Quantitative Techniques for Social Protection Policy Design

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Q2: Essay on the Financing of Defined-Benefit Social Insurance Schemes

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Introduction

The financing of social protection schemes is far from being a purely accounting exercise in which revenues must simply match expenditure. Different financing methods have significant and concrete implications, not only for the financial equilibrium of the system, but also for key dimensions such as population coverage, the distribution of resources, and the management of reserves.

This essay focuses specifically on defined-benefit, wage-based social insurance schemes, as applied to the nine classical branches of social protection outlined in ILO Convention No. 102 (Medical care benefit; Sickness benefit; Unemployment benefit; Old-age benefit; Employment injury benefit; Family benefit; Maternity benefit; Invalidity benefit; Survivors' benefit), with a particular emphasis on pension schemes.

Defined-benefit (DB) schemes wage-based are characterized by the fact that benefits are predetermined according to a formula, typically based on a worker's previous wages and years of contribution, rather than being directly linked to the amount of contributions paid. In this respect, DB schemes contrast sharply with defined-contribution (DC) schemes, in which the benefit depends directly on the sum of contributions accumulated.

The fundamental objective of the DB wage-based schemes is to provide income security in the face of life's major risks (e.g. illness, unemployment, disability, old age) by smoothing consumption over time. This type of scheme prevents poverty and reduces the need for harmful coping strategies.

However, few countries cover all nine contingencies (defined by ILO) through defined-benefit wage-based schemes. Many risks are instead addressed through tax-funded noncontributory programs, or not at all.

Moreover, these contributory wage-based schemes have important limitations. Because eligibility is tied to formal contributions, they systematically exclude those who do not participate in formal labor markets, such as informal workers, unpaid family workers, and many self-employed individuals. In low and middle-income countries, where informal employment is widespread, this creates large protection gaps.

In what follows, we analyze only the main financing approaches available for defined-benefit wage-based social insurance schemes, assessing their respective advantages and challenges across the dimensions of coverage, inter-generational redistribution, financial reserves, and financial viability.

1 Pay-As-You-Go (PAYG) Financing

In a Pay-As-You-Go (PAYG) system, the contributions collected from the current working population are immediately used to finance the benefits paid to current recipients. The system is in equilibrium when the annual total contributions collected equal the annual total benefits paid.

$$IC = EB,$$

where:

- IC = total contributions collected;
- EB = total benefits paid.

This can be developed as:

$$IC = N_c \times A_w \times CR_{PAYG}, \quad EB = N_b \times A_b,$$

where:

- N_c = number of contributors;
- A_w = average wage;
- CR_{PAYG} = contribution rate;
- N_b = number of beneficiaries;
- A_b = average benefit.

Solving for the contribution rate required to maintain financial balance every year, we obtain the following.

$$CR_{PAYG} = \frac{N_b \times A_b}{N_c \times A_w} = RD \times RF,$$

with:

- $RD = \frac{N_b}{N_c}$: the demographic ratio (i.e., dependency ratio);
- $RF = \frac{A_b}{A_w}$: the financial ratio (i.e., replacement rate).

This model presents several advantages. It does not require the accumulation of large reserves, making it relatively quick to implement. It is particularly well suited to temporary contingencies—such as sickness, maternity, or unemployment—where both the likelihood of occurrence and the average benefit duration are predictable. These risks can thus be covered with moderate contribution rates while maintaining adequate generosity. PAYG schemes also support horizontal redistribution. In work injury insurance, for example, blue-collar workers—more exposed to risk—receive higher benefits despite contributing at the same rate as white-collar workers.

Nonetheless, the PAYG approach also has limitations. Technically and politically, adjusting the contribution rate (CR_{PAYG}) each year is challenging. In practice, such revisions require negotiation with social partners, a legislative process, and thus are rarely made annually.

In addition, the DB Pensions are particularly vulnerable to demographic change. As life expectancy increases and fertility declines, the dependency ratio (RD) worsens, leading to fewer contributors per beneficiary. To restore equilibrium, policymakers must either reduce the replacement rate (RF), increase the contribution rate, or raise the retirement age—all of which may reduce benefit adequacy.

A related concern is the declining internal rate of return (IRR) across generations (due to demographic change). Earlier cohorts benefited from favorable demographics, contributing less while receiving generous pensions. In contrast, younger generations are expected to contribute more and receive less, raising significant issues of intergenerational fairness.

The internal rate of return (IRR) in a PAYG system is given by the ratio between the present value of benefits received and the present value of contributions paid by a representative individual over their life cycle. Assuming retirement at age R, death at age D, and continuous contributions from age E to R, we have:

$$IRR = \frac{\sum_{t=R}^{D} \frac{P_t}{(1+d)^{t-E}}}{\sum_{t=E}^{R} \frac{CR_{PAYG} \cdot W_t}{(1+d)^{t-E}}}$$

where:

- P_t = pension benefit received at age t;

- CR_{PAYG} = contribution rate;
- W_t = wage earned at age t;
- d = discount rate (exogenous, e.g. social discount rate);
- E = entry age into the labor market;
- R = retirement age;
- D = age at death.

This formula shows that, all else being equal, a higher CR_{PAYG} increases the present value of contributions and thus lowers the IRR. In the context of deteriorating demographic ratios, the required CR_{PAYG} rises to maintain balance, while benefits are often kept stable or even reduced, leading to a decline in the IRR for future generations, and thus a problem of inter-generational equity.

Another structural limitation of PAYG financing is its unfunded nature. Because contributions are immediately spent, and reserves are typically low, the system lacks a financial buffer. This makes it vulnerable to economic shocks (deficit during COVID-19 crisis)

This lack of funding also complicates any potential transition to a defined-contribution scheme, as current workers would need to finance both the pensions of today's retirees and their own future benefits simultaneously.

2 Scaled Premium Method

The Scaled Premium method is similar to PAYG but applied over a fixed period (e.g. 20–30 years). It sets a constant contribution rate to cover expected expenditures over that period:

$$CR_{Scaled} = \frac{PVB(t_0, t_1) - F(t_0) + PV[F(t_1)]}{PVW(t_0, t_1)}$$

where:

- $PVB(t_0, t_1)$ = present value of benefits,
- $F(t_0)$ = initial reserve,
- $PV[F(t_1)]$ = final reserve target,
- $PVW(t_0, t_1)$ = present value of wages.

Unlike PAYG, this method avoids yearly rate changes, improving political acceptability. If $CR_{Scaled} > CR_{PAYG}$, a small reserve is built up, helping absorb shocks.

However, if demographic conditions worsen, future recalibration may demand sharp rate increase, creating political challenges. Stability is thus limited to the chosen period.

3 General Average Premium (GAP) Method

The General Average Premium (GAP) method extends the scaled premium approach by applying a constant contribution rate over a very long period. Its goal is to ensure long-term balance by covering the present value of all future liabilities.

$$CR_{GAP} = \frac{PVB(\infty) - F(t_0) + PV[F(t_1)]}{PVW(\infty)}$$

where:

- $PVB(\infty)$ = present value of all future benefit obligations;
- $F(t_0)$ = initial reserve;
- $PV[F(t_1)]$ = reserve target at end of horizon;

- $PVW(\infty)$ = present value of future wages.

This method enhances long-term sustainability by building reserves early, when spending is low. It also reduces the need for sharp rate adjustments later.

Its use, however, is limited. It relies on long-term actuarial projections with uncertain assumptions. In addition, the high initial contribution rate can be politically difficult to justify, especially when today's contributors fund reserves for future generations, raising inter-generational equity concerns.

4 Fully Funded Method

A pension plan is fully funded when each generation accumulates enough assets during its working years to finance its own future pension benefits. The present value of contributions must equal the present value of future benefits for each generation.

This intertemporal balance can be expressed as:

$$\sum_{t \in \text{retirement}} \frac{P_t^{(g)}}{(1+r)^{t-E}} = \sum_{t \in \text{working}} \frac{CR^{(g)} \cdot W_t^{(g)}}{(1+r)^{t-E}}$$

where:

- g = the generation (or cohort) under consideration;
- $P_t^{(g)}$ = pension benefit received by generation g in year t;
- $W_t^{(g)}$ = wage earned by generation g in year t;
- $CR^{(g)}$ = contribution rate applied to generation g;
- r = rate of return on invested reserves;
- E = age of entry into the labour market;
- $t \in$ working = years from age E to retirement age R when contributions are paid;
- $t \in$ retirement = years from retirement age R to death age D when pensions are received.

Fully funded systems are often used for predictable lump-sum liabilities. They avoid intergenerational inequity and enhance transparency.

However, fully DB funding pensions is complex. It requires large, long-term reserves that must outperform inflation with limited risk. Poor investment returns can threaten benefit payments. Moreover, developing countries often lack safe, productive outlets for large domestic reserves investment. Furthermore, transitioning to this type of scheme is also difficult: the system take decades to mature and cannot cover with adequacy the retirees cohort who did not contribute fully.

Conclusion

The financing method chosen for defined-benefit social insurance schemes shapes not only their financial sustainability but also their equity, political acceptability, and resilience.

PAYG remains widespread due to its simplicity and solidarity, but faces demographic pressure. Scaled and GAP methods offer medium- and long-term stability, while fully funded models enhance transparency and intergenerational fairness, but at the cost of complex transitions and investment risks. In practice, a balanced mix of approaches is the most pragmatic and sustainable solution.

Q3: Parametric and Systemic Reforms of Defined-Benefit Social Insurance Schemes

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Introduction

Pension-related defined-benefit (DB) schemes, given their fiscal weight and demographic sensitivity, are frequently the focus of reform debates. In recent decades, governments have pursued two main types of reforms: parametric reforms, which adjust key parameters of existing DB systems, and systemic reforms, which modify their underlying structure—often shifting toward notional defined-contribution (NDC) models.

This essay examines the motivations behind these reforms and their implications for pension policy goals, including adequacy, sustainability, equity, and integration with broader social protection systems.

1. Motivations for Parametric and Systemic Reforms

Parametric reforms are often driven by a combination of objectives, including improving benefit adequacy, enhancing equity—particularly intergenerational and horizontal equity between social groups (e.g., public vs. private sector, men vs. women)—and, most importantly, ensuring financial sustainability.

According to the OECD's *Pensions at a Glance* reports (OECD, 2023), many countries have implemented parametric changes primarily for fiscal reasons. Mature pension systems are increasingly strained by a declining contributor-to-beneficiary ratio. In France, for example, the ratio has dropped from approximately 3.8 contributors per retiree in 1970 to around 1.7 today (COR, 2024), with projections suggesting a further decline to 1.3 by 2070.

This demographic pressure translates into fiscal pressure, especially when combined with low economic growth and limited wage increases. These conditions have led to parametric reforms such as raising the retirement age (as recently implemented in France), and in some cases, systemic reforms like Italy's 1995 Dini reform (Fornero, 2020), which replaced the DB system with a notional defined-contribution (NDC) model.

2. Parametric Reforms in Defined-Benefit Pension Systems

We begin by focusing on parametric reforms, which adjust key parameters of DB schemes without changing their fundamental structure. To understand their scope, it is helpful to present the core formulas that govern the functioning of such systems—both on the benefit and contribution sides.

The pension benefit received by an individual at retirement can be expressed as:

$$B_t = \alpha \cdot N \cdot RW$$

where:

- B_t = pension benefit at time t;
- α = accrual rate (e.g., 1.5% per year);
- N = number of contributory years (validated service years);
- RW = reference wage.

The reference wage (RW) is commonly computed as a weighted average of past earnings:

$$RW = \sum_{s=E}^{R} w_s \cdot f_s$$

where:

- w_s = wage at year s;
- f_s = weighting factor (e.g., equal weights for full-career average, or higher weights for final years);
- E = entry age in the labour market;
- R = retirement age.

On the financing side, contributions can be formalized as:

$$C_t = \tau \cdot \min(w_t, \bar{w}_t)$$

where:

- C_t = contribution paid at time t;
- τ = contribution rate (as a percentage of the insurable wage);
- w_t = individual gross wage at time t;
- $\bar{w}_t$ = ceiling on insurable earnings (social security wage ceiling).

Parametric reforms may target any of these components: adjusting the accrual rate α, modifying the method for calculating the reference wage (e.g., changing f_s), raising the retirement age R, increasing the contribution rate τ, or altering the ceiling $\bar{w}_t$. Each change can significantly impact benefit adequacy, financial sustainability, and fairness within the system.

The first and most politically sensitive parametric reform is often the increase in the statutory retirement age. Although technically simple, it has direct and visible consequences for all contributors, and affects public perceptions of fairness. This reform has been implemented in nearly all OECD countries, including recently France, Sweden, and Slovakia, which raised or linked retirement age to life expectancy, while others like Costa Rica, Czechia, and Portugal tightened early retirement rules or adjusted statutory ages (OECD, 2023).

Raising the retirement age reduces the number of beneficiaries in the short term. Its effect on the number of contributors is more uncertain: it increases contributions only if older workers remain employed. In contexts of high unemployment or disability rates among those over 60, delaying retirement may simply shift individuals to other benefits such as unemployment insurance or social assistance. As noted by the French Pensions Advisory Council (COR) during the Macron reform debate, these dynamics can offset financial gains by increasing pressure on other parts of the social protection system.

Secondly, parametric reforms may target the benefit formula itself. A common adjustment is to reduce the accrual rate, thereby lowering pension generosity uniformly across retirees. While such a measure do not have effect on horizontal equity, it inevitably reduces benefit adequacy.

Another key parameter is the reference wage used in the pension formula. In some systems—such as the French civil service—benefits are based on final salaries, a method often viewed as regressive. It tends to favor individuals with upward-sloping earnings paths, typically men, white-collar workers, and managers, while disadvantaging those with flat or fragmented careers.

To address these disparities, many experts and international institutions advocate for using full-career average wages, with equal weighting across contributory years. This approach enhances fairness and better aligns benefits with lifetime contributions.

Finally, adjusting the contribution rate is another common parametric reform, particularly during the maturation phase of pension systems. In France, for instance, the combined contribution rate has risen from 8% in 1960 to 15.45% today.

However, raising the contribution rate has important distributional implications. It disproportionately benefits early cohorts—such as baby boomers—who contributed at low rates but received generous pensions financed by higher contributions from younger generations. This raises concerns about intergenerational equity.

Moreover, there is a political and social ceiling to how far the contribution rate can be raised. Once it approaches 20% of gross wages, further increases risk undermining the disposable income of current workers and may face strong resistance.

3. Systemic Reforms: Transition from DB to NDC Schemes

In contrast to parametric adjustments, systemic reforms involve a more fundamental shift in the design of pension systems, even if this transformation remains relative (Cichon, 1999). One prominent example is the transition from defined-benefit (DB) to notional defined-contribution (NDC) schemes.

An NDC system operates within a pay-as-you-go (PAYG) framework, but mimics many features of funded DC plans. Individual contributions are recorded in notional accounts, which accumulate over time with an imputed ("fictitious") rate of return. Upon retirement, the notional capital is converted into an annuity using an actuarial divisor, which reflects life expectancy and possibly other demographic or economic parameters.

The core formula for calculating pensions in an NDC system is:

$$P = \frac{\sum_{t=E}^{R} C_t \cdot (1+g)^{R-t}}{AF(R)}$$

where:

- C_t = contribution at year t,
- g = notional interest rate,
- R = retirement age,
- E = entry year into the system,
- $AF(R)$ = annuity factor at retirement, reflecting life expectancy and discount rates.

This formula links benefits directly to lifetime contributions, improving transparency and actuarial fairness. This improved link between contributions and benefits can also incentivize workers to declare their full earnings, thereby reducing evasion and strengthening the contributory base. The notional return g is usually linked to macroeconomic indicators such as wage growth, GDP, or total insurable earnings. NDC schemes are also more easily brought into financial balance than traditional DB systems, especially if parameters are automatically adjusted in response to economic shocks.

However, the system is not inherently in automatic balance. Its financial equilibrium depends heavily on the correct calibration of the annuity factor $AF(R)$, which reflects life expectancy and discount assumptions. If this factor does not adjust to changes in the overall contribution base—such as those caused by economic shocks, the system may accumulate imbalances over time.

Finally, by more closely linking contributions to benefits, NDC systems can result in very inadequate pensions—often below the poverty line—for individuals with interrupted careers or lifelong low earnings. This is why a transition from DB to NDC should not take the form of a "pure" NDC shift, but must be accompanied by complementary redistributive mechanisms. In many countries, this involves retaining elements of the original DB formula or introducing minimum pension guarantees (e.g. minimum pension supplement in Italy) and other floors to ensure that even those with limited contribution histories receive an adequate pension and are protected from poverty.

In short, NDC reforms offer a politically viable and technically robust response to fiscal and demographic pressures. By linking benefits directly to lifetime contributions, they enhance transparency and reduce unfunded liabilities. However, their success in terms of adequacy and poverty reduction relies on the presence of complementary redistributive mechanisms.

Conclusion

Parametric and systemic reforms respond to mounting fiscal and demographic pressures on DB pension systems. While parametric changes can improve sustainability with limited disruption, systemic shifts—such as the move to NDC—offer deeper structural alignment between contributions and benefits. Yet both approaches carry trade-offs, particularly regarding adequacy and equity (regarding rate of return). To succeed, reforms must be context-sensitive, politically feasible, and complemented by redistributive measures, ensuring that pension systems remain both financially viable and socially protective in the long run.

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