating a dividend effect of 26.18%.

Levantesi et al. (2024) evaluate a hypothetical integration of the main cash non-means tested LTC component (*Indennità di Accompagnamento* (IdA)) into the Italian NDC system using a multivariate stochastic model. Their results indicate that an increase in the contribution rate of approximately one p.p. would be required under the Automatic Balance Mechanism with a Liquidity Ratio (LR-ABM). However, their analysis does not account for the redistributive role of SD.

Table B1: Pension-related indicators reported in previous studies by country

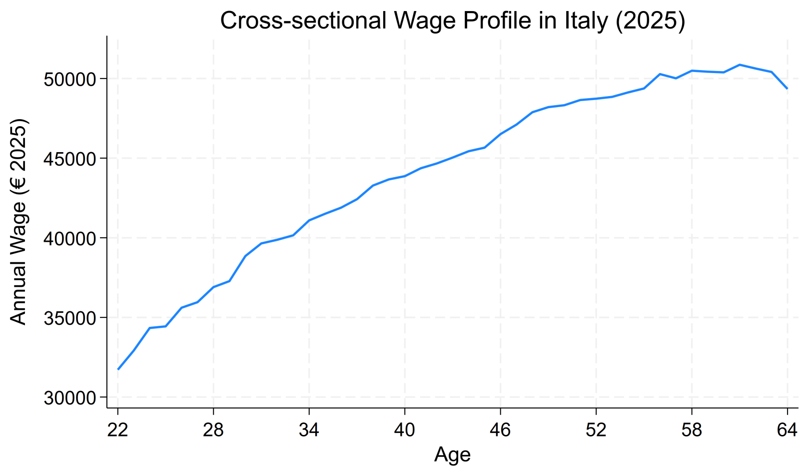
Study	θ_α	$AF_{(x_e+A)}$	D_e	$\Delta\theta_\alpha^{\text{LTC}}$
Sweden Vidal-Meliá et al. (2016)	16.00	17.23	7.39	–
Sweden Boado-Penas and Vidal-Meliá (2014)[i]	16.00	–	7.02	–
Sweden and Japan Pla-Porcel et al. (2016)[ii,iii]	16.00	14.86	10.93	1.72[a]
Our estimates	16.00	18.70	7.38	1.52

[i] The contribution base is assumed to grow at an annual rate of 2%.
[ii] The population is assumed to grow at an annual rate of 1%.
[iii] The income profile is based on the Swedish case, while mortality rates are derived from Japanese data.
[a] This figure is derived from the normal LTC cost scenario.
Variable definitions: θ_α = contribution rate; $AF_{(x_e+A)}$ = annuity divisor; D_e = dividend effect; $\Delta\theta_\alpha^{\text{LTC}}$ = additional contribution rate required to finance LTC.

Appendix C. Cross-Sectional Wage Profile

Figure C1 presents the cross-sectional wage profile in Italy in 2025 for working ages 22–64. Wages increase steeply between ages 22 and 35, rising from €31,716 to €41,507. Between ages 35 and 50, wages continue to grow, although at a slower pace, reaching €48,322. From around age 50 onward, the wage profile becomes relatively stable, fluctuating within a narrow range of approximately €49,000 to €51,000. The wage profile peaks at age 61, reaching €50,864, and then declines slightly toward age 64.

Figure C1: Cross-Sectional Wage Profile of Italy, 2025



Source: Authors' elaboration based on cross-sectional wage data from INPS.

Appendix D. Proof of Proposition 1

Let $R = x_e + A$ and $N = \omega - R$. Under the maintained benchmark calibration without LTC (but allowing for post-retirement survivor pensions through $\tilde{p}$), the macro-balance identity in calendar year t is Equation 39, that is,

$$\theta_\alpha W_t = \sum_{n=0}^{N} \Big[\bar{p}_{t-n}^{(a,co)} (1+\alpha)^n \, {}_n p_R + \bar{p}_{t-n}^{(a,co)} (1+\alpha)^n \Big({}_n\tilde{p}_R - {}_n p_R \Big) \Big] l_{(R,t-n)} + B_t^{pre}. \tag{D1}$$

By definition, the EPA annual imbalance is

$$\Delta_t^{EPA} = \theta_t W_t - \sum_{n=0}^{N} \Big[\bar{p}_{t-n}^{(a,LTC,co)} (1+\alpha)^n \, {}_n p_R + \bar{p}_{t-n}^{(a,co)} (1+\alpha)^n \Big({}_n\tilde{p}_R - {}_n p_R \Big) + C_{(R+n,t)}^{LTC} \, {}_n\pi_R^{LTC} \Big] l_{(R,t-n)} - B_t^{pre,EPA}. \tag{D2}$$

Subtract Equation D1 from Equation D2. The post-retirement survivor-pension term cancels exactly, and therefore

$$\Delta_t^{EPA} = (\theta_t - \theta_\alpha) W_t + \sum_{n=0}^{N} {}_n p_R \, l_{(R,t-n)} \Big[\bar{p}_{t-n}^{(a,co)} (1+\alpha)^n - \bar{p}_{t-n}^{(a,LTC,co)} (1+\alpha)^n \Big] - \Xi_t^{ret} + \Big(B_t^{pre} - B_t^{pre,EPA} \Big), \tag{D3}$$

where

$$\Xi_t^{ret} = \sum_{n=0}^{N} {}_n\pi_R^{LTC}\, l_{(R,t-n)}\, C_{(R+n,t)}^{LTC}.$$

Using Equation 32, namely

$$\bar{p}_{t-n}^{(a,LTC,co)} = \bar{p}_{t-n}^{(a,co)} - c_{t-n}^{LTC},$$

Equation D3 becomes

$$\Delta_t^{EPA} = (\theta_t - \theta_\alpha)W_t + \sum_{n=0}^{N} {}_np_R\, l_{(R,t-n)}\, c_{t-n}^{LTC}(1+\alpha)^n - \Xi_t^{ret} + \Big(B_t^{pre} - B_t^{pre,EPA}\Big). \tag{D4}$$

We next show that the two extra LTC blocks cancel under $\alpha = g$.

Under the stable-population assumption (Equation 1), the size of the cohort reaching retirement in year $t-n$ scales as

$$l_{(R,t-n)} = l_{(R,1)}(1+\gamma)^{t-n-1},$$

and by Equation 5,

$$C_{(R+n,t)}^{LTC} = C_{(R+n,1)}^{LTC}(1+\alpha)^{t-1}.$$

Hence

$$\Xi_t^{ret} = l_{(R,1)}(1+\gamma)^{t-1}(1+\alpha)^{t-1} \sum_{n=0}^{N} {}_n\pi_R^{LTC}\, C_{(R+n,1)}^{LTC}(1+\gamma)^{-n}. \tag{D5}$$

Next, by Equation 31, for the cohort retiring in year $t-n$,

$$PV_{t-n}^{LTC} = (1+\alpha)^{t-n-1} \sum_{m=0}^{N} {}_m\pi_R^{LTC}\, C_{(R+m,1)}^{LTC} F^m,$$

so that, because AF_R does not depend on calendar time,

$$c_{t-n}^{LTC} = c_1^{LTC}(1+\alpha)^{t-n-1}.$$

Therefore,

$$\sum_{n=0}^{N} {}_np_R\, l_{(R,t-n)}\, c_{t-n}^{LTC}(1+\alpha)^n = l_{(R,1)}(1+\gamma)^{t-1}(1+\alpha)^{t-1} c_1^{LTC} \sum_{n=0}^{N} {}_np_R(1+\gamma)^{-n}. \tag{D6}$$

If $\alpha = g$, then $F = (1+\gamma)^{-1}$, and Equation 7 implies

$$AF_R = \sum_{n=0}^{N} {}_np_R(1+\gamma)^{-n}.$$

Under $\alpha = g$, Equation 31 evaluated at $t = 1$ gives

$$PV_1^{LTC} = \sum_{n=0}^{N} {}_n\pi_R^{LTC}\, C_{(R+n,1)}^{LTC}(1+\gamma)^{-n}.$$

Since $c_1^{LTC} = PV_1^{LTC}/AF_R$, Equation D6 becomes exactly Equation D5. Hence

$$\sum_{n=0}^{N} {}_np_R\, l_{(R,t-n)}\, c_{t-n}^{LTC}(1+\alpha)^n - \Xi_t^{ret} = 0. \tag{D7}$$

By Equation 20,

$$B_t^{pre,EPA} = \sum_{k=0}^{A-1} \sum_{n=0}^{\omega-(x_e+k)} d_{(x_e+k,t-n)} \left[\bar{b}_{(x_e+k,t-n)}^{pre,LTC}(1+\alpha)^n + C_{(x_e+k+n,t)}^{LTC}\right] {}_np_{x_e+k}^S.$$

Using Equation 18, we obtain

$$B_t^{pre} - B_t^{pre,EPA} = \sum_{k=0}^{A-1} \sum_{n=0}^{\omega-(x_e+k)} d_{(x_e+k,t-n)}\, {}_np_{x_e+k}^S \left[c_{(x_e+k,t-n)}^{pre,LTC}(1+\alpha)^n - C_{(x_e+k+n,t)}^{LTC}\right].$$

Fix an age-at-death $x_e + k$ and denote $N_k = \omega - (x_e + k)$. By Equations 1 and 4, and since ${}_1q_{x_e+k}$ is age-specific but time-invariant, the number of such deaths scales over calendar time as

$$d_{(x_e+k,t-n)} = d_{(x_e+k,1)}(1+\gamma)^{t-n-1}.$$

By Equation 5,

$$C_{(x_e+k+m,t-n)}^{LTC} = C_{(x_e+k+m,1)}^{LTC}(1+\alpha)^{t-n-1} \qquad \text{for every } m \geq 0.$$

Substituting this into Equation 16 yields

$$PV_{(x_e+k,t-n)}^{pre,LTC} = (1+\alpha)^{t-n-1} \sum_{m=0}^{N_k} {}_mp_{x_e+k}^S C_{(x_e+k+m,1)}^{LTC} F^m,$$

and therefore, because $AF^S_{x_e+k}$ does not depend on calendar time,

$$c^{pre,LTC}_{(x_e+k,t-n)} = c^{pre,LTC}_{(x_e+k,1)}(1+\alpha)^{t-n-1}.$$

Hence the annuity-equivalent LTC term for the fixed age-at-death $x_e + k$ can be written as

$$\begin{aligned}&\sum_{n=0}^{N_k} d_{(x_e+k,t-n)} {}_n p^S_{x_e+k} c^{pre,LTC}_{(x_e+k,t-n)}(1+\alpha)^n \\ &\qquad = d_{(x_e+k,1)}(1+\gamma)^{t-1}(1+\alpha)^{t-1} c^{pre,LTC}_{(x_e+k,1)} \sum_{n=0}^{N_k} {}_n p^S_{x_e+k}(1+\gamma)^{-n}.\end{aligned} \tag{D8}$$

Similarly, the corresponding LTC cash term is

$$\begin{aligned}&\sum_{n=0}^{N_k} d_{(x_e+k,t-n)} {}_n p^S_{x_e+k} C^{LTC}_{(x_e+k+n,t)} \\ &\qquad = d_{(x_e+k,1)}(1+\gamma)^{t-1}(1+\alpha)^{t-1} \sum_{n=0}^{N_k} {}_n p^S_{x_e+k} C^{LTC}_{(x_e+k+n,1)}(1+\gamma)^{-n}.\end{aligned} \tag{D9}$$

If $\alpha = g$, then $F = (1+\gamma)^{-1}$, so Equation 8 implies

$$AF^S_{x_e+k} = \sum_{n=0}^{N_k} {}_n p^S_{x_e+k}(1+\gamma)^{-n}.$$

Under $\alpha = g$, Equation 16 evaluated at calendar year 1 gives

$$PV^{pre,LTC}_{(x_e+k,1)} = \sum_{n=0}^{N_k} {}_n p^S_{x_e+k} C^{LTC}_{(x_e+k+n,1)}(1+\gamma)^{-n}.$$

Since $c^{pre,LTC}_{(x_e+k,1)} = PV^{pre,LTC}_{(x_e+k,1)}/AF^S_{x_e+k}$, Equation D8 coincides exactly with Equation D9. Therefore, for each k,

$$\sum_{n=0}^{N_k} d_{(x_e+k,t-n)} {}_n p^S_{x_e+k}\left[c^{pre,LTC}_{(x_e+k,t-n)}(1+\alpha)^n - C^{LTC}_{(x_e+k+n,t)}\right] = 0.$$

Summing over $k = 0, \ldots, A-1$ yields

$$B^{pre}_t - B^{pre,EPA}_t = 0. \tag{D10}$$

Combining Equations D4, D7, and D10, we obtain

$$\Delta^{EPA}_t = (\theta_t - \theta_\alpha)W_t,$$

which is Equation 42. It follows immediately that, if $\theta_t = \theta_\alpha$, then $\Delta^{EPA}_t = 0$ for every t.