

Assessing the Sustainability and Adequacy of the Slovak Pension System: A Dynamic Microsimulation Approach

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Abstract

This paper compares long-term projections of the Slovak pension system from an aggregate cohort-component model and a dynamic microsimulation model under broadly harmonised Ageing Report assumptions. Microsimulation links individual employment and earnings histories to pension entitlements and provides distributional adequacy measures. Both models project similar expenditure profiles and declining benefit ratios, but microsimulation generates lower expenditure, mainly for disability and minimum pensions. Its higher replacement rates largely reflect differences in the definition and timing of the wage denominator. Individual results reveal declining inequality among new pension awards and persistent differences by sex and age. Sensitivity scenarios illustrate the effects of lower fertility and a constant retirement age. The findings support using the two approaches as complementary tools for assessing pension sustainability and adequacy.

Keywords: pension system, microsimulation, sustainability, adequacy, Slovakia

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Introduction

Population ageing poses a major long-term challenge to the Slovak pension system. Declining fertility and increasing life expectancy will reduce the population of working age relative to the number of pensioners, placing pressure on pension

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expenditure and contribution revenue. At the same time, reforms intended to improve fiscal sustainability can affect the level and distribution of retirement income. An assessment of the pension system must therefore consider not only its aggregate financing needs, but also the adequacy of the benefits it provides to different groups of pensioners.

Long-term pension projections for Slovakia are prepared using the Slovak Pension Model, an aggregate cohort-component model applied in the Ageing Report. The model combines national pension legislation with common demographic and macroeconomic assumptions agreed by the Ageing Working Group, providing an official basis for fiscal surveillance and international comparison. Its cohort structure is well suited to projecting aggregate recipient numbers, pension expenditure and contribution revenue over a long horizon. However, outcomes within each modelled group are represented by aggregate values and distributions. The approach consequently cannot follow complete individual employment and earnings histories or directly examine how pension outcomes vary with career interruptions, retirement pathways and other individual characteristics.

Dynamic microsimulation offers a complementary perspective. By following individuals over time, it can connect annual labour-market states and earnings to accumulated pension rights and apply eligibility and benefit rules at the individual level. This makes it possible to derive aggregate fiscal indicators and distributional adequacy measures from the same simulated population. Such flexibility comes at a cost: microsimulation requires more detailed data, additional behavioural and transition assumptions, and the reconstruction of historical information that is not observed in the base-year population. Its results may also differ from aggregate projections even when both models start from the same external scenario.

The purpose of this paper is to compare the two approaches under assumptions that are harmonised as far as their respective structures permit. The pension module of the Slovak Labour Market Model is adjusted to incorporate the demographic, labour-market and macroeconomic assumptions underlying the aggregate Ageing Report projection. The comparison distinguishes common external inputs from their implementation and from the aggregate outcomes realised within each model. It thereby examines which projections remain similar once differences in external assumptions are reduced, where substantial divergences persist and whether these divergences can be explained by the modelling of particular pension processes.

The analysis contributes in three respects. First, it evaluates the sustainability of the Slovak pension system by comparing projected expenditure, contribution revenue and the resulting balance. Second, it uses the individual-level output to

complement conventional benefit and replacement rates with distributional indicators and decompositions by sex and age. Third, it applies selected Ageing Working Group sensitivity scenarios directly within the microsimulation framework, illustrating how common alternative assumptions are transmitted through individual demographic and employment histories. The aim is not to replace the official aggregate projection, but to identify the additional information provided by microsimulation and the conditions under which results from the two approaches can be meaningfully compared.

The remainder of the paper proceeds as follows. The review of related dynamic microsimulation models follows the introduction. Section 1 describes the two pension projection models, while Section 2 explains the harmonisation of their assumptions. Section 3 compares sustainability and adequacy outcomes and presents the sensitivity analysis. The conclusions follow Section 3. The institutional structure of the Slovak pension system is summarised in Annex A, technical details of the pension module are provided in Annex B and supplementary results are reported in Annex C.

Related Dynamic Microsimulation Models

Dynamic microsimulation models have become an established tool for evaluating pension systems, particularly where distributional and long-run adequacy questions cannot be answered by aggregate cohort-component models. The general methodology is surveyed by Li and O'Donoghue (2013), who identify pension adequacy and reform evaluation as one of the primary application domains of dynamic microsimulation. Among purpose-built pension microsimulation frameworks, the MIDAS (Microsimulation of Demand and Supply) family of models represents the tradition most directly comparable to the approach adopted here. MIDAS was originally developed within a European Commission research programme and was subsequently adapted for Belgium, Germany, Ireland and several other countries. It links individual labour market careers to pension entitlements under national rules and produces both expenditure aggregates and individual-level adequacy indicators from the same simulated population (Dekkers et al., 2010). The Slovak Labour Market Model differs from MIDAS in using only individuals as the units of simulation, not allowing households as the simulated unit. This makes the model less demanding in terms of computing performance, but means that it cannot be used to project social transfers for which eligibility is evaluated at the household level. The model also differs in its treatment of economic activity and employment, as it contains a more granular occupational and sectoral structure and maintains an explicit linkage to macroeconomic projections. Another

notable model in this tradition is MISSAR (Microsimulation Model of Social Security in Argentina), developed by Calcagno (2018). It illustrates how an individual-level microsimulation approach can be applied to a public pension system operating under conditions of high informality and persistent inflation. These conditions make aggregate cohort-component projections particularly unreliable and increase the value of individual-level detail.

Numerous additional country-specific applications of dynamic microsimulation models illustrate the breadth and maturity of this modelling tradition. Inspiration in their use of administrative data, Fredriksen and Stølen (2017) use Norway's MOSART model to compare lifetime pension benefits with lifetime contributions across cohorts born between 1910 and 2070. Their results show that the 2011 Norwegian pension reform disproportionately reduced returns for cohorts born between 1950 and 1980, a finding that is accessible only through individual-level simulation. Tikanmäki et al. (2015) use a Finnish dynamic microsimulation model to assess the distributional effects of the 2017 Finnish pension reform. They find that the reform increases gross pension inequality across the pensioner population, while reducing differences within age groups in the long run; taxation mitigates much of the distributional effect. Patxot et al. (2018) apply microsimulation to the Spanish pension system and demonstrate that the retirement decision itself, rather than demographics alone, has a first-order effect on long-run sustainability. A more flexible retirement transition generates expenditure paths that differ substantially from those implied by deterministic age thresholds. Gonzalez Garibay (2023) provides a systematic review of retirement modelling in 26 dynamic microsimulation models. The review finds that score-based transition approaches of the kind used in the Slovak Labour Market Model are among the most common practical implementations and that the theoretical treatment of retirement remains heterogeneous despite growing methodological convergence. A recurring result across these applications is that microsimulation reveals distributional adequacy patterns by sex, cohort, income position and retirement pathway that are structurally invisible to aggregate projection tools. This finding directly motivates the approach adopted in the present paper.

1. Pension Projection Models in Slovakia

The analysis compares two models used to project the Slovak pension system. The Slovak Pension Model is an aggregate cohort-component model used for Slovakia's official long-term pension projections, including those prepared for the Ageing Report. The Slovak Labour Market Model is a dynamic microsimulation model that has been extended with a pension module.

1.1. Slovak Pension Model

The Slovak Pension Model is a cohort-component model used to prepare long-term projections of the Slovak pension system, including pension expenditure, contribution revenue and selected adequacy indicators. It serves as Slovakia's national pension projection model for the Ageing Report, in which Member States use country-specific models under common demographic and macroeconomic assumptions agreed by the Ageing Working Group (European Commission and EPC, 2023). The model consists of a demographic and macroeconomic block and a pension block. The former projects population, labour-market participation, employment, unemployment, wages and GDP. These results determine the population exposed to retirement, the number of contributors, the development of contributory periods and the macroeconomic variables entering the calculation and indexation of pension benefits. They are subsequently passed to the pension block, which projects new pension awards, the surviving stock of pensioners, pension amounts, contribution revenue and expenditure.

The model operates in annual steps and distinguishes the population and pensioners by age and sex. For the main pension categories, it also maintains distributions by pension amount and contributory period, allowing the expenditure projection to reflect changes in both the size and composition of successive pensioner cohorts rather than relying exclusively on a single representative or average recipient. The pension block starts from administrative data on the existing stock of pensioners and recent pension awards. Existing pensioner cohorts are advanced by age and reduced according to age- and sex-specific mortality, while new old-age and disability pensions are projected using empirical age-specific award probabilities and the population not already represented in the respective pension stock. Survivor pension inflows are linked to mortality and marital-status projections. Newly awarded old-age pensions are calculated from projected contributory periods, personal pension points, the current pension value and adjustments for retirement before or after the statutory retirement age. The distribution of personal pension points is derived from the projected earnings distribution of current pensioners, moving to the distribution of contributors throughout the projection, and modified by the solidarity rules embedded in the Slovak pension formula. Once awarded, pensions are carried forward within the relevant pensioner cohorts and indexed according to the applicable legislation, with annual expenditure obtained by aggregating recipient numbers and pension amounts across model cells.

Contribution revenue is projected from the number and earnings distribution of contributors, statutory contribution rates and the applicable assessment-base rules. Additional modules cover minimum-pension top-ups, other selected pension benefits and the interaction between the first and second pillars. Participation in

the second pillar is reflected both in contribution revenue and in the corresponding reduction of first-pillar pension entitlements. SLOPEM combines these bottom-up cohort calculations with calibration to observed base-year data and, where applicable, official medium-term fiscal projections. Beyond the calibration period, its results are driven primarily by demographic developments, labour-market assumptions, wage and price growth, retirement behaviour and pension legislation. In the baseline examined in this paper, SLOPEM applies the common demographic, labour-market and macroeconomic assumptions provided for the Ageing Report, together with the Slovak pension legislation represented in the model.

1.2. Slovak Labour Market Model

The Slovak Labour Market Model is a discrete-time individual-level micro-simulation model implemented in LIAM2 (De Menten et al., 2014) and initialised from the 2021 Population and Housing Census. It simulates annual demographic transitions, including births, deaths and immigration, educational attainment and labour-market states, including employment, unemployment, inactivity, disability and retirement. The model was originally developed to project labour supply, replacement demand and foreign labour inflows in the context of population ageing; its structure, individual-level variables and interaction with macroeconomic labour demand are described in detail by Štefánik and Miklošovič (2020). The pension extension builds directly on the demographic and labour-market trajectories generated by the existing model, while adding the information required to translate individual working lives into pension entitlements and expenditure.¹ The first component added for this purpose is the modelling of earnings for employed individuals. Earnings are estimated using sex-specific Mincer-type equations based on age, education and sector of employment. The dependent variable is the ratio of individual earnings to the economy-wide average wage, corresponding to the annual personal pension point used in the Slovak first-pillar formula. This specification separates the individual's relative position in the earnings distribution from the aggregate wage level determined by external macroeconomic assumptions. Each simulated year of employment can consequently generate both a period of pension insurance and a personal pension point, providing the link between the labour-market processes already present in SLAMM and the accumulation of individual pension rights.

Since the Census-based initial population does not contain complete historical employment and earnings records, the model subsequently runs a retrospective

¹ More detailed description of the Pension module of the Slovak Labour Market Model can be found in Annex B and a commented code of the complete model (executable in LIAM 2) can be found online at: <<https://github.com/petermartiska-png/slamm-pension-model>>.

simulation to reconstruct plausible pension-relevant histories for individuals present in the base year. The design of the retrospective module was partially inspired by the MISSAR model (Calcagno, 2018). Simulated employment states and wage equations are used to derive accumulated personal pension points, the number of years entering the calculation of the average personal pension point and total pension insurance duration. Existing pensioners are assigned initial pension amounts through a donor-cell procedure calibrated to administrative data from the Social Insurance Agency. The resulting pension-ready population then enters the prospective simulation, which continues individual demographic and labour-market trajectories, updates pension rights and applies the statutory rules governing pension eligibility, benefit calculation and indexation. Unlike SLOPEM, where these processes are represented for cohorts and aggregate groups, SLAMM applies them to individual simulated persons with distinct demographic characteristics, labour-market histories, earnings trajectories and accumulated pension rights.

The pension module covers old-age and early old-age pensions, disability pensions, widows' and widowers' pensions and minimum-income mechanisms, including the minimum pension top-up and material need benefit. Although it does not reproduce every expenditure item of the Slovak pension system, the simulated categories account for a major part of public pension expenditure. Participation in the second pillar is reflected through the corresponding reduction of first-pillar pensions, while funded assets and second-pillar benefits are not simulated. The original SLAMM specification was not developed to reproduce the demographic and macroeconomic scenario underlying SLOPEM. For the comparison presented in this paper, its baseline was therefore modified to incorporate, as far as the individual-level model structure permits, the same Ageing Working Group demographic, labour-market and macroeconomic assumptions and the same main pension-system parameters as those used in the aggregate projection. The following section describes this harmonisation and distinguishes between the alignment of common inputs, their implementation within the microsimulation model and the degree to which the resulting aggregate outcomes correspond to the SLOPEM projection.

2. Harmonisation of Assumptions

The comparison of two projection models is informative only if differences in their external assumptions are limited as far as the respective model structures allow. Otherwise, differences in projected pension expenditure may reflect different demographic or macroeconomic scenarios rather than differences in the modelling approach. The baseline of the microsimulation model used in this paper was

therefore modified to incorporate the assumptions underlying the corresponding aggregate-model projection. The harmonisation covers demographic developments, labour-market participation and employment, average wage growth, pension indexation and the main parameters of the Slovak pension system. Variables that are not simulated within the microsimulation model, most importantly GDP and labour productivity, are taken from the same external projection when constructing comparable fiscal indicators.

Harmonisation does not necessarily imply that the two models produce identical aggregate populations or labour-market outcomes. Three levels of alignment must be distinguished. Input alignment means that the same externally provided rate or trajectory is used in both models. Implementation alignment means that the relevant process in the microsimulation model applies this input as intended. Realised alignment refers to the extent to which the resulting simulated aggregate corresponds to the aggregate-model projection. This distinction is particularly important in a dynamic microsimulation model. Identical transition probabilities may generate different aggregate outcomes if the initial population or its composition differs, while stochastic assignment and the annual sequence of simulated events may introduce additional deviations. The purpose of harmonisation is therefore not to force every microsimulation aggregate to equal its aggregate-model counterpart, but to ensure that remaining differences can be interpreted in light of the respective model structures.

2.1. Demographic Assumptions

The microsimulation model applies the same age-specific fertility and mortality rates and the same age- and sex-specific net migration assumptions as those underlying the aggregate-model projection. Migration is aligned directly by year, sex and age group and is reproduced exactly in the realised microsimulation population. Fertility and mortality are implemented as individual-level processes. Consequently, common probabilities do not imply identical numbers of births and deaths because they are applied to the population generated within each model.

The microsimulation baseline retains the Census-derived initial population and does not reconcile it to the AWG population stock². Its population is approximately 2.1% higher than the aggregate projection in 2022 and 2.6% higher in 2030. The difference subsequently narrows to approximately 1.4% in 2050 and 0.4% by 2070. These gaps combine the inherited difference in the initial age-sex structure with the endogenous effect of applying common fertility and mortality

² The optional exact AWG initial-stock calibration remains available as a comparison experiment but is disabled in the selected baseline. Aggregate results from the calibration differ only slightly from the current baseline.

rates and exactly aligned net-migration flows to different populations. They should therefore not be interpreted as evidence that the model uses different demographic rate assumptions.

2.2. Labour-Market and Macroeconomic Assumptions

Labour-force participation in the microsimulation model is aligned with the AWG age- and sex-specific participation profiles from the beginning of the forward-looking projection. The realised aggregate participation rate closely follows the reference path, with a maximum deviation of approximately 0.2 percentage point. Small remaining discrepancies occur mainly in cells close to retirement age, where the participation target interacts with retirement and other status restrictions at the individual level. Employment is aligned with the aggregate AWG trajectory and, following the transition from the initial model population, differs from the reference projection by less than 0.3% from 2025 onwards and by approximately 0.01% or less from 2040.

Unemployment is not imposed as a separate target in the microsimulation model. Participation is determined first, while employment is assigned through the model's matching of active individuals to the projected structure of jobs. Individuals who remain active but are not assigned employment are classified as unemployed. The initial unemployment stock is therefore not expected to reproduce the AWG series, and later differences remain a residual of the participation and employment mechanisms. Although unemployment represents a substantially smaller population than employment, it remains relevant for pension modelling because periods without employment (unemployment or other forms of inactivity) affect contributory years and personal pension points. The comparison should consequently be understood as aligned in terms of the AWG participation inputs and aggregate employment path, while unemployment is an endogenous residual rather than a directly aligned outcome.³

The average wage path used to express individual earnings in nominal terms follows the common AWG wage-growth assumptions. The microsimulation model represents individual earnings primarily as personal wage points relative to the economy-wide average wage. The distribution generated by the wage equations is normalised so that the mean personal wage point among employed individuals remains approximately equal to one.⁴ From 2030 onwards, the realised average

³ It is important to note that an exact match of the unemployment rate does not affect the accumulation of pension entitlements into the future (in the past, certain periods of unemployment were counted towards insurance period). Individuals who are not classified as unemployed remain in another form of inactivity and therefore do not accrue pension entitlements either. Since all employed individuals are assigned in earlier stages of the simulation, the precise distinction between unemployment and other forms of inactivity is less consequential for the pension projections.

wage differs from the common wage anchor by less than 0.01%. The microsimulation model does not independently simulate labour productivity, hours worked or GDP. A common nominal GDP series is therefore used as the denominator when pension expenditure and contribution revenue are expressed as shares of GDP. This prevents differences in the macroeconomic denominator from being attributed to the pension projection models.

2.3. Pension System Assumptions

Both projections apply the same core legislative parameters determining old-age pension entitlements. These include the statutory retirement age schedule, the link between retirement age and life expectancy, the treatment of retirement before or after the statutory age, pension contribution rates, personal pension point rules and the interaction between the first and second pillars. The current pension point value used for newly awarded pensions follows the statutory rule under which it increases by 95% of average wage growth. Pensions already in payment are indexed using the same pension indexation path as in the reference projection. Observed statutory and extraordinary pension indexation is applied in the initial years, after which the common long-term assumptions are applied.

The harmonisation concerns the parameters of the pension system rather than imposing identical numbers of pension awards or pensioners. In the aggregate model, these outcomes are projected for cohorts and groups using observed award probabilities and aggregate stock-flow relationships. In the microsimulation model, eligibility conditions and transition probabilities are applied to individuals with simulated demographic and employment histories. Similarly, both models represent the main rules governing disability, survivor and minimum pensions, but their implementation reflects the information and entities available within each model. These differences are retained because eliminating them through direct calibration would also eliminate part of the structural distinction that the comparison is intended to examine.

Table 1 summarises the degree of harmonisation across the main assumptions. The strongest realised alignment is achieved for net migration, employment after the initial transition period and average wage growth. Fertility, mortality and participation inputs follow the AWG paths, although their individual-level implementation and the different Census-derived initial stock led to differences in realised population and activity aggregates. Unemployment is not targeted directly, while GDP and productivity are treated as common external variables rather than simulated outcomes.

⁴ The normalisation is done to ensure that the average of the simulated wage distribution corresponds to the average wage assumed in the model. The adjustment is minimal in the model.

The resulting setup does not constitute an experiment in which the effect of model architecture is isolated perfectly. The Census-derived initial population differs from the AWG stock, unemployment is not directly aligned, and selected pension processes remain model-specific. It does, however, substantially narrow the role of competing external assumptions. The subsequent comparison can therefore identify where the two approaches produce similar projections under a common scenario and where differences persist because aggregate cohort relationships and individual life-course simulation translate that scenario into pension outcomes differently.

Table 1

Harmonisation of the Main Demographic, Labour-Market and Pension Assumptions

Assumption	Implementation in the microsimulation model	Degree of alignment
Fertility	Common age-specific fertility rates applied to simulated women	Exact input alignment; realised births differ
Mortality	Common age- and sex-specific mortality rates applied individually	Exact input alignment; realised deaths are stochastic
Net migration	Common flows by year, age group and sex	Exact input and realised alignment
Total population	Census-derived initial population; no AWG stock calibration in the baseline	Not stock-aligned; subsequent trajectory is endogenous
Participation	Alignment with age- and sex-specific AWG rates	Close input, implementation and realised alignment
Employment	Alignment with the aggregate AWG employment path	Close alignment after the initial transition
Unemployment	Residual outcome of participation and employment assignment	Not aligned
Average wage growth	Common aggregate wage path combined with individual wage points	Close realised alignment from 2030
GDP and productivity	Not simulated within the microsimulation model	Common external series used for comparison
Pension indexation	Common indexation path and observed initial adjustments	Aligned
Current pension point value	Statutory growth at 95% of average wage growth	Aligned
Pension eligibility and calculation rules	Applied at the individual level	Common legislation; model-specific implementation

Source: Authors.

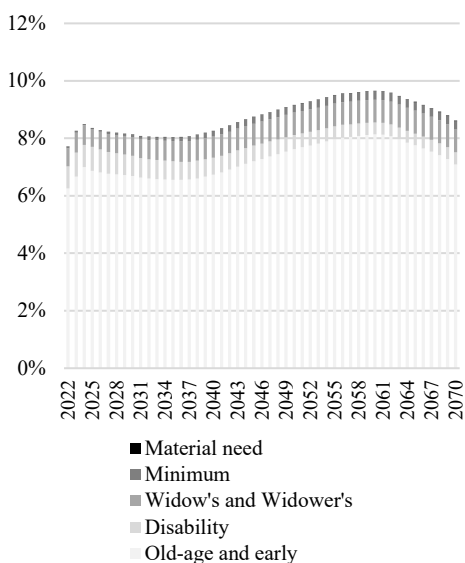
3. Results

3.1. Pension Expenditure and Fiscal Sustainability

Figure 1 presents the expenditure projected by the microsimulation model for the pension categories included in the analysis, while Figure 2 compares their combined expenditure with the corresponding aggregate-model projection. Both models produce a similar general profile: expenditure increases as population ageing intensifies, reaches its highest level around 2060 and declines towards the end of the projection period. In the baseline, total expenditure is approximately 8.2%

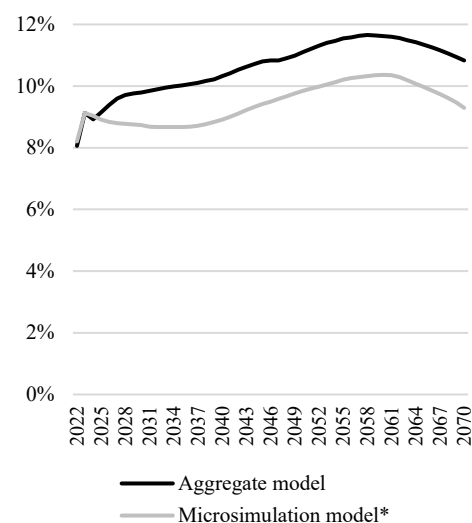
of GDP in 2022, 10.4% at the 2060 peak and 9.3% in 2070. The gap relative to the aggregate projection is approximately 1.2 percentage points at the peak and 1.5 percentage points in 2070. The long-run expenditure results are tabulated in Annex C (Table A3).

Figure 1
Pension Expenditure in Microsimulation Model, by Benefit Category (% of GDP)



Source: Slovak Labour Market Model.

Figure 2
Pension Expenditure Projected by the Aggregate and Microsimulation Models (% of GDP)



Note: * Expenditure modelled in the microsimulation model does not include all expenditure items. For comparison purposes, they have been added to the modelled expenditure from the Slovak Pension Model, keeping them the same in both models.

Source: Slovak Labour Market Model; Ageing Report 2024.

The lower expenditure cannot be attributed to a single common demographic or macroeconomic assumption. The models use the same nominal wage-growth path and closely aligned population, employment and pension-indexation assumptions. Migration can affect the composition of contributors and future pension entitlements,⁵ but it does not explain the aggregate expenditure gap through an extra inflow of workers. Instead, the gap is concentrated in particular pension categories

⁵ Pension entitlements of migrants are treated differently in both models. The aggregate model includes migrants in the general population and treats them as such, granting them equal benefits at retirement. On the other hand, the microsimulation model separates foreign and domestic careers and grant only partial benefits depending on the careers performed in Slovakia, leading to lower expenditure. At the moment of immigration, the individuals' career in Slovakia is accumulated into the pension rights. The granting of a pension is determined by the full career, including the years worked abroad.

and reflects how the two models translate common assumptions into recipient stocks and pension amounts. Old-age pension expenditure is relatively close, while substantially larger differences arise in disability and minimum pensions. Survivor pensions and minimum-income mechanisms contribute to a lesser extent. The category-level evidence therefore points chiefly to benefit-specific modelling choices, not a higher wage path or labour migration as the source of the difference.

3.1.1. Old-Age and Early Old-Age Pensions

Old-age and early old-age pensions account for the largest share of expenditure in both projections. The two models generate a broadly similar long-term profile, with expenditure increasing until around 2060 and declining thereafter. Expenditure on these benefits increased from approximately 6.3% of GDP in 2022 to 7.1% in 2070 in the microsimulation model, compared with an increase from 6.1% to 7.5% in the aggregate model. The difference ranges from approximately 0.1 to 0.6 percentage point of GDP, remaining mostly below 0.4 percentage point.

The remaining divergence reflects the different construction of pensioner cohorts and their entitlements. The aggregate model projects new pension awards and contributory periods for groups defined by age, sex and benefit characteristics. The microsimulation model instead accumulates contributory years and personal pension points along individual employment histories and determines retirement through individual eligibility conditions and transition probabilities. Differences in unemployment, retirement timing and the distribution of career lengths therefore affect both the number and composition of new retirees. Nevertheless, the relative proximity of the two expenditure paths suggests that the dominant old-age pension category is comparatively robust to the choice between aggregate cohort modelling and individual-level simulation.

3.1.2. Disability Pensions

Disability pensions generate the largest difference between the two projections. Their expenditure declines from approximately 0.8% to 0.4% of GDP in the microsimulation model, while the aggregate model projects an increase from about 0.7% to 1.3%. Two assumptions explain these contrasting trajectories.

First, the aggregate model does not recalculate disability pensions as old-age pensions when recipients reach the statutory retirement age. To compensate for the resulting underestimation of old-age pension expenditure, disability pension expenditure is increased through an aggregate adjustment. The microsimulation model treats this transition explicitly. Once a disability pensioner reaches retirement age, the model calculates a potential old-age pension and reclassifies the recipient

if the resulting benefit is higher. Second, the aggregate model assumes that increases in the statutory retirement age lead to greater inflows into disability pensions, as individuals remain exposed to disability risk for longer before becoming eligible for an old-age pension. Empirical evidence on this spillover effect is mixed. Duggan et al. (2007) find that an increase in the full retirement age in the United States raised disability insurance participation, while Staubli and Zweimüller (2013) find that an increase in the early retirement age in Austria had only a small effect on disability and partial-retirement benefit receipt, with considerably larger spillovers into unemployment. An increase in disability pension take-up is therefore plausible, but its magnitude depends on the accessibility and relative generosity of alternative pathways out of employment.

This mechanism is not imposed in the microsimulation model. Available Slovak administrative data have not yet shown an increase in disability pension receipt: the number of disability pensioners has continued to decline, while partial disability pensions account for a growing share of the recipient stock. Since partial disability benefits are lower, this compositional change further reduces expenditure. The difference between the projections therefore reflects both a technical compensating adjustment in the aggregate model and different assumptions about the future incidence and composition of disability pensions.

3.1.3. Widow's and Widower's Pensions

The projections of widow's and widower's pensions differ more moderately. Microsimulation expenditure increased from approximately 0.6% to 0.8% of GDP between 2022 and 2070, whereas the aggregate projection declined from approximately 0.7% to 0.5%. The opposite long-term directions indicate differences in how the stock of survivor pensions evolves, although their contribution to the overall expenditure gap remains smaller than that of disability and minimum pensions.

The aggregate model derives new survivor pensions from mortality and marital-status projections and subsequently advances the recipient cohorts by age. The microsimulation model does not contain household or partner links and therefore approximates survivor pension receipt using age- and sex-specific incidence targets and administrative data information. Benefit amounts are differentiated by sex, and the statutory concurrence rule reduces the lower benefit where a survivor pension is received together with an old-age pension. This approach captures survivor pension expenditure and its interaction with individual pension income, but it cannot reproduce the demographic relationship between a deceased insured person and the surviving partner directly. The difference should consequently be interpreted partly as a consequence of the simplified representation of partnerships in the microsimulation model and an overall different approach in the aggregate model.

3.1.4. *Minimum Pensions and Material Need Benefits*

Minimum pensions constitute another important source of divergence. The aggregate-model projection increases minimum-pension expenditure from approximately 0.1% of GDP at the beginning of the period to around 0.7% towards its end. The microsimulation projection remained substantially lower, at approximately 0.1% – 0.3% of GDP. The difference becomes particularly visible in the second half of the projection horizon and accounts for a material part of the total expenditure gap.

Both models project minimum-pension top-ups by comparing pension income with the applicable threshold, but approximate eligibility at different levels of detail. The aggregate model calculates entitlements across income bands and pension insurance periods and calibrates expenditure to observed base-year totals. Carrying this calibration and the associated approximations forward as pensioner composition changes may contribute to higher projected expenditure. The microsimulation model evaluates top-ups individually using simulated pension income and insurance histories, without a comparable aggregate expenditure adjustment. In both models, rising pension income can reduce or eliminate the top-up. The expenditure difference therefore reflects different representations of income and eligibility and the treatment of calibration, rather than a fundamentally different mechanism. The microsimulation estimate also remains uncertain because qualified contributory periods are not observed and some disadvantaged groups may be imperfectly represented.

Material-need benefits form only a small part of the expenditure projection and do not materially affect the comparison. In the microsimulation model, they provide a simplified income floor for persons reaching pension age without a sufficient pension entitlement. As eligibility for material need assistance is normally assessed at the household level, its individual-level representation should be interpreted as an approximation rather than a complete projection of the benefit system.

3.1.5. *S1 and S2 Fiscal Sustainability Indicators*

The lower pension expenditure path also improves the standard fiscal sustainability indicators. Replacing the pension expenditure projection underlying the Debt Sustainability Monitor 2025 with the microsimulation expenditure path, while leaving all other fiscal and macroeconomic components unchanged, reduces the S2 indicator from 7.2% to 6.2% of GDP. The S1 indicator declines from 6.2% to 5.4% of GDP.⁶ The effect is smaller than the maximum annual difference between the

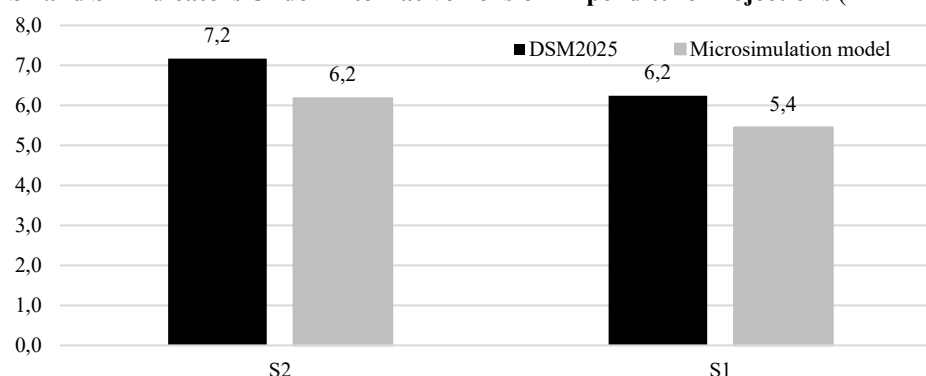
⁶ The S1 indicator measures the permanent improvement in the structural primary balance required to bring the debt-to-GDP ratio to 60% within the specified medium-term horizon, taking projected ageing costs into account. The S2 indicator measures the permanent adjustment required to stabilise the debt-to-GDP ratio over an infinite horizon, including the present value of future age-related expenditure.

two pension expenditure projections because both indicators summarise expenditure pressures over a longer horizon and also incorporate the initial fiscal position and other age-related expenditure.

These results should not be interpreted as a complete alternative assessment of Slovak fiscal sustainability. In particular, the calculation replaces only the pension expenditure trajectory and does not incorporate differences in contribution revenue generated by the two pension models. It instead illustrates the sensitivity of standard sustainability indicators to the modelling of long-term pension expenditure. The reduction in both indicators confirms that differences between aggregate and microsimulation pension projections can be sufficiently large to affect the resulting assessment of long-term fiscal pressures.

Figure 3

S1 and S2 Indicators Under Alternative Pension Expenditure Projections (% of GDP)



Source: Slovak Labour Market Model; Debt Sustainability Monitor 2025.

3.2. Pension Contribution Revenue

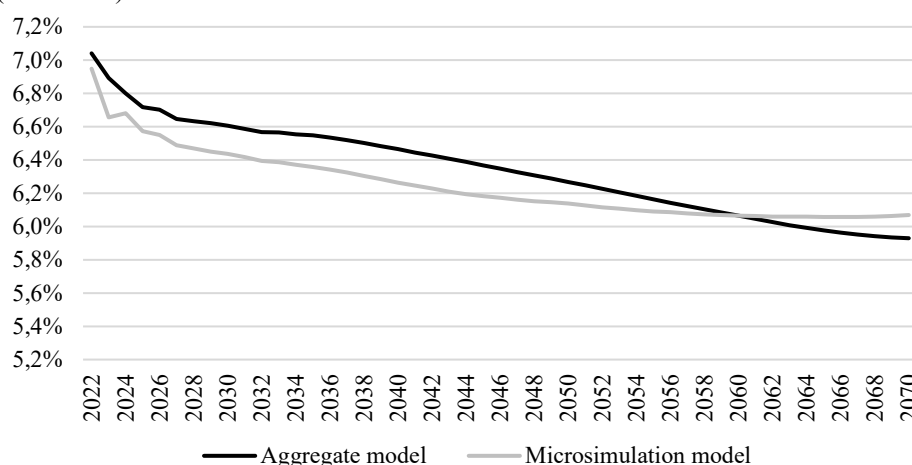
Figure 4 compares public pension contribution revenue projected by the two models. The aggregate model declines from approximately 7.0% of GDP in 2022 to 5.9% in 2070. In the microsimulation, first-pillar revenue declines from approximately 6.9% to 6.1% of GDP. The difference is approximately –0.2 percentage point in 2030 and +0.2 percentage point in 2070. Revenue and balance results are reported in Annex C (Table A4).

For comparability with the 2024 Ageing Report, the microsimulation baseline applies the same historical second-pillar contribution schedule used in the AWG projection: 5.5% of gross wages in 2022 – 2024, 5.75% in 2025 – 2026 and 6% from 2027 onward. These contributions are calculated only for simulated second-pillar savers who pay social contributions and are deducted from the 18% old-age insurance contribution when first-pillar revenue is calculated.

In the microsimulation, contribution-paying status is assigned to a calibrated subset of employed individuals, and second-pillar contributions depend additionally on saver status. The effective assessment base consequently reflects the simulated composition of contributors by age, sex, education, sector and earnings. Even with aligned aggregate employment and wage growth, contribution revenue need not coincide exactly with the aggregate model. The divergence in first-pillar revenue should therefore be interpreted as a consequence of contributor selection, the wage and assessment-base distribution, effective collection calibration and the simulated composition of second-pillar savers. The common scenario schedule differs from the contribution rate under current legislation.

Figure 4

Public Pension Contribution Revenue by the Aggregate and Microsimulation Models (% of GDP)



Source: Slovak Labour Market Model; Ageing Report 2024.

3.3. Pension System Balance

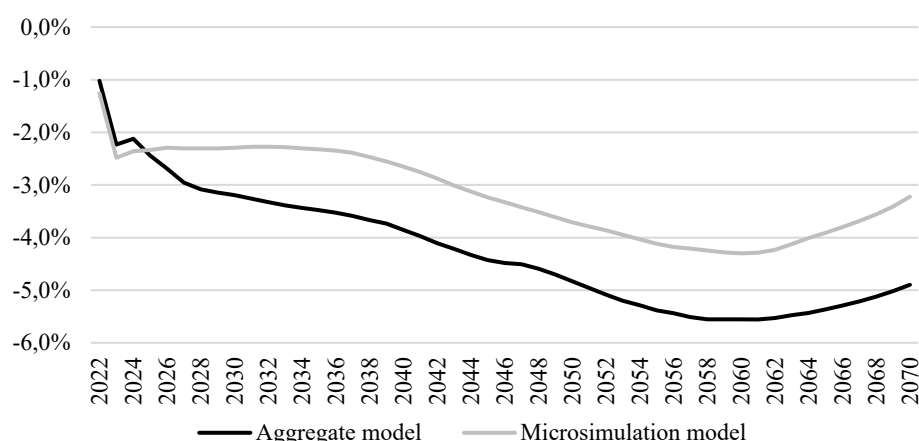
Figure 5 combines the projected first-pillar contribution revenue and pension expenditure presented in the previous sections. Both models project a persistent deficit that deteriorates as ageing-related expenditure increases, reaches its highest level around 2060 and subsequently narrows towards the end of the projection horizon. In the microsimulation model, the balance is approximately -3.2% of GDP in 2070, compared with -4.9% in the aggregate projection. Around 2060, near the expenditure peak, the respective balances are approximately -4.3% and -5.6% of GDP.

The more favourable long-run balance in the microsimulation model results primarily from lower projected pension expenditure. Differences in first-pillar

contribution revenue partly offset this effect in the earlier projection years but reinforce it towards the end of the horizon. By 2070, expenditure is approximately 1.5 percentage points of GDP lower and contribution revenue approximately 0.2 percentage point higher, resulting in a deficit approximately 1.7 percentage points smaller than in the aggregate model. Both projections apply the same schedule for the allocation of contributions between the first and second pillars. The differences are explained by the modelling frameworks, particularly the projection of pension entitlements and expenditure, together with the composition of contributors, their earnings and effective assessment bases. The comparison therefore illustrates that, even under broadly harmonised demographic, macroeconomic and legislative assumptions, differences in model structure and implementation can lead to materially different assessments of the long-term financing gap of the pension system.

Figure 5

Projected Balance of the Public Pension System (% of GDP)



Source: Slovak Labour Market Model; Ageing Report 2024.

3.4. Adequacy Indicators: The Added Value of Microsimulation

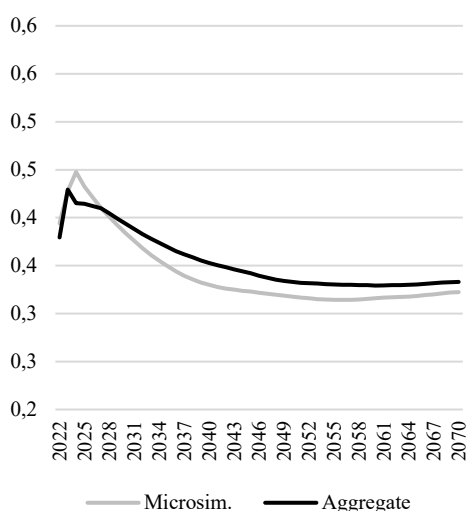
3.4.1. Benefit and Replacement Rates

Figures 6 and 7 compare the benefit ratio and replacement rate projected by the two models. The benefit ratio⁷ follows a similar trajectory in both projections. It declines from approximately 0.39 at the beginning of the period to 0.32 in the microsimulation model and 0.33 in the aggregate model by 2070. The long-term difference is therefore only around 0.01. Both models consequently indicate that the

⁷ The benefit ratio is defined as the average old-age pension in payment divided by the economy-wide average wage in the same year.

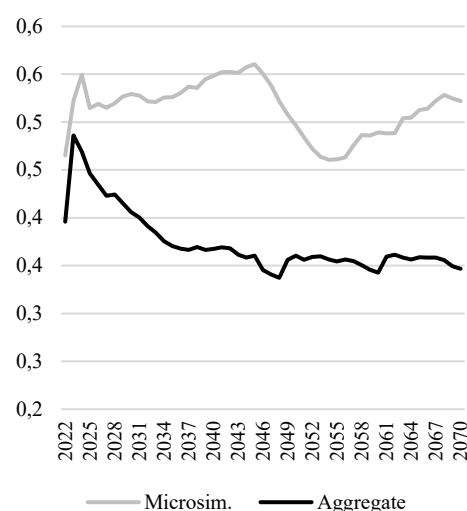
average first-pillar pension will gradually decline relative to the average wage. This reflects the interaction of wage growth with the indexation of pensions already in payment, the rule under which the current pension point value increases by 95% of average wage growth and the growing effect of second-pillar participation on first-pillar pensions. Numerical detail is in Annex C (Tables A5, A6 and A7).

Figure 6
Benefit Ratio Projected by the
Aggregate and Microsimulation Models



Source: Slovak Labour Market Model; Ageing Report 2024.

Figure 7
Replacement Rate Projected by the
Aggregate and Microsimulation Models



Source: Slovak Labour Market Model; Ageing Report 2024.

The difference is substantially larger for the replacement rate⁸. Over the projection period, the replacement rate generated by the microsimulation model is, on average, approximately 0.14 higher than that of the aggregate model. The aggregate model calculates the indicator by comparing the average newly awarded old-age pension with the economy-wide average wage in the same year. It therefore uses a contemporaneous and common wage denominator for the full group of new pensioners. The microsimulation indicator is instead calculated at the individual level as the ratio of the newly awarded pension to the person's last observed wage, after which the individual ratios are averaged.

These definitions become increasingly different when retirement does not follow immediately after employment. In the microsimulation model, some individuals

⁸ The replacement rate measures the initial old-age pension relative to earnings before retirement. Its precise wage denominator differs between the two models, as discussed in the text.

experience unemployment or inactivity before receiving an old-age pension. Their last observed wage may consequently have been earned several years before the pension award and may also reflect the declining relative wage profile of older workers. The pension is calculated under the parameters applicable in the award year, while the denominator is a non-contemporaneous individual wage. This mechanically increases the measured replacement rate, particularly as the statutory retirement age rises and the interval between the last employment spell and pension award becomes longer for some individuals.

The higher replacement rate in the microsimulation model should therefore not be interpreted as evidence that the pension system becomes more generous, but rather ascribed to a more realistic methodology of projection. A substantial part of the difference reflects the definition and timing of the wage denominator rather than higher pension entitlements. The two indicators answer somewhat different questions: the aggregate-model measure compares the average initial pension with the current average wage in the economy, whereas the microsimulation measure describes the relationship between an individual's pension and their own last observed earnings. The latter captures heterogeneous transitions from employment to retirement, but it is also more sensitive to career interruptions and to the time elapsed since the last wage observation.

3.4.2. *Distribution of Old-Age Pensions*

The individual-level results also make it possible to evaluate the distribution of pension income directly. Table 2 reports the mean, median, 10th and 90th percentiles, the ratio between the 90th and 10th percentiles and the Gini coefficient⁹ for newly awarded old-age pensions and the stock of regular old-age pensioners. Unlike the aggregate adequacy indicators, these measures show how pension income is distributed within the pensioner population.

Inequality among newly awarded old-age pensioners declines over the projection horizon. The Gini coefficient falls from 0.23 in 2022 to 0.17 in 2070, reaching its lowest value of 0.16 in 2060. The ratio between the 90th and 10th percentiles similarly declines from 3.10 to 2.18. This indicates that the distribution of newly awarded pensions becomes more compressed. The development reflects the redistributive elements of the pension formula and greater convergence in simulated contributory periods as the statutory retirement age rises. Floors and solidarity adjustments limit the dispersion at the lower end, while the partial reduction of high personal wage points restricts the upper end of the pension distribution.

⁹ The Gini coefficient measures inequality across the income distribution. It ranges from zero, indicating complete equality, to one, indicating maximum inequality.

Table 2

Distributional Indicators for Old-Age Pensions

	Mean Income	Median Income	p10	p90	p90/p10	Gini
Newly awarded old age pensioners						
2022	517.5	484.4	282.2	874.3	3.10	0.23
2030	804.7	778.1	448.5	1 296.0	2.89	0.22
2040	1 282.4	1 223.6	711.4	2 000.4	2.81	0.21
2050	1 827.3	1 868.0	1 081.3	2 508.6	2.32	0.17
2060	2 753.1	2 811.3	1 694.9	3 738.5	2.21	0.16
2070	3 711.1	3 657.8	2 393.1	5 218.2	2.18	0.17
Stock of regular old age pensioners						
2022	557.4	527.0	339.8	818.8	2.41	0.19
2030	846.4	800.5	491.7	1 307.5	2.66	0.21
2040	1 129.2	1 070.0	633.6	1 758.2	2.78	0.21
2050	1 626.4	1 569.3	889.7	2 465.9	2.77	0.21
2060	2 353.4	2 345.3	1 326.7	3 401.5	2.56	0.19
2070	3 359.1	3 378.8	1 944.8	4 732.0	2.43	0.18

Note: Pension income is expressed in current euros.

Source: Slovak Labour Market Model.

The stock of regular old-age pensions follows a different intermediate path. Its Gini coefficient increases from 0.19 in 2022 to 0.21 between 2030 and 2050 before declining to 0.18 by 2070. The p90-to-p10 ratio similarly rises to approximately 2.78 around 2050 and subsequently falls to 2.43. The temporary increase reflects the coexistence of older pension cohorts, whose benefits have been indexed after award, and newer cohorts entering retirement with pensions calculated from more recent wage and career histories. As the more compressed distributions of newly awarded pensions gradually replace older cohorts, inequality within the pensioner stock declines towards the end of the projection period.

3.4.3. Gender and Age Group Decomposition

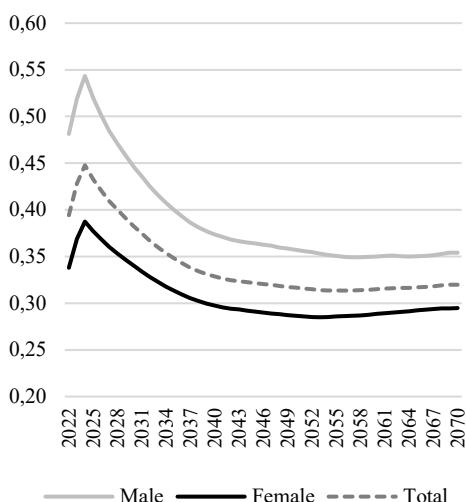
Figures 8 and 9 decompose the benefit ratio and replacement rate by sex. Men have a consistently higher benefit ratio throughout the projection. In 2022, the ratio is approximately 0.48 for men and 0.34 for women, reflecting differences in lifetime earnings, contributory periods and career interruptions. The gap nevertheless narrows over time. By 2070, the benefit ratio declines to approximately 0.35 for men and 0.29 for women. This convergence does not primarily result from a substantial improvement in women's relative pension position. Instead, the male benefit ratio falls more rapidly, partly because men have stronger labour-market attachment and longer second-pillar participation histories, which increase the cumulative reduction applied to their first-pillar pensions.

The replacement rates of men and women initially converge, reaching similar levels around the middle of the projection horizon, before diverging again after

approximately 2050. By 2070, the replacement rate is around 0.56 for men and 0.48 for women. Part of the renewed divergence may be related to differences in retirement timing. Women with children remain eligible for reductions in the statutory retirement age, while men generally retire at a higher age. Combined with declining relative wages at older ages and periods of unemployment or inactivity before retirement, the higher retirement age may increase the interval between the last observed wage and pension award more strongly for men. Since the microsimulation replacement rate uses this last wage as its denominator, a longer interval can mechanically raise the measured ratio. The gender profile should therefore be interpreted cautiously: it reflects differences in career and retirement pathways as well as pension entitlements, and does not necessarily imply that the pension formula becomes increasingly more generous towards men.

Figure 8

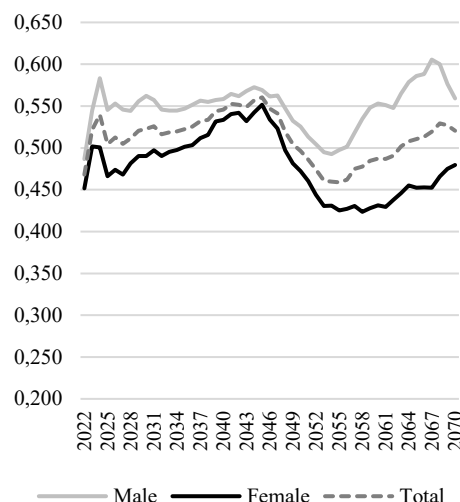
Benefit Ratio by Sex



Source: Slovak Labour Market Model; Ageing Report 2024.

Figure 9

Replacement Rate by Sex

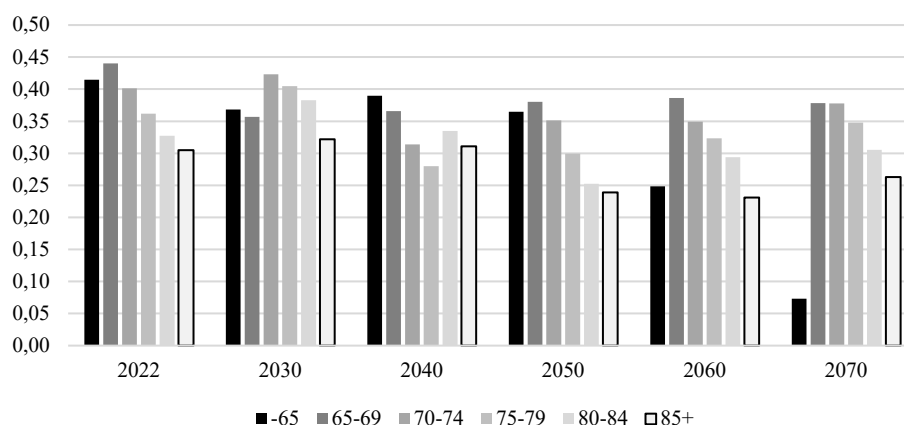


Source: Slovak Labour Market Model; Ageing Report 2024.

Figure 10 presents the benefit ratio by age group. A broad age gradient is visible across the projection: pensioners in the oldest age groups generally receive lower pensions relative to the contemporaneous average wage than younger pensioners. In 2022, the benefit ratio was approximately 0.44 among recipients aged 65 – 69 and 0.30 among those aged 85 and over. By 2070, the corresponding values are approximately 0.38 and 0.26. The under-65 estimate in 2070 is based on a very small and compositionally selected group and should not be interpreted as a representative pension adequacy measure.

The age gradient reflects the different indexation of newly awarded pensions and pensions already in payment. New pensions are calculated using the current pension point value, which follows wage developments with a partial adjustment, while existing pensions are subsequently indexed primarily to prices. As pensioners age, their benefits therefore tend to fall behind the wages of the working population. Differences across individual years are not fully monotonic because each age group contains different award cohorts and is affected by changes in retirement behaviour and cohort composition.

Figure 10

Benefit Ratio by Age Group of Old-Age Pension Recipients

Note: The under-65 group shrinks as statutory retirement ages rise; its 2060 – 2070 values reflect compositional change.

Source: Slovak Labour Market Model.

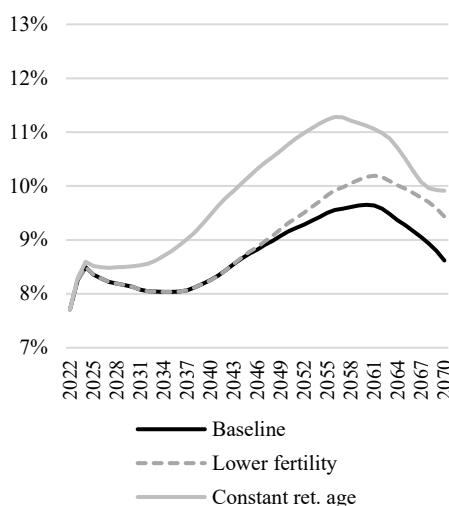
3.5. Sensitivity Analysis

The harmonisation of the external assumptions also allows the sensitivity scenarios defined by the Ageing Working Group to be applied directly in the micro-simulation model. This provides a consistent framework for examining whether alternative demographic and policy assumptions generate effects similar to those reported in the 2024 Ageing Report. Two scenarios are considered: lower fertility and a constant statutory retirement age. They were selected because they produce the largest increases in projected pension expenditure among the demographic and policy sensitivity scenarios reported for Slovakia. Results are tabulated in Annex C (Table A8).

Figures 11 and 12 present pension expenditure and the replacement rate under the two scenarios relative to the baseline projection. Both scenarios increase expenditure, although their timing and underlying mechanisms differ. Lower fertility

has almost no effect during the first part of the projection horizon and increases expenditure by approximately 0.8% of GDP in 2070. Keeping the retirement age constant has an earlier and larger effect, raising expenditure by approximately 1.3% of GDP at the end of the projection. The replacement rate is largely unaffected by lower fertility, whereas it decreases substantially when the retirement age is held constant.

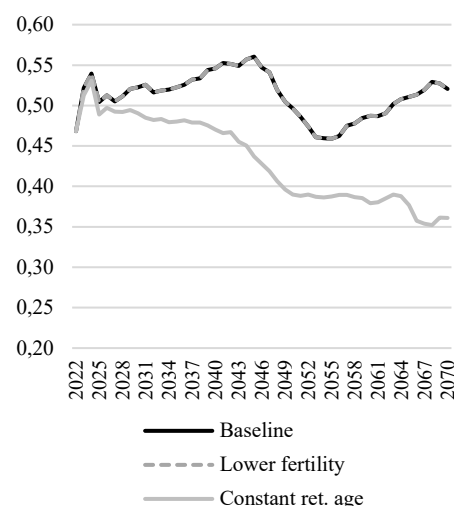
Figure 11
Pension Expenditure under Alternative Sensitivity Scenarios (% of GDP)



Note: Expenditure includes only the pension-benefit categories explicitly simulated by SLAMM.

Source: Slovak Labour Market Model; Ageing Report 2024.

Figure 12
Replacement Rate under Alternative Sensitivity Scenarios



Source: Slovak Labour Market Model; Ageing Report 2024.

The lower fertility scenario applies age-specific fertility rates that are 20% below the baseline assumptions. Its fiscal effect emerges only gradually because the smaller cohorts born during the projection period do not enter the labour market until approximately two decades later and do not reach retirement age within the projection horizon. Consequently, the number of old-age pensioners and their pension entitlements are initially almost unaffected. Expenditure nevertheless increases relative to GDP once the smaller cohorts enter working age, as lower employment reduces economic output and the contribution base supporting a largely unchanged pensioner population. The expenditure effect reaches approximately 0.8% of GDP by 2070. The replacement rate remains close to the baseline because the scenario does not directly alter the pension formula, retirement conditions or the earnings histories of cohorts retiring during the projection period.

The constant retirement age scenario keeps the statutory retirement age at its currently legislated level instead of allowing it to increase in line with life expectancy. This raises the number of pensioners, shortens working careers and reduces employment and GDP relative to the baseline. The expenditure effect is therefore visible earlier and is more pronounced throughout the projection horizon, reaching approximately 1.3% of GDP in 2070. Its development also reflects the retirement of relatively large cohorts around the middle of the projection period.

The scenario has a substantial effect on the replacement rate calculated by the microsimulation model. Under the baseline, the increasing retirement age can widen the interval between an individual's last observed wage and the award of an old-age pension, particularly where employment is followed by unemployment or inactivity. Because the individual replacement rate uses the last observed wage as its denominator, this interval can mechanically increase the measured ratio. When the retirement age remains constant, this gap does not expand to the same extent and the replacement rate declines. By 2070, it reaches approximately 0.36, nearly identical to the value produced by the aggregate model under the corresponding Ageing Report scenario (Table A8 in the annex). This convergence supports the interpretation that much of the baseline difference between the two projections reflects the definition and timing of the wage denominator rather than differences in the generosity of pension entitlements.

Conclusions

This paper compares long-term projections of the Slovak pension system produced by an aggregate cohort-component model and a dynamic microsimulation model. The comparison is based on a microsimulation baseline that incorporates the demographic, labour-market and macroeconomic assumptions of the Ageing Report wherever applicable within the individual-level framework. This substantially reduces the extent to which differences in the results can be attributed to competing external scenarios, although different base-year populations, unemployment assumptions and selected modelling assumptions remain.

The two approaches generate a similar general expenditure profile and relatively close projections for old-age and early old-age pensions, the largest expenditure category. Larger differences are concentrated in disability and minimum pensions. In the microsimulation model, disability pensioners reaching retirement age can be explicitly reassessed and reclassified as old-age pensioners, while no additional increase in disability inflows is imposed as the retirement age rises. The aggregate model instead retains disability pensions within that category and applies an adjustment intended partly to compensate for their treatment. The projections, therefore,

differ not merely because one model is more disaggregated, but because the two structures translate recipient transitions and future benefit incidence into expenditure in different ways.

The projected public pension balance is more favourable in the microsimulation model, with the deficit reaching approximately 2.1% of GDP in 2070 compared with around 3.0% in the aggregate projection. This difference primarily reflects the lower expenditure path generated by the microsimulation model. The contribution-revenue difference changes sign over the projection horizon: it offsets part of the expenditure advantage in earlier years and reinforces it by 2070. Both projections apply the AWG-comparable second-pillar contribution schedule, under which the contribution rate reaches 6% from 2027. The remaining differences in contribution revenue therefore do not arise from alternative legislative assumptions concerning the allocation of contributions between the two pillars. Instead, they reflect differences in the modelling frameworks, including the selection and composition of contributors, their effective assessment bases, the calibration of contribution collection and the simulated participation in the second pillar.

The benefit ratio produces a much more consistent adequacy assessment across the two models, with a long-term difference of only around 0.01. Both projections indicate that the average first-pillar pension will decline relative to the average wage. By contrast, the replacement rate is considerably higher in the microsimulation model. This discrepancy mainly reflects different definitions rather than greater simulated pension generosity. The aggregate indicator uses the contemporaneous economy-wide average wage, whereas the microsimulation indicator relates each newly awarded pension to the recipient's last observed wage. When employment does not continue until retirement, the wage denominator can precede the pension award by several years, mechanically increasing the measured replacement rate.

The individual-level results add information that cannot be obtained from the aggregate projection alone. Inequality among newly awarded old-age pensions generally declines over the projection horizon, while inequality within the pensioner stock initially increases before falling as newer cohorts replace existing recipients. Men retain a higher first-pillar benefit ratio than women, although the gap narrows mainly because the male ratio declines more rapidly. Older pensioners generally receive lower benefits relative to the current average wage because pensions in payment do not fully track wage growth. These results demonstrate that changes in an aggregate adequacy indicator can conceal materially different developments across sex, age and pension-award cohorts. The subgroup results provide a basis for discussing gender and inter-cohort differences in the Slovak pension system.

The sensitivity analysis further shows the value of applying common alternative assumptions within both modelling frameworks. Lower fertility affects pension expenditure only gradually, as smaller cohorts enter the labour market but do not reach retirement within the projection horizon. A constant retirement age has an earlier and larger effect, increasing expenditure by approximately 1.3 percentage points of GDP in 2070. It also reduces the replacement rate in the microsimulation model because the increasing interval between the last observed wage and pension award found in the baseline no longer develops to the same extent. In this scenario, the long-term replacement rates produced by the two models converge, underscoring the importance of measurement and retirement pathways in interpreting the baseline difference. These results illustrate how individual career histories can help interpret differences in aggregate adequacy measures.

Several limitations remain. The microsimulation model does not simulate second-pillar assets and benefits, so its adequacy indicators refer primarily to first-pillar pensions and cannot assess the total retirement income of funded-pillar participants. The absence of household and partner links requires survivor pensions and material-need benefits to be approximated at the individual level. Pension rights accumulated before the base year are reconstructed through synthetic retrospective histories rather than observed complete careers. Future development should therefore focus on integrating funded-pillar outcomes, improving household-related processes and validating individual career histories against additional administrative data.

The results support treating aggregate and microsimulation pension models as complementary tools. The aggregate model provides a transparent and internationally comparable benchmark for long-term fiscal projections. Microsimulation provides a closer representation of individual pension transitions and reveals the distributional mechanisms underlying aggregate outcomes. Using common assumptions across both approaches makes their comparison more informative and helps distinguish genuine differences in projected sustainability from differences caused by legislation, indicator definitions or the treatment of specific pension processes.

References

- BARR, N. – DIAMOND, P. (2006): The Economics of Pensions. *Oxford Review of Economic Policy*, 22, No. 1, pp. 15 – 39.
- CALCAGNO, L. (2018): Argentina's Social Security System: A Dynamic Microsimulation Model for Projecting Its Sustainability, Adequacy and Redistributive Impact. [PhD Thesis.] Orléans: Université d'Orléans. DOI: 10.5281/zenodo.1420273.
- De MENTEN, G. – DEKKERS, G. – BRYON, G. – LIÉGEOIS, P. (2014): LIAM2: A New Open Source Development Tool for Discrete-Time Dynamic Microsimulation Models. *Journal of Artificial Societies and Social Simulation*, 17, No. 3, p. 9. DOI: 10.18564/jasss.2574.

- DEKKERS, G. – BUSLEI, H. – COZZOLINO, M. – DESMET, R. – GEYER, J. – HOFMANN, D. – RAITANO, M. – STEINER, V. – TANDA, P. – TEDESCHI, S. – VERSCHUEREN, F. (2010): The Flip Side of the Coin: The Consequences of the European Pension Reforms for the Adequacy of Social Security. *International Journal of Microsimulation*, 3, No. 1, pp. 41 – 63. DOI: 10.34196/ijm.00022.
- DUGGAN, M. – SINGLETON, P. – SONG, J. (2007): Aching to Retire? The Rise in the Full Retirement Age and Its Impact on the Social Security Disability Rolls. *Journal of Public Economics*, 91, No. 7 – 8, pp. 1327 – 1350. DOI: 10.1016/j.jpubeco.2006.12.007.
- FREDRIKSEN, D. – STØLEN, N. M. (2017): Life Time Pension Benefits Relative to Life Time Contributions. *International Journal of Microsimulation*, 10, No. 2, pp. 177 – 207. DOI: 10.34196/ijm.00161.
- GONZALEZ GARIBAY, M. (2023): The Retirement Decision in Dynamic Microsimulation Models: An Exploratory Review. *International Journal of Microsimulation*, 16, No. 3, pp. 19 – 48. DOI: 10.34196/ijm.00287.
- PATXOT, C. – SOLÉ, M. – SOUTO, G. – SPIELAUER, M. (2018): The Impact of the Retirement Decision and Demographics on Pension Sustainability: A Dynamic Microsimulation Analysis. *International Journal of Microsimulation*, 11, No. 2, pp. 84 – 108. DOI: 10.34196/ijm.00181.
- STAUBLI, S. – ZWEIMÜLLER, J. (2013): Does Raising the Early Retirement Age Increase Employment of Older Workers? *Journal of Public Economics*, 108, pp. 17 – 32. DOI: 10.1016/j.jpubeco.2013.09.003.
- TIKANMÄKI, H. – SIHVONEN, H. – SALONEN, J. (2015): Distributional Effects of the Forthcoming Finnish Pension Reform – A Dynamic Microsimulation Approach. *International Journal of Microsimulation*, 8, No. 3, pp. 75 – 98. DOI: 10.34196/ijm.00122.
- EUROPEAN COMMISSION and EPC (2024): The 2024 Ageing Report: Economic and Budgetary Projections for the EU Member States (2022 – 2070). Brussels: European Commission.
- EUROPEAN COMMISSION and EPC (2023): 2024 Ageing Report: Underlying Assumptions and Projection Methodologies. Brussels: European Commission.
- EUROPEAN COMMISSION (2026): Debt Sustainability Monitor 2025. Brussels: European Commission.
- IFP (2026): 85th Meeting of the Committee for Tax Forecasts: Pension Expenditure Forecast. Bratislava: Institute for Financial Policy.
- IFP (2025): Pension Lottery: Commentary on Developments in Early Retirement. Bratislava: Institute for Financial Policy.
- LI, J. – O'DONOGHUE, C. (2013): A Survey of Dynamic Microsimulation Models: Uses, Model Structure and Methodology. *International Journal of Microsimulation*, 6, No. 2, pp. 3 – 55.
- OECD (2023): Pensions at a Glance 2023: OECD and G20 Indicators. Paris: OECD Publishing.
- ŠTEFÁNIK, M. – MIKLOŠOVIČ, T. (2020): Modelling Foreign Labour Inflows Using a Dynamic Microsimulation Model of an Ageing Country – Slovakia. *International Journal of Microsimulation*, 13, No. 2, pp. 102 – 113. DOI: 10.34196/ijm.00220.
- Act No. 461/2003 Coll. on Social Insurance, as Amended.
- Act No. 352/2022 Coll. Amending Act No. 461/2003 Coll.

Annex A – The Slovak Pension System

The Slovak pension system is a multi-pillar arrangement whose structure is summarised in Table A1. The dominant component for this paper is the first pillar.

Table A1

Slovak Pension System Structure

Feature	First pillar (PAYG)	Second pillar (funded DC)	Third pillar (voluntary)	Min. income floor
Type	Mandatory DB	Mandatory DC (opt-out)	Voluntary DC	Social assistance
Contribution rate	18% gross wage	4% gross wage	Voluntary + employer	–
Benefit formula	$P = APPV \times PIP \times CPPV$	Accumulated assets/payout product	Fund performance	Min. pension top-up; MNB
CPPV indexation	95% avg. wage growth (post-2022)	n/a	n/a	Subsistence minimum
Coverage	Universal	~60% of labour force	Voluntary (~35%)	Residual
In SLAMM	Explicitly simulated	1st-pillar reduction	Not modelled	Simplified top-up

Note: The second-pillar contribution rate shown in the table reflects current legislation. For comparability with the 2024 Ageing Report, the projections use a rate of 5.5% of gross wages in 2022 – 2024, 5.75% in 2025 – 2026 and 6% from 2027 onwards. These contributions are redirected from the total 18% old-age contribution.

Source: Authors' classification based on Act No. 461/2003 Coll.; Act No. 43/2004 Coll.; European Commission and EPC (2024).

The first pillar is a mandatory pay-as-you-go earnings-related defined-benefit scheme financed from payroll contributions (18% of gross wage) and administered by the Social Insurance Agency. Entitlement requires at least 15 years of pension insurance. The point-based benefit formula is $P = APPV \times PIP \times CPPV \times (1 + \text{valorisation})$, where APPV is the average personal pension point value (individual earnings / economy-wide average wage, averaged over the post-1984 assessment period), PIP is the pension insurance period (years), and CPPV is the current pension point value. Since the 2022 reform, CPPV grows at 95% of nominal average wage growth. A solidarity adjustment partially uplifts APPV values below 1.0 and partially caps values above 1.25 (maximum 3.0), compressing the distribution of pension outcomes relative to earnings. The statutory retirement age is linked to life expectancy for cohorts born after 1966, with reductions for women depending on the number of raised children.

Early retirement is possible up to two years before the statutory retirement age or by reaching 40 years of working career (regardless of age), subject to a minimum pension threshold, with a permanent reduction determined by the retirement pathway and the legislation represented in the projection. Retirement after the statutory age earns a 6% bonus per year. Pensions in payment are indexed to pensioner household price growth; newly awarded pensions reflect the CPPV at the date of award. The distinction between these two indexation regimes – CPPV-driven for new awards, price-driven for existing pensions – is fundamental to the adequacy results in Section 3.4.3, where it generates the age gradient in benefit ratios.

The second pillar redirects part of gross wages to individual accounts in private pension management companies. For comparability with the 2024 Ageing Report, this microsimulation uses a contribution schedule of 5.5% in 2022 – 2024, 5.75% in 2025 – 2026 and 6% from 2027 onward. Participants receive a reduced first-pillar pension to reflect the redirected contributions. The model represents second-pillar membership, contributions and the corresponding first-pillar reduction, but does not simulate funded assets or second-pillar benefits. The third pillar is voluntary and employer-co-financed and is not modelled in the microsimulation. Minimum-income mechanisms include a material-need benefit for persons without pension entitlement at retirement age and a minimum-pension top-up for pensioners with low benefits.

A n n e x B – Pension Module: Technical Summary

B.1 Wage Model and Pension Point Accumulation

Individual pension points are modelled as sex-specific Mincer-type equations with OMB¹⁰ (individual wage relative to the economy-wide average wage) as the dependent variable. The explanatory variables include age, age squared, education level, sector of employment and their interactions. Separate specifications are estimated where necessary to reflect differences across sex and age groups. The use of OMB rather than nominal wages separates relative earnings profiles from macroeconomic wage dynamics and directly produces the variable entering the statutory pension formula. The cumulative pension point stock (cumulative_omb) and the number of years entering the APPV denominator (roky_pomb) are updated separately, reflecting the institutional distinction between pension insurance periods that generate wage points and recognised periods that only extend insurance duration, such as selected periods of disability.

B.2 Retrospective Simulation

The retrospective module runs the microsimulation model backwards over approximately five decades preceding the 2022 base year. In each step, labour market states are assigned through logistic scoring aligned with historical calibration targets for employment, disability and inactivity. Wage equations subsequently assign annual pension points consistent with the estimated historical wage distributions. The resulting employment and earnings histories provide the pension insurance periods and pension points required for the prospective calculation of pension entitlements. Existing pensioners receive initial benefit amounts through a donor-cell matching procedure. The cells are defined by sex, age band, pension-award-year band, insurance duration, APPV band and, where relevant, the number of children. Assigned benefits are calibrated to the Social Insurance Agency administrative averages for 2022.

¹⁰ Model uses Slovak abbreviation of the pension point value – osobný mzdový bod (OMB).

B.3 Prospective Pension Calculation

Old age pensions are awarded using the statutory formula with actuarial bonuses (6% per year above the statutory retirement age) and reductions for early retirement. Retirement is modelled as a score-based transition aligned to external targets rather than as a deterministic age threshold. Pensions in payment are updated through price indexation; newly awarded pensions reflect the CPPV prevailing in the award year. For participants in the funded second pillar, the calculated first-pillar pension is reduced according to the share of their contributory career during which contributions were diverted to the funded scheme. Disability is modelled as a stock-flow process with logistic-score inflows aligned to administrative targets; disability pensioners reaching retirement age are converted to old age status when the old age benefit exceeds the disability pension. Survivor pensions are assigned through age-sex incidence targets; new awards are calculated as 60% of the deceased-donor pension base differentiated by sex, with concurrence rules (lower pension reduced by half when both own old age and survivor pensions are received) applied at the individual level. Minimum income mechanisms are evaluated individually: material need benefit for persons without pension entitlement; minimum pension top-up for pensioners below a calibrated threshold of 1.75 times the subsistence minimum (with a take-up rate calibrated to observed expenditure).

A n n e x C – Supplementary Tables

Table A2

Realised Demographic and Labour-Market Alignment

	2022	2030	2040	2050	2060	2070
Employment 15 – 74						
AR2024	2 634 461	2 523 085	2 360 284	2 195 379	2 060 988	2 044 870
Microsimulation model	2 499 200	2 520 990	2 360 025	2 195 275	2 060 950	2 044 840
diff (%)	-5.13%	-0.08%	-0.01%	0.00%	0.00%	0.00%
Unemployment 15 – 74						
AR2024	161 543	155 415	157 090	144 517	134 905	134 089
Microsimulation model	351 280	268 420	264 495	235 210	217 655	202 500
diff (%)	117.45%	72.71%	68.37%	62.76%	61.34%	51.02%
Population						
AR2024	5 479 308	5 442 194	5 295 211	5 173 380	5 020 002	4 816 897
Microsimulation model	5 591 980	5 584 845	5 405 800	5 247 780	5 071 825	4 835 630
diff (%)	2.06%	2.62%	2.09%	1.44%	1.03%	0.39%
Net migration						
AR2024	96 195	-710	7 660	8 485	6 810	7 655
Microsimulation model	96 195	-710	7 660	8 485	6 810	7 655
diff (%)	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Fertility rate; 30 years						
AR2024	10.6%	10.7%	10.8%	10.9%	11.0%	11.1%
Microsimulation model	10.6%	10.7%	10.8%	10.9%	11.0%	11.1%
diff (%)	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Mortality rate; 65 years M						
AR2024	2.5%	2.0%	1.6%	1.2%	1.0%	0.8%
Microsimulation model	2.5%	2.0%	1.6%	1.2%	1.0%	0.8%
diff (%)	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

Source: Slovak Labour Market Model; Ageing Report 2024.

Table A3
Pension Expenditure by Benefit Category

	2022	2030	2040	2050	2060	2070	Δ2022-70
Old-age and early							
AR2024	6.1%	7.2%	7.3%	7.8%	8.2%	7.5%	1.5%
Microsimulation model	6.3%	6.7%	6.7%	7.6%	8.1%	7.1%	0.8%
<i>diff</i>	0.2%	-0.5%	-0.6%	-0.2%	-0.1%	-0.4%	-0.6%
Disability							
AR2024	0.7%	1.1%	1.3%	1.3%	1.2%	1.3%	0.6%
Microsimulation model	0.8%	0.7%	0.6%	0.5%	0.4%	0.4%	-0.3%
<i>diff</i>	0.1%	-0.4%	-0.7%	-0.8%	-0.8%	-0.9%	-0.9%
Widow's and Widower's							
AR2024	0.7%	0.8%	0.7%	0.7%	0.6%	0.5%	-0.1%
Microsimulation model	0.6%	0.7%	0.7%	0.8%	0.8%	0.8%	0.2%
<i>diff</i>	-0.1%	-0.1%	0.0%	0.1%	0.2%	0.3%	0.4%
Minimum							
AR2024	0.1%	0.1%	0.4%	0.7%	0.8%	0.7%	0.7%
Microsimulation model	0.1%	0.1%	0.2%	0.3%	0.3%	0.3%	0.2%
<i>diff</i>	0.0%	0.0%	-0.2%	-0.4%	-0.5%	-0.4%	-0.4%
Material need							
AR2024	0.00%	0.01%	0.02%	0.04%	0.05%	0.05%	0.0%
Microsimulation model	0.01%	0.01%	0.01%	0.01%	0.01%	0.03%	0.02%
<i>diff</i>	0.00%	0.00%	-0.01%	-0.03%	-0.04%	-0.02%	-0.03%

Source: Slovak Labour Market Model; Ageing Report 2024.

Table A4
Expenditure, Revenue and Pension System Balance

	2022	2030	2040	2050	2060	2070	Δ2022-70
Expenditure							
AR2024	8.1%	9.8%	10.3%	11.1%	11.6%	10.8%	2.8%
Microsimulation model	8.2%	8.7%	8.9%	9.8%	10.4%	9.3%	1.1%
<i>diff</i>	0.1%	-1.1%	-1.4%	-1.3%	-1.2%	-1.5%	-1.6%
Revenue							
AR2024	7.0%	6.6%	6.5%	6.3%	6.1%	5.9%	-1.1%
Microsimulation model	6.9%	6.4%	6.3%	6.1%	6.1%	6.1%	-0.9%
<i>diff</i>	-0.1%	-0.2%	-0.2%	-0.2%	0.0%	0.2%	0.2%
Balance							
AR2024	-1.0%	-3.2%	-3.9%	-4.8%	-5.6%	-4.9%	-3.9%
Microsimulation model	-1.3%	-2.3%	-2.6%	-3.7%	-4.3%	-3.2%	-2.0%
<i>diff</i>	-0.2%	0.9%	1.2%	1.1%	1.3%	1.7%	1.9%

Source: Slovak Labour Market Model; Ageing Report 2024.

Table A5
Old-Age Pension Adequacy Indicators

	2022	2030	2040	2050	2060	2070	Δ2022-70
Benefit ratio							
AR2024	0.38	0.39	0.35	0.33	0.33	0.33	-0.05
Microsimulation model	0.39	0.38	0.33	0.32	0.32	0.32	-0.07
<i>diff</i>	0.01	-0.01	-0.02	-0.01	-0.01	-0.01	-0.02
Replacement rate							
AR2024	0.40	0.41	0.37	0.36	0.34	0.35	-0.05
Microsimulation model	0.47	0.52	0.55	0.50	0.49	0.52	0.05
<i>diff</i>	0.07	0.11	0.18	0.14	0.15	0.17	0.10

Source: Slovak Labour Market Model; Ageing Report 2024.

Table A6

Adequacy Indicators by Sex

	2022	2030	2040	2050	2060	2070	$\Delta 2022-70$
RR all	0.47	0.52	0.55	0.50	0.49	0.52	0.05
RR male	0.49	0.56	0.56	0.53	0.55	0.56	0.07
RR female	0.45	0.49	0.53	0.47	0.43	0.48	0.03
BR all	0.39	0.38	0.33	0.32	0.32	0.32	-0.07
BR male	0.48	0.45	0.37	0.36	0.35	0.35	-0.13
BR female	0.34	0.34	0.30	0.29	0.29	0.29	-0.04

Source: Slovak Labour Market Model.

Table A7

Adequacy Indicators by Age

	2022	2030	2040	2050	2060	2070	$\Delta 2022-70$
-65	0.41	0.37	0.39	0.36	0.25	0.07	-0.34
65 – 69	0.44	0.36	0.37	0.38	0.39	0.38	-0.06
70 – 74	0.40	0.42	0.31	0.35	0.35	0.38	-0.02
75 – 79	0.36	0.40	0.28	0.30	0.32	0.35	-0.01
80 – 84	0.33	0.38	0.33	0.25	0.29	0.31	-0.02
85+	0.30	0.32	0.31	0.24	0.23	0.26	-0.04

Source: Slovak Labour Market Model.

Table A8

Pension Expenditure and Replacement Rate under Selected AWG Sensitivity Scenarios

	2022	2030	2040	2050	2060	2070	$\Delta 2022-70$
Expenditure – deviation from each model's baseline, percentage points of GDP							
Lower fertility							
AR2024	0.0	0.0	0.0	0.2	0.6	1.0	1.0
Microsimulation model	0.0	0.0	0.0	0.2	0.5	0.8	0.8
Constant retirement age							
AR2024	0.0	0.3	0.9	1.5	1.6	1.5	1.5
Microsimulation model	0.0	0.4	1.2	1.6	1.5	1.3	1.3
Replacement rate – levels							
Lower fertility							
AR2024	0.40	0.41	0.37	0.36	0.34	0.35	-0.05
Microsimulation model	0.47	0.53	0.55	0.50	0.49	0.52	0.06
Constant retirement age							
AR2024	0.40	0.41	0.37	0.36	0.34	0.35	-0.05
Microsimulation model	0.47	0.50	0.47	0.39	0.38	0.35	-0.12

Source: Slovak Labour Market Model.