POPULATION AGING AND STRENGHTENED PROGRESSIVITY OF PENSIONS: THE CASE OF HUNGARY

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Abstract

Due to the rapid population aging, to sustain the Hungarian public pension system requires substantial changes. It is obvious that in addition to raising the contribution rate and the statutory retirement age in the long-run, the benefit ratio (i.e., the ratio of average pensions to average wages) must be reduced. We model the process of strengthening the progressivity of initial pensions (i.e., decreasing the ratio of high benefits to high earnings) while preserving the real value of the pensions in payment, offering various scenarios.

Keywords: public pension systems, population aging, redistribution

JEL codes: H55

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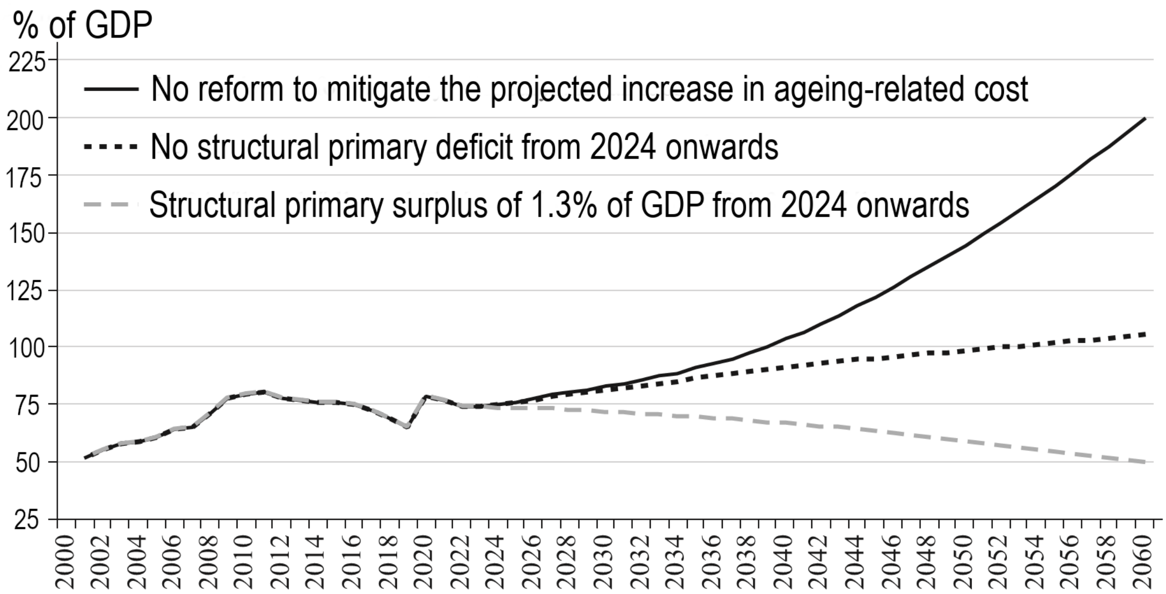
1 Introduction

The question is often raised: how to sustain the Hungarian public pension system under the rapid aging of the population? The answer, which we explain here, is that the challenges facing the pension system, although not intractable, are difficult to manage. Raising the contribution rate and the statutory retirement age alleviate the problem, but the progressivity of the benefits (i.e., decreasing ratio of benefit to earning) should also be strengthened. This idea is formulated in the European Commission Aging Report (2024, p. 6) as follows: while the benefit ratio declines from 43% (2022) in the EU to 36% (2070), "the projections assume that the minimum pension follow wage growth over time."

Based on OECD (2024a), Figure 1 presents the public debt ratio trajectory (debt expressed as a percentage of GDP) of maintaining the current Hungarian pension system, under three scenarios: a) the primary budget deficit remains unchanged, b) it disappears, c) it becomes positive, equalling to 1.3% of GDP from 2024 to 2060. In scenario a), the public debt rises to 200% of GDP; in scenario b), it stops above 100%; while in scenario c) it falls to 50% of GDP. Of course, it is much more practical and realistic to reform the pension system than adhering to these options. This will be done in the paper without being able to estimate the debt dynamics.

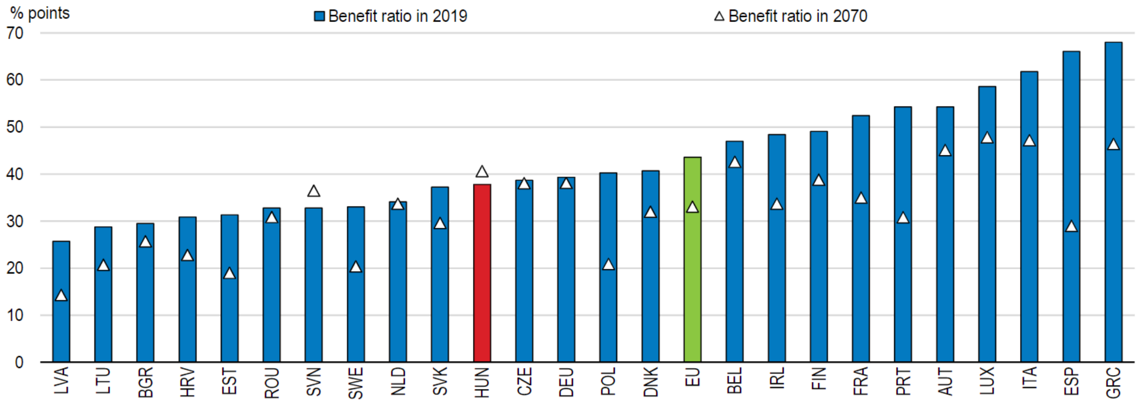
Figure 1. Impact of pension burdens on public debt, with three balances, HU, 2024-2060



Source: OECD (2024a, Figure 2.26).

We quote two more charts from the OECD (2024a) report. This report emphasizes and Figure 2 affirms that besides Slovenia, Hungary is the only country where the government does not plan to reduce the gross benefit ratio: the government will stabilize it at around 40%, while the Polish government would halve its current benefit ratio, now quite close to Hungary's, by 2070. (It should be remembered that this indicator is the result of numerous modelling effects and is not very reliable.)

Figure 2. Current and projected benefit ratios, OECD countries

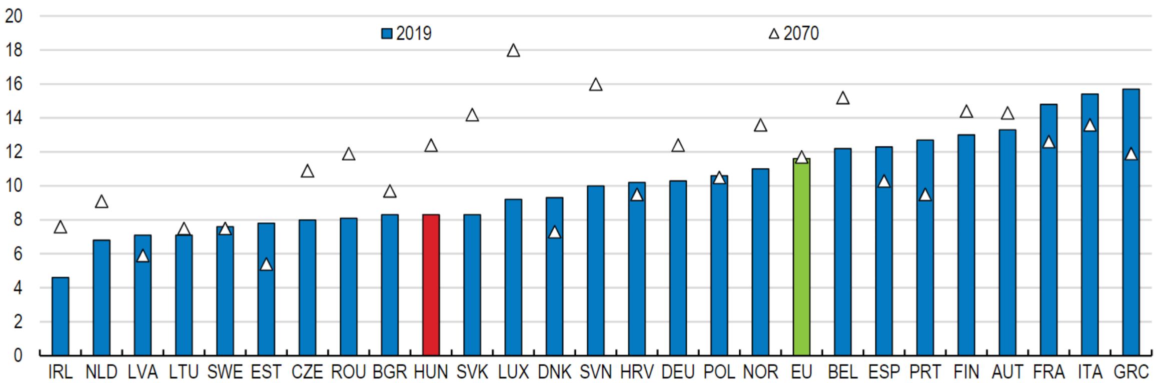


Note: The benefit ratio is the ratio between the average pension and the average wage, both measured in gross terms.
Source: 2021 Ageing Report (European Commission, 2021, p. 84[29]).

Source: OECD (2024a, Figure 2.27).

Figure 3 shows the current and the expected shares of pension expenditure in GDP in EU countries (in 2019 and 2070, respectively), in ascending order. The spread between 4 and 16% is noteworthy; the lowest value (due to a significant private pillar) is, for example, the Irish 4%, while the highest one points to too early retirement and too generous replacement: Italian 15%, Greece 16%.

Figure 3. Current and expected share of pension expenditure in GDP, EU countries



Source: OECD (2024a, Figure 2.28).

In a pure pay-as-you-go pension system, the equilibrium contribution rate is equal to the product of the system dependency ratio and the benefit ratio. If we assume that the contribution rate cannot be increased much higher, and that raising the statutory retirement age cannot effectively limit the increase in the old-age dependency ratio due to population ageing, then the benefit ratio must indeed be reduced. The question is whether productivity and real wage growth are sufficient to prevent the relative level of pensions, especially for the lowest income earners, from falling too low.

Digression: Following the World Bank (1994), the view that privatizing the public pension system would alleviate and even solve the problems of the pension system have become widespread. Since then, it has become clear, both theoretically and practically, that this is not so simple (for example, Beattie and McGillivray, 1995; Simonovits, 2003; and Barr, 2023). In fact, according to this paper, in contrast to the private pension system, increasing progressivity of the public system is one of the means of solution.

A further complication in decreasing the benefit ratio is that the real value of pensions in payment is rarely reduced, so all the burden of adjustment fall to the initial pensions. While in the first model, pensioners are not differentiated by age; the distinction between initial benefits and benefits in payment is neglected. In the second, we make this distinction. The population is divided into 10-year age groups. Taking into account the expected changes in the age-group composition of the Hungarian population over time, the above questions can be examined, and the magnitude of the problems can be perceived by relying on meaningful, if not actual, wage and pension data. Then the indexation of benefits in payment also becomes important, especially if the *longevity gap*—individuals with higher earnings statistically live longer—is taken into account. On the one hand, indexation to prices is less costly and diminishes intracohort redistribution but increases intercohort redistribution. On the other hand, indexation to wages is more costly and diminishes intercohort redistribution but increases intracohort redistribution (Simonovits, 2015 and Andersen and Jorgensen (2025).

The main characteristics of the seven scenarios used in the two models are summarized in Table 1. The meaning of the four criteria (age-variant benefits, fixed contribution rate, earnings-related (in fact, proportional) pension and wage index weight) is quite well known, the details are explained in the text.

Table 1. Characteristics of seven scenarios

Scenario	Age-variant benefits	Fixed contribution rate	Earnings-related (initial) pension	Wage index weight
1	no	yes	yes	–
2	no	yes	no[a]	–
3	no	yes	no[b]	–
4	yes	no	yes	0
5	yes	no	yes	1
6	yes	no	yes	0.5
7	yes	no	no	0

a) preserving the relative value of the minimum pension, b) preserving the real value of the maximum pension.

We will now briefly refer to the background literature. Lindbeck and Persson (2003) discussed the gains from pension reforms in general. Diamond and Orszag (2004) analyzed the sustainability of the US public pension system and made specific calculations on how the financial problems of the system could be addressed by increasing redistribution within the pension system. Knell et al. (2006) analyzed the impact of pension reforms of 2001–2005 on the fiscal sustainability and future benefits in Austria. Confining attention to the Hungarian pension system, Fehér (2010) suggested the replacement of the generous earning-related benefits with very low basic pensions. Bajkó et al. (2015) focused on population projections, Freudenberg, Berki and Reiff (2016) discussed the impact of previous reforms, and thoroughly explored the sustainability issues, but did not consider the issue of redistribution or further reforms.

Gál and Radó (2019) showed how raising the effective retirement age alleviated the pressure on the pension system of aging societies, including Hungary. Knell (2018) analyzed the impact of rising life expectancy and retirement age on the NDC pension system.

Kindermann and Pueschel (2021) would make the German pension system progressive with a basic pension dependent on employment, in addition to income redistribution, also providing compensation for the unfairness of lower earnings–shorter lifespan.

Reiff and Simonovits (2023) examined the inequalities in the Hungarian pension system and found that both within-cohort and intercohort inequality had increased significantly, which was undesirable. Simonovits (2023) suggested increasing the progressivity from an equity perspective, but did not address longer-term issues. Oblath and Simonovits (2024) analyzed in detail how overestimated earnings statistics distort the benefit ratios of the Hungarian pension system.

In addition to make the Austrian pension system sustainable, Sánchez-Romero, Schuster, and Prskawetz (2024) modelled various reforms and examined their redistributive effects. For example, in addition to proportionally reducing the benefits and raising retirement age, they also considered making the statutory retirement age increase with life expectancy, or adjusting the length of contribution. In a blog, Knell (2025) argued that introducing progressivity into the Austrian public pension system could make the system fairer and possibly less expensive.

Since OECD (2024b) has been prepared to advise the Hungarian government by alternative reform plans, it is worth outlining its main ideas. It very strongly recommended the phasing-out of Women40 (granting every Hungarian woman with at least 40 years of entitlements penalty-free retirement), indexing the statutory retirement age to future life expectancy, and proportionally cutting back future benefits without addressing the relative immiseration of the those with low initial benefits and we find the foregoing benefit calculations optimistic. This is the main justification for coming up with another type of reforms in this paper. Similarly to the OECD (2024b), we do not consider the political aspects of such reforms.

The rest of the paper is structured as follows. In Section 2, we consider age-invariant benefits, and in Section 3, we introduce age-dependence. Section 4 contains the conclusions. Appendix A shows the macro impact of raising the retirement age in a theoretical model. Appendix B demonstrates the reduction of the balanced contribution rate in a model with longevity gap when the replacement rate is fixed and the progressivity is strengthened. Appendix C illustrates that in a theoretical model, the piecewise linear benefit can be well approximated by an appropriate linear one.

2 Age-invariant benefits

2.1 Frame

From the perspective of the pension system with constant retirement age, population aging is a process in which every worker supports more and more pensioners. This is partly offset by a parallel increase in the effective retirement age. Based on the European Commission Aging Report-2024, we first present the demographic and pension projections for Hungary without considering the finer structure of the population.

Table 2. Pension expenditure forecast, HU

Category	2022	2030	2040	2050	2060	2070
Pension expenditure, % of GDP	7.7	7.7	9.0	10.7	11.5	12.0
Pension contribution, % of GDP	6.8	6.9	6.8	6.8	6.8	6.8
Other indicators						
Pensioners, ’000	2 549	2 610	2 832	3 057	3 160	3 135
Benefit ratio, %	38.2	37.1	38.2	39.8	39.9	41.5
Replacement rate[a], %	39.9	46.8	47.5	48.2	47.4	48.3
Contribution years	35.9	37.1	38.5	38.4	38.1	39.0
Contributors, ’000	4 701	4 765	4 543	4 298	4 125	4 046
Dependency ratio, %	54.2	54.8	62.3	71.1	76.6	77.5

Source: European Commission, Aging Report-2024, p. 295. a) The ratio of initial benefits to last wages.

Let a non-negative integer t be the index of the calendar year, let P_t and M_t be the number of retirees and workers in the given year, respectively; and the ratio $p_t = P_t/M_t$ is called *system dependency ratio.* The foregoing ratio increases from 54 to 77% (last row).

With a good approximation, the current equilibrium condition of the pension system is the equality of contribution revenues and pension expenditures. In formula:

$$\tau_t^* M_t w_t = P_t b_t, \tag{1}$$

where τ_t^* is the equilibrium contribution rate, b_t is the average pension, w_t is the super-gross average wage, and their ratio is the so-called *gross benefit ratio*: $\beta_t = b_t/w_t$. If the personal income tax and contribution rates vary rapidly (they have drastically decreased in Hungary since 2010), then the gap between gross and net benefit ratios cannot be ignored (Oblath and Simonovits, 2024), but we will not deal with this for now.

By rearranging (1) for the equilibrium contribution rate, we obtain the following well-known equation:

$$\tau_t^* = \frac{P_t b_t}{M_t w_t} = p_t \beta_t. \tag{2}$$

Though we consider wage heterogeneity in the paper, for technical reasons, we assume that the earnings proportions and (with the exception of Appendix A) the retirement age are constant. Due to population aging, either the average benefit ratio must be reduced or the contribution rate must be increased, in both cases considering the enhancement of redistribution. We work with real variables throughout. With age-invariant benefits, the reduction is easier than it would be otherwise.

2.2 Proportional changes to pensions

In the case of a constant contribution rate, the benefit ratio is inversely proportional to the dependency ratio:

$$\beta_t = \frac{\tau_0}{p_t}, \qquad t = 0, 1, 2, 3. \dots.$$

In Scenario 1, we examine earnings-related pensions. Individual and average (pension, wage) pairs are denoted by uppercase and lowercase letters, respectively:

$$B_t = \beta_t W_t \qquad \text{and} \qquad b_t = \beta_t w_t.$$

Let G be the time-invariant growth coefficient of the average real wage per unit period (here a decade): $w_t = Gw_{t-1}$. Then the time dependence of the average pension is given by

$$b_t = \beta_t G^t. \tag{3}$$

If real wages rise fast enough: $G = 1.02^{10}$, then due to (3) and the effect of population aging and employment adjustment reported in Table 2, the real value of the average pension remains approximately constant for 3 decades (Table 3). Anyway, fast population aging puts pressure on the public finances. For example, the contributions received according to the 18% gross pension contribution rate would have only accounted for 75% of the expenditures in 2023, so the equilibrium contribution rate would have been 24%, but we calculated it at 20%. (For convenience, the time index varies from 0 to 4 in the formulas, and from 2020 to 2050 in the tables.)

Table 3. Impact of proportional changes in pensions, 2020–2050

Decade t	Old-age system dependency ratio p_t	Gross benefit ratio $\beta_t = b_t/w_t$	Average pension* b_t
2020	0.480	0.417	0.417
2030	0.592	0.338	0.412
2040	0.704	0.284	0.422
2050	0.816	0.245	0.444

* Average pension as a proportion of the average super-gross earnings in 2020

This is a good initial point in theory, but unacceptable in practice, because the benefit ratio is getting lower and lower: it is dropping from 42 (in 2020) to 25% (in 2060). This is still tolerable for higher pensions, but no longer for lower ones.

2.3 Preserving the relative value of the minimum pension

Scenario 2 preserves the value of the minimum old-age benefit relative to average earnings by increasing redistribution. For example, for individual wages (W) and pensions (B), consider the rule

$$B_t = \beta_t[\alpha_t W_t + (1 - \alpha_t)w_t], \tag{4}$$

where α_t is the weight of the earnings-related part of pensions, in short: the *proportionality coefficient* in decade t, and $1 - \alpha_t$ is the benefit ratio of the unconditional (basic) pension. With notation $W_t = \omega w_t$,

$$B_t = \beta_t[\alpha_t \omega + 1 - \alpha_t]w_t. \tag{5}$$

If we take the average, then regardless of the value of α_t and the distribution of earnings, the average benefit ratio is β_t. In reality, the redistribution is typically implemented by a progression with at least two parameters (bend-point and reduction coefficient) but we will ignore this complication for simplicity (see also Appendix C). In the following, we calculate the redistributive effects for 3 wage types – half the average, the average, and twice the average.

Recall the real wage dynamics $w_t = w_0 G^t$ where the length of a period is equal to 10 years. Based on the assumption that the minimum wage is half the average, $\beta_0/2 = \beta_t(1-\alpha_t/2)$,

$$\alpha_t = 2 - \frac{\beta_0}{\beta_t w_t}. \qquad (6)$$

Taking the value $\beta_0 = 0.417$ from Table 3, Table 4 shows that the *real value* of the average pension (after a temporary slight decrease) is slowly increasing; the minimum pension is increasing in parallel with average earnings; and the maximum pension is decreasing from 0.83 to 0.58. The proportionality coefficient of initial pensions is falling, and this may undermine the willingness of paying contributions.

Table 4. Relative preservation of the minimum pension with increased redistribution, 2020–2050

Decade t	Average pension B_t^{av}	Proportional coefficient α_t	Minimum pension $B_t^{\min}$	Maximum pension $B_t^{\max}$
2020	0.417	0.999	0.208	0.833
2030	0.412	0.766	0.254	0.727
2040	0.422	0.532	0.310	0.647
2050	0.444	0.299	0.378	0.577

2.4 Preserving the value of the maximum pension

If we find the redistribution of scenario 2 excessive, then we may choose scenario 3, which slows down the increase of the minimum pension and stops the depreciation of the maximum pension; based on the fact that the maximum wage is double the average, $2\beta_0 = \beta_t(1+\alpha_t)w_t$, but also prevents excessive proportionality (when $\alpha_t > 1$):

$$\alpha_t = \max\left[1, \frac{\beta_0}{\beta_t w_t} - 1\right] \qquad \text{and} \qquad B_t^{\max} = (1+\alpha_t)\beta_t w_t = B_0^{\max}. \qquad (7)$$

Table 5 presents this solution. Due to the almost complete preservation of the real value of maximum pension, redistribution increases only very slightly, and therefore the minimum pension increases only very slowly, while its relative value drops.

Table 5. Preservation of the real value of maximum pensions

Decade t	Average pension B_t^{av}	Proportional coefficient α_t	Minimum pension $B_t^{\min}$	Maximum pension $B_t^{\max}$
2020	0.417	1.000	0.208	0.833
2030	0.412	1.000	0.206	0.824
2040	0.422	0.976	0.216	0.834
2050	0.444	0.879	0.249	0.834

3 Age-variant benefits

3.1 Frame

We can now turn to age-variant benefits. This requires distinction between initial pensions and pensions in payment, in other words: valorization and indexation. While initial pensions fully follow the development of real wages, pensions in payment often do only partially or not at all.

Before outlining the alternative scenarios, we present the common framework. We work with ten-year age groups, $n_{a,t}$ is the number of the a-th age group of decade t, where the two limits are $10a$ and $10a+9$ years. Csaba G. Tóth provided Table 6, which contains a much more detailed forecast of the number of the Hungarian age groups than Table 2 does. For the sake of completeness, we indicate the average age of the current population (which is not the same as life expectancy at birth): this is gradually increasing from 43 to 48 years. The approximative formula for this is

$$\bar{A}_t = 10\frac{\sum_{a=0}^{9} n_{a,t}(a+0.5)}{\sum_{a=0}^{9} n_{a,t}}. \tag{8}$$

Finally, we add the steeply rising forecasted life expectancies for males and females, separately, from 72–79 (in 2020) to 79–84 (in 2050).

Table 6. Age-group size dynamics, 2020–2050, '000

Generation	Age group	2020	2030	2040	2050
Child	0- 9 yr	920.8	897.0	812.7	773.9
	10-19 yr	982.3	927.4	905.0	821.1
Working	20–29 yr	1166.2	1000.0	948.3	926.5
	30-39 yr	1264.6	1168.5	1005.9	955.5
	40-49 yr	1582.6	1259.5	1170.9	1013.0
	50-59 yr	1232.4	1517.0	1217.3	1139.5
Pensioners	60-69 yr	1292.6	1082.8	1355.1	1099.0
	70-79 yr	858.5	980.4	858.2	1105.4
	80-89 yr	373.4	457.1	549.6	523.2
	90- yr	67.8	98.0	142.5	184.7
Total		9741.2	9387.6	8965.5	8541.9
Dependency ratio		49.4%	52.9%	66.9%	72.2%
Average age		42.9 yr	44.5 yr	47.3 yr	48.3 yr
Life expectancy	Male	72.2 yr	75.1 yr	77.1 yr	79.0 yr
	Female	78.7 yr	81.1 yr	82.5 yr	83.9 yr

Source. Based on Obádovics and Tóth (2023).

For now, we are only considering earnings-related initial pensions ($\alpha_t = 1$), therefore we can immediately take the age-variant averages:

$$b_{6,t} = \beta_t w_t. \tag{9}$$

The pensions in payment for decade t are obtained by indexing the corresponding pensions of the previous decade (initial benefits or benefits in payment). Let ι be a number between 0 and 1, denoting the weight of the wage index, which is 0 for indexation to prices, 1 for indexation to wages; and 1/2 for the so-called Swiss indexation. Then

$$b_{a,t} = b_{a,t-1}(w_t/w_{t-1})^{\iota}, \qquad a = 7, 8, 9. \tag{10}$$

Even if we disregard the age-dependence of earnings, the balance of the pension system is now much more complicated than in (1):

$$\sum_{a=6}^{9} n_{a,t} b_{a,t} = \tau_t^* M_t w_t, \tag{11}$$

where $M_t = \sum_{a=2}^{5} n_{a,t}$ denotes the size of the working-age population in period t.

For convenience, we arbitrarily assume that the values of the average pensions in payment in 2020 were independent of when they were started:

$$b_{7,0} = b_{8,0} = b_{9,0}.$$

According to Oblath and Simonovits (2024), the initial pensions in 2020 were much higher than the average, so we somewhat arbitrarily calculate with $b_{6,0} = 1.05b_0$, hence for the weighted pension average

$$P_0 b_0 = [P_0 - n_{6,0}]b_{7,0} + n_{6,0} b_{6,0},$$

the average value of the earliest pensions in payment is given by

$$b_{7,0} = \frac{P_0 b_0 - n_{6,0} b_{6,0}}{P_0 - n_{6,0}}. \tag{12}$$

Using the headcount data in Table 6, we recalculate the above scenarios.

3.2 Indexation to prices

In scenario 4, we freeze the pensions in payment: $\iota = 0$ and increase the initial pensions in parallel with average earnings, assuming an increase in the equilibrium contribution rate.

In the subsequent periods ($t = 1, 2, 3$), both the age-dependent individual and average values of pension follow equations

$$B_{6,t} = B_{6,t-1}G \qquad \text{and} \qquad B_{a,t} = B_{a-1,t-1}, \qquad a = 7, 8, 9, \qquad t = 1, 2, 3, \tag{13}$$

as well as

$$b_{6,t} = b_{6,t-1}G \qquad \text{and} \qquad b_{a,t} = b_{a-1,t-1}, \qquad a = 7, 8, 9, \qquad t = 1, 2, 3. \tag{14}$$

In Table 7, following (12)–(14), we present the path of the average age-related pensions over time. Note how the gap between the average of the earliest and the most recent pensions widens, the 10% gap in 2020 (0.425/0.385) widening to 81% (0.77/0.425) by 2050.

Table 7. Age-variant average pensions (in proportion to the average wage in 2020) 2020–2050, indexation to prices

Age	Benefits			
a	$b_{a,2020}$	$b_{a,2030}$	$b_{a,2040}$	$b_{a,2050}$
60	0.425	0.518	0.631	0.770
70	0.385	0.425	0.518	0.631
80	0.385	0.385	0.425	0.518
90	0.385	0.385	0.385	0.425

Based on (11), Table 8 shows how the equilibrium contribution rate rises from 20 to 26%.

Table 8. Equilibrium contribution rate, 2020–2050, indexation to prices

τ_{2020}	τ_{2030}	τ_{2040}	τ_{2050}
0.200	0.198	0.246	0.259

To diminish the huge gap between the pensions of successive age groups, it is necessary, at least partially, to take into account real wage growth in the indexation of pensions in payment.

3.3 Indexation to wages and prices

We turn to the analysis of mixed indexation, including pure indexation to wages: $0 < \iota \leq 1$. Instead of (14), the average values of age-dependent pensions in the subsequent periods are

$$b_{6,t} = b_{6,t-1}G \qquad \text{and} \qquad b_{a,t} = b_{a-1,t-1}G^{\iota}, \qquad a = 7, 8, 9, \qquad t = 1, 2, 3. \tag{15}$$

In scenario 5, we examine pure indexation to wages: $\iota = 1$. We will see that here the benefit ratio is steady but the system is very expensive.

Table 9 displays the path of elimination of age-dependence of pensions within three decades: all age-dependent average benefits rise from cc. 0.4 to 0.77 regardless of age.

Table 9. Age-variant average pensions (in proportion to the average wage in 2020) 2020–2050, indexation to wages

Age	Average pension			
a	$b_{a,2020}$	$b_{a,2030}$	$b_{a,2040}$	$b_{a,2050}$
60	0.425	0.518	0.631	0.770
70	0.385	0.518	0.631	0.770
80	0.385	0.469	0.631	0.770
90	0.385	0.469	0.571	0.770

By Table 10, the equilibrium contribution rate will now rise to 31% rather than 26%.

Table 10. Equilibrium contribution rate, 2020–2050, indexation to wages

τ_{2020}	τ_{2030}	τ_{2040}	τ_{2050}
0.200	0.220	0.283	0.307

In scenario 6, we will see how much the 50–50% mixed indexation reduces the lag of earlier pensions compared to indexation to prices, and the increase in the contribution rate compared to pure indexation to wages. According to Table 11, mixed indexation only slows down but does not eliminate the relative decline of pensions started earlier compared to current initial pensions.

Table 11. Age-variant average pensions (in proportion to the average wage in 2020) 2020–2050, mixed indexation

Age	Average pension			
a	$b_{a,2020}$	$b_{a,2030}$	$b_{a,2040}$	$b_{a,2050}$
60	0.425	0.518	0.631	0.770
70	0.385	0.469	0.572	0.697
80	0.385	0.425	0.518	0.631
90	0.385	0.425	0.469	0.572

Table 12 attests that over 3 decades the equilibrium contribution rate will increase from 20 to only 28% rather than 31%.

Table 12. Equilibrium contribution rate, 2020–2050, mixed indexation

τ_{2020}	τ_{2030}	τ_{2040}	τ_{2050}
0.200	0.208	0.263	0.281

4 Redistributive initial pensions

In Scenario 7 we return to the progressive pensions of Scenarios 1–3, but here we restrict ourselves to initial pensions only. Turning to individual wages (W_t) and initial pensions ($B_{6,t}$), the rule

$$B_{6,t} = \beta_t[\alpha_t W_t + (1 - \alpha_t)w_t],$$

where α_t is the weight of the earnings-related part in year t. With notation $W_t = \omega w_t$,

$$B_{6,t} = \beta_t[\alpha_t \omega + (1 - \alpha_t)]w_t. \qquad (16)$$

On average, the effect of redistribution disappears:

$$b_{6,t} = \beta_t w_t, \qquad t = 1, 2, 3. \qquad (17)$$

Keeping the replacement value of the minimum initial pensions (Table 13) and freezing the pensions in payment, the average pensions reduced in comparison to Tables 7 and 8 (Table 14) and the equilibrium contribution rates (we obtain Table 15). The solution is only written for the endogenous proportionality coefficient and the initial pension for the three periods corresponding to the three distinguished earnings, namely average, minimum and maximum wages. It is surprising that the proportionality coefficient is so close to 1, which is why the maximum initial pension increases relatively slowly, is also acceptable.

Table 13. Proportionality coefficient and trajectory of initial pensions, 2020–2050, indexation to prices

Decade	Proportional coefficient	Average	Minimum initial pension	Maximum
t	α_t	$b_{60,t}$	$B_{60,t}^{\min}$	$B_{60,t}^{\max}$
2030	0.959	0.498	0.259	0.974
2040	0.917	0.583	0.316	1.118
2050	0.872	0.683	0.385	1.278

The time- and age-dependence of the average pensions in payment is presented in Table 14. The restrained decrease in the proportionality factor of initial pensions hardly alleviates the relative devaluation of earlier pensions. For example, in 2050, the oldest benefits remain 0.425, while the youngest rise to 0.683.

Table 14. Time and age dependence of the average pension, 2020–2050, indexation to prices

Age	Average pension			
a	$b_{a,2020}$	$b_{a,2030}$	$b_{a,2040}$	$b_{a,2050}$
60	0.425	0.498	0.583	0.683
70	0.385	0.425	0.498	0.583
80	0.385	0.385	0.425	0.498
90	0.385	0.385	0.385	0.425

Table 15 shows how the increase in the equilibrium contribution rate slows down: the final value is 24 instead of 28%.

Table 15. Equilibrium contribution rate, 2020–2050, indexation to prices, progression

τ_{2020}	τ_{2030}	τ_{2040}	τ_{2050}
0.200	0.194	0.233	0.237

5 Conclusions

In this study, we analyzed a relatively simple pair of models, with which we considered decreasing benefit ratios or increasing contribution rates due to population aging, and examined how progressivity should be strengthened in Hungary. In the first model, we did not distinguish initial pensions and pensions in payment, making their joint reduction easy. In the second, more realistic model, we distinguished these types of benefits, and only the initial pensions could be reduced, therefore the freezing of the contribution rate is impractical.

Due to technical difficulties, we have neglected the financially beneficial impact of further raise in the statutory retirement age and the resulting rise of the effective retirement age. Taking into account such a raise, the pressure of the population aging is eased but is not eliminated.

Our model can be further developed in three directions. a) Introducing annual cohorts opens the way to studying the impact of the rising effective retirement age; b) the deterioration of the demographic situation must also be taken into account in the calculation of initial pensions and pensions in payment. Within the second direction, the slower increase in initial pensions and the adjustment of pensions in payment to this modification requires further investigation. c) As mentioned in the Introduction, OECD (2024b) proposed the indexation of statutory retirement age to life expectancy in Hungary which may diminish the reduction of the benefit ratio or the contribution rate. (However, the widening of the longevity gap (for example, Ayuso et al. (2017) and Lackó and Simonovits (2023)—narrows this possibility.) Due to insufficient fertility, population aging can only be addressed by simultaneously raising the retirement age, increasing the contribution rate, and strengthening progression.

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Appendix A. The impact of raising the effective retirement age

Due to technical problems, in the main part of this paper, we neglected the financially beneficial impact of raising the effective retirement age. In this Appendix, we try to make up this omission with a theoretical model. To save space, we first formulate the model with rising life expectancy and retirement age and then compare the result with a variant of constant retirement age. A more realistic model would assume survival curves shifting up, but we try to avoid this complication.

Considering rising retirement age we have to be careful with modeling (Knell, 2018). Note that the discrete nature of the rise in statutory retirement age (SRA) implies some break in retirement. Consider for example, the Hungarian pension system, where the rigid SRA was 64 in 2019 and 65 in 2022 for cohorts born in 1955 and 1957, respectively. In the two years between (namely 2020 and 2021), it was 64.5; those born in the first and second half of 1956, it opened in the first half of 2020 and the second half in 2021, respectively; hence nobody (except those delaying their retirement or using Women40) retired between July 1, 2020 and June 30, 2021.

To avoid problems with jumping retirement ages we shall work in continuous time. We assume that everybody in a cohort (born in moment s) retires at the same age, denoted by $R(s)$ and dies at the same age, denoted by $D(s)$. We assume two linear growth equations:

$$D(s) = D_0 + \delta s \qquad \text{and} \qquad R(s) = R_0 + \rho s. \tag{A.1}$$

For simplicity, we assume that the system started in calendar year 2000. Here $D_0 = 80$ and $R_0 = 62$, while $\delta = 0.21$ and $\rho = 0.14$. Table A.1 reports the rising age and time of starting work, retiring and exit.

Table A.1. Cohorts's life expectancy and retirement age: rising retirement age

Birth year T_0+s	Start working T_0+s+Q	Retirement age $R(s)$	Retirement time $T_0+s+R(s)$	Exit age $D(s)$	Exit time $T_0+s+D(s)$
1935	1960	62.0	1997.0	80.0	2015.0
1940	1965	62.7	2002.7	81.1	2021.1
1945	1970	63.4	2008.4	82.1	2027.1
1950	1975	64.1	2014.1	83.2	2033.2
1955	1980	64.8	2019.8	84.2	2039.2
1960	1985	65.5	2025.5	85.3	2045.3
1965	1990	66.2	2031.2	86.3	2051.3
1970	1995	66.9	2036.9	87.3	2057.4
1975	2000	67.6	2042.6	88.4	2063.4

We have to determine the cohort x of youngest pensioner who is already retired in year $T_0+D(s)$:

$$T_0+x+R_0+\rho x=T_0+s+D_0+\delta s, \qquad \text{i.e.,} \qquad x(s)=\frac{D_0+(1+\delta s)-R_0}{1+\rho},$$

hence her age at retirement is equal to

$$R[s]=R_0+\rho x(s)=\frac{R_0+\rho D_0+\rho(1+\delta s)}{1+\rho}. \tag{A.2}$$

For example, for $s=0$, $R[0]=64.2$ rather than 62.

Next we determine the cohort-specific initial benefits and benefits in payment:

$$b(R[s],s)=e^{gs}\beta \qquad \text{and} \qquad b(a,s)=\beta e^{-g(a-R[s])}, \qquad R[s]\le a\le D(s). \tag{A.3}$$

(For simplicity, we assume that despite of growing contribution periods, the total accrual rate β remains constant.) The total and the average benefits are respectively equal to

$$B(s)=\int_{a=R[s]}^{D(s)} b(a,s)\,da \qquad \text{and} \qquad \bar{b}(s)=\frac{B(s)}{D(s)-R[s]}. \tag{A.4}$$

Inserting (A.3) into (A.4) yields

$$B(s)=e^{gs}\beta\int_{a=R[s]}^{D(s)} e^{-g(a-R[s])}\,da=e^{gs}\beta\int_{u=0}^{D(s)-R[s]} e^{-gu}\,du=g^{-1}e^{gs}\beta\left(1-\ e^{-g(D(s)-R[s])}\right).$$

Inserting (A.1)–(A.2) yields a closed formula for $B(s)$ etc.

Table A.2 displays the paths of economic variables. Column 2 shows a quite balanced dependency ratio, while column 3 displays steadily rising initial benefits. Column 4 presents a correspondingly rising but lower average benefits. Finally, the balanced contribution rate is slightly rising from 0.18 (2015) to 0.22 (2063).

Table A.2. Paths of economic variables: rising retirement age

Exit time $T_0+s+D(s)$	Dependency ratio $p(s)$	Initial benefit $b(s)$	Average benefit $\bar{b}(s)$	Balanced contr. rate $\tau(s)$
2015.0	0.486	0.500	0.429	0.183
2021.1	0.487	0.553	0.470	0.188
2027.1	0.487	0.611	0.515	0.193
2033.2	0.487	0.675	0.564	0.198
2039.2	0.487	0.746	0.618	0.203
2045.3	0.488	0.824	0.677	0.207
2051.3	0.488	0.911	0.742	0.211
2057.4	0.488	1.007	0.813	0.214
2063.2	0.488	1.113	0.891	0.218

For a comparison, now we fix the retirement age at R_0 and put $\rho = 0$. Tables A.3 and A.4 yield the following picture.

Table A.3. Cohorts's life expectancy and retirement age: constant retirement age

	Start	Retirement	Exit	
Birth year T_0+s	working T_0+s+Q	time T_0+s+R	age $D(s)$	time $T_0+s+D(s)$
1935	1960	1997	80.0	2015.0
1940	1965	2002	81.1	2021.1
1945	1970	2007	82.1	2027.1
1950	1975	2012	83.2	2033.2
1955	1980	2017	84.2	2039.2
1960	1985	2022	85.3	2045.3
1965	1990	2027	86.3	2051.3
1970	1995	2032	87.3	2057.4
1975	2000	2037	88.4	2063.4

Table A.4 displays the paths of economic variables. Column 2 shows a steeply rising dependency ratio, while column 3 displays steadily rising initial benefits. Column 4 presents correspondingly rising but lower average benefits. Finally, the balanced contribution rate is also steeply rising from 0.2 (2015) to 0.28 (2063).

Table A.4. Paths of economic variables: constant retirement age

Exit time $T_0 + s + D(s)$	Dependency ratio $p(s)$	Initial benefit $b(s)$	Average benefit $\bar{b}(s)$	Balanced contr. rate $\tau(s)$
2015.0	0.486	0.500	0.420	0.204
2021.1	0.515	0.553	0.460	0.214
2027.1	0.543	0.611	0.503	0.224
2033.2	0.572	0.675	0.550	0.233
2039.2	0.600	0.746	0.602	0.242
2045.3	0.628	0.824	0.659	0.251
2051.3	0.657	0.911	0.722	0.260
2057.4	0.685	1.007	0.790	0.269
2063.4	0.714	1.113	0.865	0.277

Comparing Tables A.3–A.4 and Tables A.1–A.2, it is clear that a sufficiently steeply rising retirement age path significantly reduces the financial burden of population aging: the contribution rate rises from 0.18 to 0.22 rather than from 0.2 to 0.28. Note that as a simplification, we neglected the impact of rising contribution period in benefits but not in contributions. A fuller analysis of the empirical model needs to incorporate the impact of rising retirement age as well.

Appendix B. The impact of longevity gap

In this Appendix we demonstrate with a simplest example (neither the population, nor the economy grows) that due to the longevity gap, with a given average replacement rate, the more progressive the pension system, the lower the balanced contribution rate.

Consider a two-type population, with types L and H, with wages $w_{\rm L}, w_{\rm H}$ and frequencies $f_{\rm L}, f_{\rm H}$,

$$f_{\rm L}, f_{\rm H} > 0, \qquad f_{\rm L} + f_{\rm H} = 1$$

and

$$w_{\rm L} < 1 < w_{\rm H}, \qquad f_{\rm L}w_{\rm L} + f_{\rm H}w_{\rm H} = 1.$$

Each type works a unit interval and spends time $m_{\rm L}, m_{\rm H}$ in retirement. Due to the longevity gap,

$$m_{\rm L} < m < m_{\rm H}, \qquad f_{\rm L}m_{\rm L} + f_{\rm H}m_{\rm H} = m.$$

In our model, the progressivity of the benefit is achieved as a linear combination of proportional and flat benefits:

$$b_i = \beta[\alpha w_i + (1 - \alpha)], \qquad i = {\rm L}, {\rm H}, \tag{B.1}$$

where $\alpha, 1 - \alpha \geq 0$ are the weights of the proportional and the flat benefits, respectively. We define the type-specific life balances:

$$z_i = \tau w_i - m_i b_i, \qquad i = {\rm L}, {\rm H}. \tag{B.2}$$

Inserting (B.1) into (B.2), yields

$$z_i = (\tau - m_i\beta\alpha)w_i - m_i\beta(1 - \alpha), \qquad i = {\rm L}, {\rm H}. \tag{B.3}$$

We postulate now the balance condition:

$$\mathbf{E}z = f_\mathrm{L}z_\mathrm{L} + f_\mathrm{H}z_\mathrm{H} = 0. \tag{B.4}$$

Substituting (B.3) into (B.4), the balanced contribution rate is given:

$$\tau^*(\alpha) = \beta[m(1-\alpha) + (f_\mathrm{L}m_\mathrm{L}w_\mathrm{L} + f_\mathrm{H}m_\mathrm{H}w_\mathrm{H})\alpha]. \tag{B.5}$$

By Chebyshev sum inequality (Simonovits, 1995), $m \le f_\mathrm{L}m_\mathrm{L}w_\mathrm{L}+f_\mathrm{H}m_\mathrm{H}w_\mathrm{H}$, the coefficient of $(1-\alpha)$ is greater than that of α, therefore function $\tau^*(\cdot)$ is decreasing.

Numerical example: $\beta = 1/2$, $f_\mathrm{L} = 2/3$, $w_\mathrm{L} = 1/2$, $m_\mathrm{L} = 0.45$ and $m_\mathrm{H} = 0.6$. Hence $m = 0.5$. Table B.1. displays the impact of rising progressivity. Note that $\alpha = 0.8$ achieves neutrality, while the balanced contribution rate drops from 0.275 to 0.25.

Table B.1. The impact of rising progressivity

Proportionality factor	Short-lived		Long-lived		Contribution rate
	benefit	lifetime balance	benefit	lifetime balance	
α	b_L	z_L	b_H	z_H	$\tau(\alpha)$
1.0	0.25	0.025	1.0	–0.05	0.275
0.8	0.30	0.000	0.9	0.00	0.270
0.6	0.35	–0.025	0.8	0.05	0.265
0.4	0.40	–0.050	0.7	0.10	0.260
0.2	0.45	–0.075	0.6	0.15	0.255
0.0	0.50	–0.100	0.5	0.20	0.250

Appendix C. Two forms of progressive benefits

In the main text and in Appendix B, we linearly approximated progressive benefits. Here we reformulate it as

$$b_1(w) = \beta[\alpha w + (1-\alpha)\mathbf{E}w]$$

where w denotes the gross wage of a generic worker, α and β stand for the proportionality factor and the replacement ratio, respectively. It is assumed that average wage is equal to unity: $\mathbf{E}w = 1$. This formula is much simpler than the piecewise linear function used in practice but it is not an accident that the latter form prevails. Here we demonstrate that our approximation is acceptable.

Confining attention to a single bending point with two proportionality factors, *practical* progressive benefits are formulated as follows:

$$b_2(w) = \begin{cases} \gamma_1 w & \text{if } w \le \underline{w} \\ \gamma_1\underline{w} + \gamma_2(w-\underline{w}) & \text{if } w > \underline{w} \end{cases}$$

where $\underline{w}$ denotes the bending point and $\gamma_1 > \gamma_2 > 0$ stand for higher and the lower replacement ratios, respectively. (Note that in the US and in the Hungarian systems, there are two rather than one bending point and three rather than two replacement ratios.) Assuming that the wage distribution is given by positive $(f_i)_{i=1}^n$, $\sum_{i=1}^n f_i = 1$, it is sensible to fit the linear version to the piecewise linear one to minimize their standard deviation:

$$\sigma(\alpha,\beta) = \sum_{i=1}^n f_i[b_1(w_i) - b_2(w_i)]^2$$

In Table C.1, we demonstrate on a numerical example that the two forms are not that different from each other. Wages are uniformly distributed in $[0.5, 1.5]$, $\gamma_1 = 0.5$, $\gamma_2 = 0.3$, $\underline{w} = 1$, $\beta = 0.47$, $\alpha = 0.85$, especially in our symmetrical example.

Table C.1. The closeness of the two forms of progressivity

Wage	Linear	Piecewise linear
	benefits	
w	$b_1(w)$	$b_2(w)$
0.50	0.27	0.25
0.60	0.31	0.30
0.70	0.35	0.35
0.80	0.39	0.40
0.90	0.43	0.45
1.00	0.47	0.50
1.10	0.51	0.53
1.20	0.55	0.56
1.30	0.59	0.59
1.40	0.63	0.62
1.50	0.67	0.65