

**BRATISLAVA UNIVERSITY OF ECONOMICS AND BUSINESS**  
**FACULTY OF ECONOMICS AND FINANCE**

**SELF-REPORT OF DISSERTATION**

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Self-report of Dissertation

**Modelling the Sustainability and Adequacy of the Pension System  
in Slovakia**

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## **1. Overview of the Current Status of the Issues Addressed in the Dissertation at Home and Abroad**

Population ageing represents one of the main long-term challenges for public finances and social protection systems in Slovakia. The pension system is particularly exposed to demographic change, as its expenditure depends directly on the number of pension beneficiaries, the duration of pension receipt, labour market participation, wage growth and the number of contributors financing the system. At the same time, pensions are the main source of income in old age and therefore play an important role in preventing poverty and maintaining living standards after retirement. For this reason, the Slovak pension system must be assessed not only from the perspective of long-term financial sustainability, but also from the perspective of pension adequacy.

The long-term sustainability of public finances, including the pension system, is regularly assessed by several national and international institutions. At the national level, the key institution is the Council for Budget Responsibility, which publishes the annual Report on the Long-term Sustainability of Public Finances (Council for Budget Responsibility, 2025). This report evaluates the long-term position of Slovak public finances and identifies demographic ageing as one of the major sources of future expenditure pressure. In the most recent assessment, the Council for Budget Responsibility again classified Slovak public finances as long-term unsustainable, with future pressures related especially to ageing-sensitive expenditure items, including pensions, healthcare and long-term care.

At the European level, the most important reference framework is the Ageing Report, prepared by the European Commission and the Economic Policy Committee (European Commission and EPC, 2024). The 2024 Ageing Report provides long-term projections of age-related public expenditure for EU Member States over the period 2022–2070. It covers pensions, healthcare, long-term care, education and unemployment benefits, and serves as the main European reference for comparing the fiscal consequences of population ageing. In the case of Slovakia, the pension projections used in the Ageing Report framework are prepared using the Slovak Pension Model, SLOPEM, with the participation of the Institute for Financial Policy of the Ministry of Finance of the Slovak Republic (European Commission and EPC, 2024b).

These projections are therefore an important benchmark for the dissertation.

However, the sustainability perspective captures only one side of the pension policy problem. Pension adequacy represents the second, equally important dimension. A pension system may be financially sustainable but provide benefits that are too low to prevent poverty or to ensure a reasonable standard of living in old age. Conversely, a system may provide relatively generous benefits but create long-term fiscal pressures that undermine its stability. Sustainability and adequacy therefore must be evaluated jointly, as policy measures often affect the two dimensions in opposite directions. For example, slower growth of newly awarded pensions may improve fiscal sustainability but may also reduce future replacement rates. In contrast, measures increasing pension benefits may improve adequacy, but at the cost of higher long-term expenditure.

The adequacy of pensions is also assessed in international policy reports. In the European context, the key publication is the Pension Adequacy Report, prepared by the European Commission and the Social Protection Committee (European Commission and Social Protection Committee, 2024). The 2024 Pension Adequacy Report focuses on current and future income adequacy in old age, with attention to statutory pensions, supplementary pensions, minimum income protection, gender inequalities and the role of survivors' pensions. While the Ageing Report focuses primarily on the expenditure and fiscal side of population ageing, the Pension Adequacy Report complements this perspective by examining whether pension systems provide sufficient income for older people.

The dissertation builds on this policy and analytical context. Existing national and European projection frameworks provide a well-established basis for assessing the aggregate sustainability of the Slovak pension system. However, many important features of the Slovak pension system operate at the individual level. Pension entitlements depend on lifetime earnings, pension insurance periods, personal wage points, redistributive elements of the benefit formula, participation in the second pillar, early retirement rules, disability and survivor pension pathways, and minimum income mechanisms in old age. These mechanisms affect different individuals and population groups in different ways. Aggregate cohort models can capture their overall effect on expenditure, but they are less suited to analysing how these rules translate into heterogeneous pension outcomes across individuals. This is one of the standard

motivations for using dynamic microsimulation, which preserves heterogeneity of micro-units and allows simulated life histories to be linked to policy rules (Li and O'Donoghue, 2013; Dekkers, 2010).

For this reason, the dissertation applies a dynamic microsimulation approach. It extends the Slovak Labour Market Model, SLAMM, with a pension module that links simulated labour market histories to the rules of the Slovak pension system. This makes it possible to analyse aggregate pension expenditure and individual pension outcomes within the same modelling framework. The model is compared with the medium-term forecast of the Committee for Tax Forecasts and with the long-term projections of SLOPEM used in the Ageing Report framework. At the same time, it provides additional information on adequacy, distributional outcomes and the effects of selected policy scenarios. The dissertation therefore contributes to the existing domestic and international literature by complementing aggregate sustainability analysis with individual-level evidence on pension adequacy and distributional effects.

## 2. Aim and Focus of the Dissertation

The main aim of the dissertation is to assess the future sustainability and adequacy of the Slovak pension system using a dynamic microsimulation model. The dissertation builds on the existing Slovak Labour Market Model (SLAMM), developed at the Institute of Economic Research of the Slovak Academy of Sciences (Štefánik and Miklošovič, 2020), and extends it with a pension module. This extension makes it possible to link simulated labour market histories of individuals with the rules of the Slovak pension system and to analyse both aggregate pension expenditure and individual pension outcomes within one modelling framework.

The focus of the dissertation is motivated by including an additional dimension to the assessment of the Slovak pension system beyond aggregate indicators. Pension expenditure, pension system balance and average benefit ratios are essential for the evaluation of fiscal sustainability. However, they do not show how pension outcomes differ across individuals and population groups. Pension adequacy depends on individual labour market histories, accumulated pension rights, earnings position, sex, retirement timing, participation in the second pillar and the interaction between statutory pension rules and minimum income mechanisms. The dissertation therefore focuses on connecting the aggregate fiscal dimension of the pension system with its individual-level and distributional dimension.

The purpose of the dissertation is not to replace existing official projection tools. The Slovak Pension Model, SLOPEM, remains the relevant benchmark for long-term pension expenditure projections in the Ageing Report framework. Its role is important because it ensures consistency with common demographic, macroeconomic and labour market assumptions used in European long-term projections. The contribution of this dissertation is more specific. It examines whether the individual-level structure of SLAMM can provide additional information in those parts of the Slovak pension system where entitlements depend directly on individual histories and institutional rules.

The main research question of the dissertation is formulated as:

*Can the sustainability and adequacy of the Slovak pension system be assessed using a dynamic microsimulation model that extends the existing labour market model with a pension module?*

This question reflects the central idea of the dissertation: the pension system should be evaluated not only by whether it is financially sustainable, but also by whether the resulting pension benefits remain adequate for individuals and for different population groups. Answering this question requires that the model is able to reconstruct pension-relevant histories, simulate future pension entitlements according to Slovak pension rules and interpret the results at both aggregate and individual levels.

The main research question is divided into several partial research questions. The first group of questions concerns the comparison between the microsimulation model and the cohort-component model used in SLOPEM. The dissertation evaluates whether the microsimulation model can reproduce the main aggregate indicators of sustainability and adequacy and whether it provides additional analytical detail compared with a cohort-based approach. This comparison is important because microsimulation is not expected to be universally more accurate than an aggregate model. Instead, its added value lies mainly in indicators that depend on heterogeneity within cohorts.

The second group of questions concerns the sustainability of pensions granted in Slovakia in relation to previous income and system revenues. The dissertation therefore analyses pension expenditure, contribution revenues and the balance of the pension system under the baseline projection. It also evaluates whether the model can translate selected changes in the legislative environment into fiscal and adequacy outcomes. This scenario-based part of the dissertation is used to demonstrate whether the pension module can consistently reflect changes in pension rules.

The third group of questions focuses on pension adequacy. The dissertation analyses indicators such as the benefit ratio and replacement rate and compares their development with the results of SLOPEM where possible. At the same time, the microsimulation framework allows these indicators to be evaluated not only on average, but also across groups of individuals. This is particularly important because a pension system may appear adequate on average while still creating adequacy risks for selected groups.

The final research question concerns heterogeneity by income group and sex. This dimension is central for the added value of the microsimulation approach. Pension outcomes depend on individual histories, and these histories differ systematically across groups. Income

groups differ in wage levels, employment stability, contribution histories and exposure to redistributive elements of the pension formula. Men and women differ in labour market participation, wage profiles, career interruptions, retirement age rules and life expectancy. The model therefore compares pension levels, replacement rates and selected adequacy indicators across these groups.

The dissertation has three main contributions. The first is methodological: it develops a pension module within an existing dynamic microsimulation framework and evaluates whether this extension can complement the cohort-based projection approach. The second is empirical: it produces projections of pension benefits, pension expenditure, contribution revenues and system balance for Slovakia under a baseline scenario and selected alternative scenarios. The third is distributional: by simulating individuals, the model can identify how pension sustainability and adequacy differ across income groups, between men and women and across different pension pathways.

The overall ambition of the dissertation is therefore not only to project the future cost of the Slovak pension system, but also to assess what these projected costs mean for individuals. A sustainable system with inadequate benefits would not fulfil the social function of pensions, while an adequate system that cannot be financed would not be stable in the long run. The dissertation addresses this tension by developing a modelling framework in which both dimensions can be analysed jointly.

### **3. Methodology of Work and Research Methods**

The dissertation uses a dynamic microsimulation approach to assess the sustainability and adequacy of the Slovak pension system. The methodological basis of the work is the Slovak Labour Market Model (SLAMM), developed at the Institute of Economic Research of the Slovak Academy of Sciences (Štefánik and Miklošovič, 2020). SLAMM was originally designed to project labour supply, employment structure and labour market developments in Slovakia. The dissertation extends this framework with a pension module, which transforms simulated labour market histories into pension-relevant variables and applies the institutional rules of the Slovak pension system to calculate pension entitlements and pension expenditure.

Similar applications of dynamic microsimulation have been used in pension analysis in other countries, for example to evaluate the sustainability and adequacy effects of pension reforms in Belgium, Spain and other European systems (Dekkers, 2010; Solé et al., 2019; Patxot et al., 2018). The dissertation follows this general modelling tradition but applies it to the institutional setting of the Slovak pension system and builds on the existing SLAMM model.

The research design combines institutional analysis, model extension, retrospective reconstruction of missing histories, prospective simulation of pension benefits and comparison with existing official projection tools. The starting point is the institutional analysis of the Slovak pension system. This part identifies the rules that are relevant for microsimulation modelling, especially eligibility conditions, retirement age rules, the old age pension formula, redistributive adjustment of the average personal wage point, indexation of pensions, participation in the second pillar, early retirement rules, disability pensions, survivor pensions and selected minimum income mechanisms in old age. The purpose of this step is to translate legal and institutional rules into model procedures that can be applied to individual simulated records.

The core research method is dynamic microsimulation. In contrast to aggregate cohort models, microsimulation follows individual units over time and updates their characteristics through simulated life-course transitions (Li and O'Donoghue, 2013; Spielauer, 2002). Individuals age in annual steps and their demographic, educational, labour market and pension-related characteristics are updated during the simulation. This makes it possible to link the development of the labour market with the development of pension entitlements. In the original

SLAMM model, employment trajectories are relevant mainly because they determine labour supply and replacement demand. In the pension extension, the same trajectories are also interpreted as contribution histories. Each year of employment may generate a wage, an assessment base, a pension point and a year of pension insurance. Each transition into retirement may generate a pension claim and each year of pension receipt contributes to pension expenditure.

**Graph 1: Structure of the SLAMM microsimulation model**

| Macroeconomic block                                                                                                                               | Dynamic microsimulation block                                                                                                                     | Model outputs                                                                                                                                                 |
|---------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <ul style="list-style-type: none"> <li>• output by sector</li> <li>• sectoral labour demand</li> <li>• employment by sector/occupation</li> </ul> | <ul style="list-style-type: none"> <li>• population</li> <li>• education</li> <li>• economic activity</li> <li>• employment allocation</li> </ul> | <ul style="list-style-type: none"> <li>• labour supply</li> <li>• labour shortages</li> <li>• replacement demand</li> <li>• foreign labour inflows</li> </ul> |

*Source: author's adaptation based on Štefánik and Miklošovič (2020)*

The pension module builds on the existing demographic and labour market modules of SLAMM. The demographic module updates age, sex and mortality and therefore determines the size and age structure of the simulated population. The education module determines educational attainment, which is relevant for labour market participation and wage modelling. The economic activity module assigns individuals to activity and inactivity states, including retirement and disability statuses. The employment module allocates economically active persons to employment, unemployment and labour market segments. These modules provide the basis for the pension extension, because pension entitlements depend on employment, earnings, contribution periods, retirement timing and disability status.

A key methodological step is the construction of individual earnings and pension points. The Slovak pension formula is earnings-related and uses personal wage points to link individual assessment bases to the average wage in the economy. The model therefore needs to assign relative wages to simulated individuals. This is done using wage equations estimated by sex and based on individual characteristics such as age, education and sector of employment, following the standard Mincerian approach to modelling earnings (Mincer, 1958; Mincer, 1974). These estimated wage profiles are then used to generate personal wage points, which enter the pension formula and contribute to the accumulated pension rights of individuals.

The second methodological step is the retrospective reconstruction of pension-relevant histories. The initial population of SLAMM does not contain complete historical information on previous employment, contribution periods, personal wage points or pension amounts for all individuals. This is a major limitation for pension modelling, because pension benefits depend not only on current characteristics but also on accumulated career histories. The dissertation therefore develops a retrospective simulation procedure that approximates missing pension histories before the base year of the model. In line with the retrospective-prospective structure used in social security microsimulation models, such as Calcagno (2018), this procedure reconstructs accumulated pension insurance periods, personal wage points and existing pension amounts for the initial population. It allows the model to start from a population that is consistent with observed pension outcomes and with the institutional requirements of the Slovak pension formula.

## **Graph 2: Retrospective construction of relevant pension histories**

| <b>Census population</b>                                                                                                                                                                                                                                                                                                        |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <ul style="list-style-type: none"> <li>• retrospective labour market simulation</li> <li>• simulated historical employment and PPV paths</li> <li>• accumulated PIP, cumulative PPV and years of pension insurance</li> <li>• donor mapping and calibration of current pensions</li> <li>• prospective pension input</li> </ul> |

*Source: author's elaboration*

Minimum income mechanisms in old age are also included in the model in simplified form. The model represents material need benefits for persons in pension-relevant statuses and minimum pension top-ups for eligible old age pensioners and disabled persons above retirement age. These mechanisms are important for pension adequacy, because they protect individuals with low or insufficient pension entitlements. At the same time, their modelling is limited by data availability, especially by the absence of fully observed qualified periods required for exact minimum pension eligibility. For this reason, the model uses simplified thresholds and calibration assumptions rather than a fully legalistic reconstruction of all eligibility criteria.

The empirical strategy of the dissertation consists of several validation and comparison steps. First, the pension module is compared

with the medium-term forecast of the Committee for Tax Forecasts. This comparison evaluates whether the model produces plausible numbers of pensioners and average benefit levels for the main pension categories in the short and medium term. It is not interpreted as a one-to-one comparison of identical forecast systems, because the scope and methodology of the two approaches differ. Its purpose is to assess whether the microsimulation model is sufficiently aligned with official budgetary projections to be used for further analysis. The dissertation shows that the simulated numbers of recipients, average benefit levels and expenditure-relevant developments remain broadly comparable with the official medium-term projection.

Second, the long-term projection of the pension module is compared with the Slovak Pension Model, SLOPEM, used in the Ageing Report framework. This comparison is central for assessing the credibility of the model in the long-term sustainability context. SLOPEM is a cohort-component model designed for official long-term projections under the common methodological framework of the Ageing Working Group. SLAMM, by contrast, is a dynamic microsimulation model that simulates individuals and applies pension rules to their simulated histories. The comparison therefore focuses not only on the numerical similarity of expenditure paths, but also on the interpretation of differences between the two modelling approaches.

Third, the model is used to calculate adequacy indicators and distributional outcomes. The main adequacy indicators include the benefit ratio and the replacement rate. These indicators are evaluated at the aggregate level and, where possible, compared with SLOPEM. The microsimulation structure then allows the same indicators to be decomposed by sex, age and income group. This distributional part is one of the main methodological advantages of the model, because it makes it possible to evaluate pension adequacy not only for an average pensioner, but also for groups with different labour market and earnings histories.

Finally, the dissertation uses scenario analysis to test how the model responds to changes in pension policy parameters. Three alternative scenarios are analysed: faster growth of the current pension point value, removal of the second pillar and a unified retirement age for women and men. These scenarios are stylised and are not intended to represent a full reform package. Their purpose is to demonstrate that the pension module can consistently translate changes in institutional rules into aggregate expenditure, revenue and adequacy outcomes. Scenario

analysis is therefore used as a methodological tool for evaluating the usefulness of the model for policy assessment.

The data used in the dissertation combine several sources. The underlying SLAMM model relies on demographic and labour market information used to construct the initial population and simulate future trajectories. The pension extension adds administrative and model-based information on wages, pension recipients, pension benefits, contribution histories and benefit categories. External benchmarks are used for calibration and validation, especially the medium-term forecast of the Committee for Tax Forecasts and long-term projections from SLOPEM. The model is calibrated to reproduce observed or benchmarked aggregate outcomes where this is necessary for interpretation, while retaining the individual-level structure needed for adequacy and distributional analysis.

The methodology therefore combines several research methods: institutional analysis of pension rules, econometric estimation of wage profiles, retrospective simulation, dynamic microsimulation, calibration to administrative and official projection data, validation against external benchmarks, comparison with cohort-based modelling and scenario analysis. Together, these methods allow the dissertation to assess the Slovak pension system from two complementary perspectives. Sustainability is evaluated through aggregate expenditure, revenues and balance. Adequacy is evaluated through pension levels, replacement rates, benefit ratios and distributional indicators derived from individual simulated records. The main methodological contribution of the dissertation is that both perspectives are generated from the same dynamic microsimulation framework.

#### 4. Structure of the dissertation

The dissertation is structured into five main chapters, followed by the conclusion, résumé, technical annexes and references. The order of the chapters follows the logic of the research design. The thesis first defines the institutional and analytical framework of the Slovak pension system, then formulates the research objective and research questions, describes the underlying microsimulation model, explains the construction of the pension module and finally presents the empirical results.

The first chapter, *Institutional and Modelling Framework of the Slovak Pension System*, introduces the Slovak pension system and the two main evaluation criteria used throughout the dissertation: sustainability and adequacy. It describes the structure of the Slovak pension system, including the first pillar, second pillar, third pillar, special pension schemes and minimum income mechanisms in old age. The chapter also discusses pension adequacy and pension sustainability as complementary dimensions of pension policy. Its purpose is to identify the institutional rules that are relevant for microsimulation modelling.

The second chapter, *Research Objectives and Research Questions*, translates this institutional and analytical framework into the main objective of the dissertation. It formulates the main research question and the related partial research questions. These questions concern the comparison between the microsimulation model and the cohort-based approach used in SLOPEM, the sustainability of pension expenditure and system revenues, the adequacy of pension benefits under different legislative settings, and heterogeneity of results by income group and sex. The chapter also explains the expected contribution of the dissertation.

The third chapter, *Slovak Labour Market Model (SLAMM)*, presents the model that forms the basis for the pension extension. It describes the general purpose of SLAMM, its micro-macro structure, initial population, demographic module, education module, economic activity module, employment module, data sources, calibration strategy and existing policy applications. The chapter also explains why SLAMM is a suitable base for constructing a pension module and identifies data limitations relevant for the pension extension.

The fourth chapter, *Construction of the Pension Module*, describes the methodological core of the dissertation. It explains how earnings and personal wage points are modelled, how missing pension-

relevant histories are reconstructed retrospectively and how future pension benefits are simulated prospectively. The chapter covers the modelling of old age pensions, early old age pensions, disability pensions, survivor pensions, minimum pensions and material need benefits in old age. Its purpose is to show how the rules of the Slovak pension system are translated into individual-level simulation procedures.

The fifth chapter, *Results*, presents the empirical outputs of the model. It starts with nowcasting and medium-term validation against the pension forecast of the Committee for Tax Forecasts. It then compares long-term expenditure and revenue projections with SLOPEM, evaluates the balance of the pension system and analyses adequacy indicators. The chapter further examines heterogeneity by sex and age, distributional outcomes by income group and selected alternative policy scenarios. It concludes by summarising the added value of microsimulation and the main limitations of the current model.

The dissertation ends with the *Conclusion*, which summarises the answers to the research questions and discusses the main contribution of the work. The *Résumé* provides an extended summary in Slovak. The *Technical annex* documents selected modelling procedures and estimated equations, including wage equations, the disability pension module, the survivor pension module and the calculation of old age pension awards and benefits. The *References* section lists the sources used in the dissertation. Together, these parts provide both the substantive interpretation of the results and the technical documentation needed to understand how the pension module was constructed.

## 5. Results of the Work

The empirical part of the dissertation evaluates whether the developed pension module can be used to assess the sustainability and adequacy of the Slovak pension system. The results are presented in several steps. First, the model is compared with the medium-term pension forecast prepared for the Committee for Tax Forecasts. Second, long-term pension expenditure and revenues are compared with the Slovak Pension Model, SLOPEM, used in the Ageing Report framework. Third, the balance of the pension system is evaluated. Fourth, adequacy and distributional indicators are analysed. Finally, selected policy scenarios are used to illustrate how the model reacts to changes in pension rules.

The first part of the empirical analysis focuses on the nowcasting and medium-term validation of the model. This step is important because the pension module starts from the base year and then simulates pension outcomes forward. Before using the model for long-term projections, it is necessary to verify whether it produces plausible short- and medium-term results. The comparison is made against the pension forecast prepared for the Committee for Tax Forecasts, which represents the relevant official projections in the state budget. The comparison includes the main pension categories modelled in SLAMM: old age pensions, early old age pensions, disability pensions and survivor pensions.

The results show that the model produces pension developments that are broadly comparable with the official medium-term forecast. In the case of old age pensions, the simulated number of pensioners and average benefits follow a trajectory close to the benchmark. This is important because old age pensions represent the largest expenditure category and therefore dominate total pension expenditure. The results for newly awarded old age pensions are also broadly consistent with observed and forecasted values, although some differences arise from the treatment of recent inflation shocks and from the calibration of newly awarded benefits.

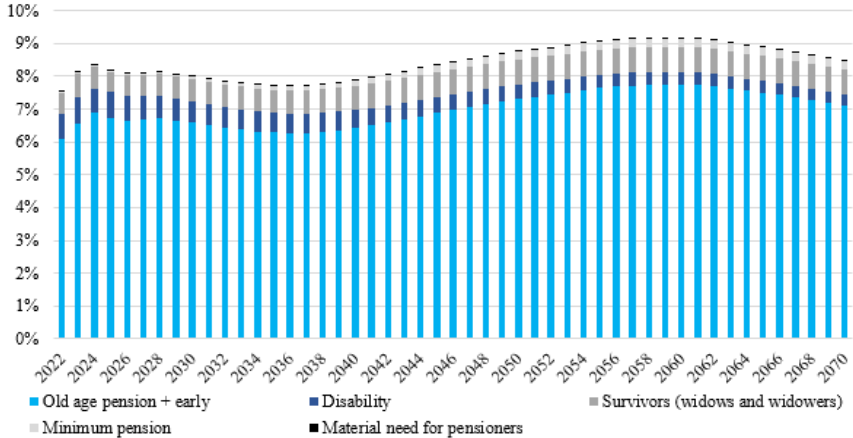
Early old age pensions are more difficult to reproduce because their development was affected by recent legislative changes and by a temporary macroeconomic shock. The model captures the general importance of this category and are valid in a stable environment, but the exact short-term dynamics vary due to inflationary increase in the average benefit and a wave of new pensioners caused by it. Disability pensions and survivor pensions also show larger differences than old age pensions. These differences reflect both data limitations and the fact that these

benefit categories are modelled through simplified procedures. Nevertheless, the medium-term validation suggests that the pension module is sufficiently aligned with official projections to be used for long-term sustainability and adequacy analysis.

The comparison with the Committee for Tax Forecasts should not be interpreted as a comparison of identical models. The official forecast is designed for short- and medium-term budgetary purposes and is based on administrative aggregates, observed data and expert assumptions. SLAMM is a dynamic microsimulation model that starts from individual simulated records and applies pension rules to individual histories. A perfect match is therefore neither expected nor required. The purpose of the comparison is to assess whether the model produces plausible pension dynamics in the period for which official data and forecasts are available. The results support the use of SLAMM as a complementary analytical tool.

The second part of the results evaluates the long-term expenditure projection. The main benchmark is SLOPEM, which is used for the Slovak pension expenditure projection in the Ageing Report framework. SLOPEM is a cohort-component model designed for official long-term projections under common European assumptions. SLAMM follows a different modelling logic. It simulates individuals and applies pension rules to their simulated labour market and pension histories. The comparison therefore evaluates not only whether the expenditure path is numerically similar, but also whether the differences between the models can be explained by methodological and institutional assumptions.

**Graph 3: Decomposition of pension expenditure projection(% GDP)**



Source: SLAMM

The long-term projection shows that pension expenditure increases gradually over the projection horizon, mainly due to population ageing and the rising number of pension beneficiaries. Old age and early old age pensions represent the dominant expenditure category. This is expected, as they cover the largest group of pensioners and are directly affected by demographic ageing, retirement age rules, wage growth, pension indexation and the current pension point value. Other categories, such as disability pensions, survivor pensions, minimum pensions and material need benefits in old age, have a smaller but important role.

The decomposition of expenditure by pension type is one of the main advantages of the model. It shows how different components of the pension system contribute to the total expenditure path. Old age pensions drive the long-term development, while the contribution of disability and survivor pensions depends more strongly on modelling assumptions. The model also includes selected adequacy-oriented mechanisms, such as minimum pensions and material need benefits in old age. These components are smaller in expenditure terms, but important for understanding the adequacy function of the pension system.

**Table 1: Comparison of projected pension expenditure in SLAMM and SLOPEM, selected categories (% GDP)**

|                                              | 2022   | 2030   | 2040   | 2050   | 2060   | 2070   | Δ2022-70 |
|----------------------------------------------|--------|--------|--------|--------|--------|--------|----------|
| <b>SLAMM</b>                                 |        |        |        |        |        |        |          |
| Old age and early                            | 6.1%   | 6.6%   | 6.4%   | 7.3%   | 7.8%   | 7.1%   | 1.0%     |
| Disability                                   | 0.8%   | 0.7%   | 0.5%   | 0.4%   | 0.4%   | 0.4%   | -0.4%    |
| Widow's and widower's                        | 0.6%   | 0.7%   | 0.7%   | 0.8%   | 0.8%   | 0.8%   | 0.1%     |
| Minimum pensions                             | 0.1%   | 0.1%   | 0.2%   | 0.2%   | 0.2%   | 0.2%   | 0.2%     |
| Material need                                | 0.006% | 0.005% | 0.003% | 0.001% | 0.000% | 0.001% | -0.005%  |
| <b>SLOPEM</b>                                |        |        |        |        |        |        |          |
| Old age and early                            | 6.1%   | 7.2%   | 7.3%   | 7.8%   | 8.2%   | 7.5%   | 1.5%     |
| Disability                                   | 0.7%   | 1.1%   | 1.3%   | 1.3%   | 1.2%   | 1.3%   | 0.6%     |
| Widow's and widower's                        | 0.7%   | 0.8%   | 0.7%   | 0.7%   | 0.6%   | 0.5%   | -0.1%    |
| Minimum pensions                             | 0.1%   | 0.1%   | 0.4%   | 0.7%   | 0.8%   | 0.7%   | 0.7%     |
| Material need                                | 0.004% | 0.006% | 0.019% | 0.039% | 0.054% | 0.053% | 0.049%   |
| <b>Heatmap of differences (p. p. of GDP)</b> |        |        |        |        |        |        |          |
| Old age and early                            | 0.0    | -0.6   | -0.8   | -0.5   | -0.4   | -0.4   | -0.5     |
| Disability                                   | 0.0    | -0.4   | -0.7   | -0.8   | -0.9   | -0.9   | -1.0     |
| Widow's and widower's                        | -0.1   | -0.1   | 0.0    | 0.1    | 0.2    | 0.2    | 0.3      |
| Minimum pensions                             | 0.0    | -0.1   | -0.2   | -0.4   | -0.6   | -0.5   | -0.5     |
| Material need                                | 0.0    | 0.0    | 0.0    | 0.0    | -0.1   | -0.1   | -0.1     |

Source: Ageing Report 2024; SLAMM

This methodological difference is visible already in the starting point of the projection. SLOPEM models pension expenditure directly at the aggregate level and calibrates the first year to observed expenditure. SLAMM, on the other hand, calibrates the number of recipients and

benefit levels in the first year as accurately as allowed by the initial individual level data. Since the model must assign pensions to individuals, reconstruct pension histories and map existing benefit amounts, a small discrepancy in the initial level of expenditure is unavoidable. The difference is, however, limited. In the base year, the main expenditure categories in SLAMM are close to the SLOPEM values, which indicates that the microsimulation model is reasonably well anchored to the aggregate starting point.

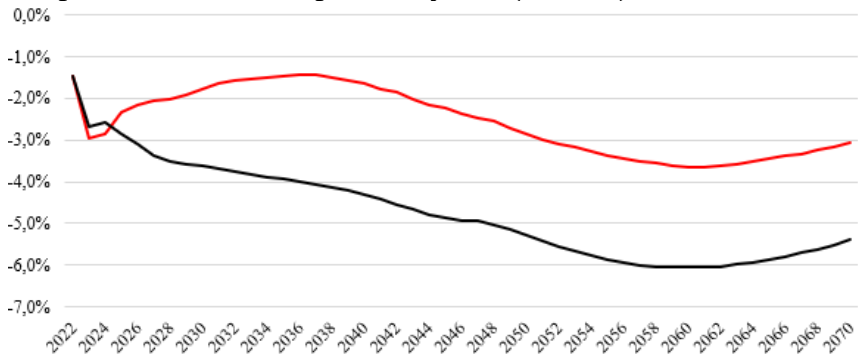
The comparison with SLOPEM shows that SLAMM produces broadly comparable results for the largest expenditure category, old age and early old age pensions. This is the most important result for the assessment of long-term sustainability, because these pensions dominate total pension expenditure. Differences between the models are larger for disability pensions, survivor pensions and minimum income mechanisms. These differences are not random. They follow from specific modelling choices, such as the treatment of disability pensioners reaching retirement age, the modelling of survivor pension concurrence, the coverage of minimum income components and the classification of benefit categories.

The results therefore suggest that the microsimulation model is sufficiently reliable for long-term sustainability analysis at the level of broad expenditure categories. At the same time, it does not mechanically reproduce SLOPEM, and exact equality should not be expected. SLOPEM remains the official model for Ageing Report projections, because it is designed for aggregate comparability under common European assumptions. SLAMM provides a complementary projection that is anchored in the same institutional environment but follows individual-level histories and benefit calculations. Its value lies not only in reproducing the aggregate expenditure path, but also in explaining how this expenditure emerges from individual transitions, pension entitlements and benefit interactions.

The third part of the results focuses on the revenue side and on the balance of the pension system. Revenues are modelled through pension contribution rates applied to simulated labour income. The dissertation distinguishes between contributions including and excluding the second pillar, because part of old age insurance contributions is redirected to individual pension savings accounts. This distinction is important for evaluating the public pension balance. In the short and medium term, the second pillar reduces revenues of the first pillar, while the corresponding reduction in first pillar pension expenditure appears only gradually as second-pillar savers retire.

The comparison of contribution revenues shows that the difference between SLAMM and SLOPEM depends strongly on labour market assumptions. Under the baseline SLAMM setting, the number of contributors and contribution revenues differ from the Ageing Report assumptions. For this reason, the dissertation also evaluates an alternative employment scenario closer to the Ageing Report framework. This comparison shows that projected revenues are sensitive not only to contribution rates and wage growth, but also to the number of contributors and the assumed labour market development. This is important because the sustainability of the pension system depends jointly on expenditure and revenues.

**Graph 4: Balance of the pension system (% GDP)**



Source: Ageing Report 2024; SLAMM

The balance of the pension system is defined as contribution revenues minus pension expenditure. The results show that the Slovak pension system remains structurally deficit-generating over the long term. Under SLAMM assumptions, the projected balance is more favourable than in SLOPEM, mainly due to differences in labour market assumptions and in the expenditure categories included in the comparison. However, the deficit is not eliminated. The main conclusion is therefore not that the sustainability problem disappears in the microsimulation model, but that its estimated magnitude depends on assumptions about employment, contribution revenues, benefit categories and the treatment of non-modelled pension expenditure.

This result is important for the interpretation of the model. SLAMM should not be seen as producing a more optimistic or more pessimistic projection by definition. Rather, it provides an alternative modelling framework in which the fiscal balance can be connected to individual pension histories. The model can therefore be used to assess

not only whether the pension system is projected to generate deficits, but also which pension rules and individual trajectories contribute to expenditure and adequacy outcomes.

The next part of the results evaluates pension adequacy. The dissertation uses two main aggregate indicators: the benefit ratio and the replacement rate. The benefit ratio compares the average pension benefit with the average wage in the economy. It measures the relative position of pensioners compared with the working age population. The replacement rate compares the pension benefit with previous earnings and therefore reflects the extent to which the pension system replaces income after retirement. Both indicators are important, but they capture different dimensions of adequacy.

**Table 2: Comparison of old age pension adequacy indicators**

|                               | 2022 | 2030  | 2040  | 2050  | 2060  | 2070  | Δ2022-70 |
|-------------------------------|------|-------|-------|-------|-------|-------|----------|
| <b>SLAMM</b>                  |      |       |       |       |       |       |          |
| Benefit ratio                 | 0.39 | 0.39  | 0.33  | 0.32  | 0.31  | 0.30  | -0.09    |
| Replacement rate              | 0.43 | 0.53  | 0.57  | 0.56  | 0.51  | 0.58  | 0.15     |
| <b>SLOPEM</b>                 |      |       |       |       |       |       |          |
| Benefit ratio                 | 0.38 | 0.39  | 0.35  | 0.33  | 0.33  | 0.33  | -0.05    |
| Replacement rate              | 0.41 | 0.44  | 0.43  | 0.44  | 0.45  | 0.46  | 0.05     |
| <b>Heatmap of differences</b> |      |       |       |       |       |       |          |
| Benefit ratio                 | 0.01 | -0.01 | -0.02 | -0.01 | -0.02 | -0.03 | -0.04    |
| Replacement rate              | 0.03 | 0.08  | 0.14  | 0.12  | 0.06  | 0.13  | 0.10     |

*Source: Ageing Report 2024; SLAMM*

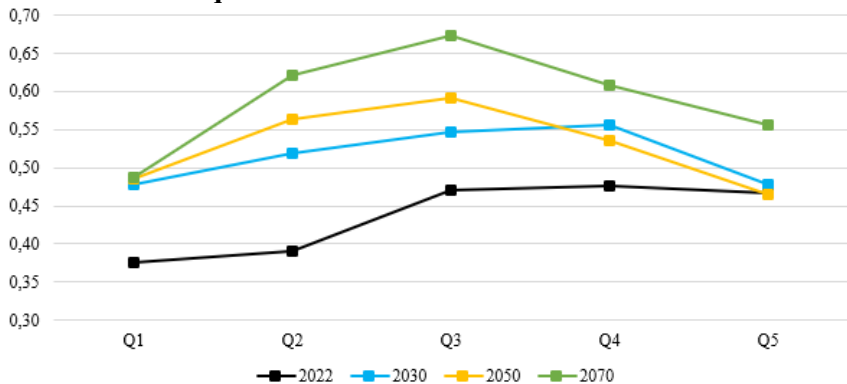
The comparison of adequacy indicators shows that SLAMM produces values broadly consistent with SLOPEM at the aggregate level. This result supports the validity of the model for analysing adequacy. However, the main added value of microsimulation is not the aggregate value of the benefit ratio or replacement rate itself. Aggregate adequacy indicators can also be produced by cohort models. The key advantage of SLAMM is that the same indicators can be calculated for different groups of individuals and linked to their simulated labour market histories.

The analysis therefore decomposes adequacy indicators by sex and age. The results show that pension adequacy differs between men and women, reflecting differences in employment histories, earnings profiles, career interruptions and retirement age rules. Women typically have lower pension levels due to lower lifetime earnings and more frequent career interruptions, but the effect on replacement rates may differ depending on the interaction between earnings histories, redistributive elements of the pension formula and minimum income mechanisms. The analysis by age also shows that the relative position of pensioners changes

over time. Older pensioners may fall behind newly retired cohorts if pensions in payment are indexed differently from newly awarded pensions.

The distributional analysis extends this perspective further by examining pension outcomes by lifetime-income group. This part directly demonstrates the added value of the microsimulation model. Since each simulated individual has a labour market and earnings history, the model can assign individuals to income groups and evaluate how pension rules affect them. The dissertation uses several distributional indicators, including inequality measures for pension income and adequacy indicators by income quintile.

**Graph 5: Median replacement rate of new old age pensions by lifetime-income quintile**



Source: SLAMM

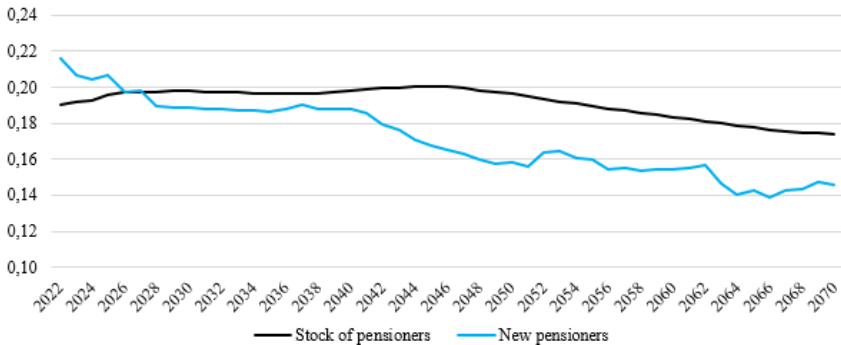
The results show that replacement rates are higher for lower-income groups and lower for higher-income groups. This reflects the redistributive design of the Slovak first pillar. The pension formula is earnings-related, but it includes solidarity elements that increase the relative pension entitlements of low earners and limit the proportionality of benefits for high earners. As a result, low-income individuals may receive lower pensions in absolute terms, but their pensions replace a larger share of previous earnings. High-income individuals receive higher pensions in absolute terms, but their replacement rates are lower.

At the same time, the distributional analysis shows that adequacy risks are not fully eliminated. Individuals with low or interrupted careers may still have low pension entitlements, especially if they do not meet the qualifying conditions for minimum income protection. The model can identify these groups more directly than an aggregate projection model,

because it follows individual histories rather than representative cohorts. This is particularly useful for evaluating policy measures that affect specific groups, such as women, low earners, second pillar savers, early retirees or persons with disability histories.

The dissertation also analyses inequality in pension income using indicators such as the Gini coefficient and the P90/P10 ratio. The results indicate that the Slovak pension system compresses pension income inequality relative to lifetime earnings inequality. This is consistent with the redistributive elements of the benefit formula. However, the level of inequality differs between newly awarded pensions and the total stock of pensions. Newly awarded pensions reflect current pension rules and current earnings histories more directly, while the total pension stock also reflects past legislation, indexation, mortality and cohort composition. This distinction is important because policy changes affect new retirees first and only gradually change the whole pensioner population.

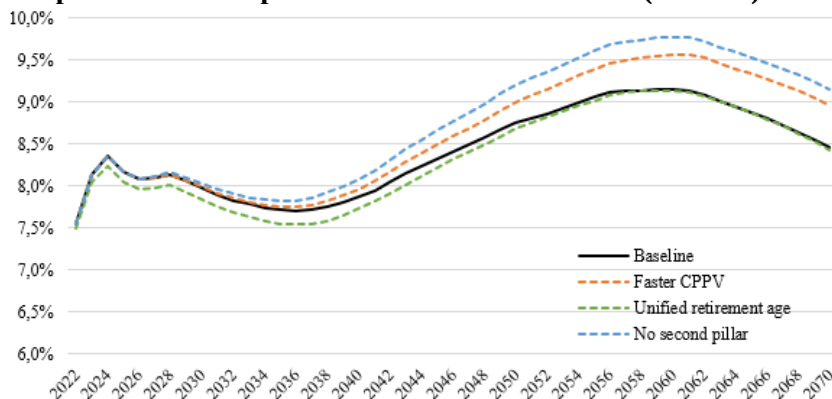
**Graph 6: Gini coefficient of newly awarded and total old age pension income**



Source: SLAMM

The final part of the empirical analysis uses alternative policy scenarios. The scenarios are not intended to represent complete reform proposals. They are stylised changes in selected parameters of the pension system. Their purpose is to illustrate how the pension module reacts to changes in institutional rules and how these changes affect expenditure and adequacy outcomes. The dissertation analyses scenarios involving faster growth of the current pension point value, the absence of the second pillar and a unified retirement age for men and women.

**Graph 7: Pension expenditure under alt. scenarios (% GDP)**



Source: SLAMM

The scenario with faster growth of the current pension point value increases newly awarded pensions. This improves adequacy for future retirees but gradually increases pension expenditure as more cohorts retire under the more generous rule. The effect grows over time because each newly awarded cohort enters the stock of pensions with a higher initial benefit. This scenario illustrates the tension between adequacy and sustainability. More generous indexation of new pension awards can improve replacement rates, but it also creates additional long-term expenditure pressure.

The scenario without the second pillar removes the reduction of first pillar pensions for second pillar savers. In the expenditure projection, this produces the highest pension expenditure path among the analysed scenarios. This result is expected because individuals who would otherwise receive a reduced first pillar pension receive the full first pillar benefit. However, the interpretation of this scenario must be cautious. It focuses on the first pillar and does not fully evaluate the loss of funded pension income from the second pillar. It is therefore an analytical experiment, not a complete assessment of whether the second pillar should or should not exist.

The unified retirement age scenario affects pension outcomes through retirement timing. In the Slovak system, reductions in retirement age related to the number of raised children still affect women. Removing these differences changes the timing of retirement and the length of the contribution career for affected groups. The aggregate effect on

expenditure is smaller than in the scenarios related to the current pension point value or the second pillar, but the distributional effect is important. Women are affected more directly, and the scenario changes both pension expenditure and adequacy outcomes for this group.

The scenario analysis confirms that SLAMM can translate institutional changes into both aggregate and individual outcomes. This is one of the most important methodological findings of the dissertation. Aggregate models can evaluate the expenditure effect of policy changes, but a dynamic microsimulation model can also identify how the same change affects different individuals. The expenditure path provides information on sustainability, while individual-level outputs provide information on adequacy and distributional effects.

Overall, the results support the main research question of the dissertation. The pension module developed within SLAMM can be used to assess the sustainability and adequacy of the Slovak pension system. It produces aggregate expenditure projections that are broadly comparable with existing official projection tools for the main pension categories. It also produces adequacy indicators that can be compared with SLOPEM at the aggregate level. Most importantly, the model provides additional information on heterogeneity across individuals and population groups.

The results also clarify the complementary role of microsimulation. The model should not be interpreted as a replacement for the official SLOPEM model or for the Committee for Tax Forecasts forecast. These tools remain essential for official aggregate projections and budgetary purposes. The contribution of SLAMM lies in extending the analysis to individual pension entitlements, distributional outcomes and scenario-based assessment. This makes it particularly useful for analysing pension rules whose effects depend on individual histories, such as lifetime earnings, contribution periods, participation in the second pillar, early retirement, disability transitions, survivor pension concurrence and minimum income protection.

The dissertation therefore shows that sustainability and adequacy can be analysed within the same modelling framework. Pension expenditure, contribution revenues and system balance are calculated from the same individual records as pension levels, replacement rates and distributional indicators. This creates a direct connection between the fiscal and social dimensions of the pension system. A policy change can be evaluated not only by its effect on total expenditure, but also by its

effect on different groups of pensioners. This is the main added value of the developed pension module.

The empirical results also identify several limitations. Some benefit categories are more difficult to model than others, especially disability pensions, survivor pensions and minimum income mechanisms. The results for these categories are sensitive to data availability and to assumptions about transitions and eligibility. The second pillar is represented primarily through its effect on first pillar pension reductions, while the full funded pension income is not modelled in detail. Minimum pension eligibility is also simplified, especially for current pensioners, due to missing information on qualified contribution periods. These limitations should be considered when interpreting the results.

Despite these limitations, the dissertation demonstrates that dynamic microsimulation is a useful approach for analysing the Slovak pension system. The model produces plausible aggregate projections and, at the same time, offers analytical outputs that are not available in standard aggregate models. It can therefore complement existing official projection tools and support a more detailed assessment of pension sustainability, adequacy and distributional effects.

## 6. Conclusion

The dissertation demonstrates that the sustainability and adequacy of the Slovak pension system can be assessed using a dynamic microsimulation model. By extending the Slovak Labour Market Model with a pension module, the dissertation creates a framework that links individual labour market histories with the institutional rules of the Slovak pension system. This makes it possible to analyse pension expenditure, revenues and system balance, while also evaluating pension adequacy and distributional outcomes at the individual level.

The results show that the developed model produces aggregate pension expenditure projections that are broadly comparable with existing official projection tools, especially for the main pension categories. At the same time, the model provides additional analytical value by allowing pension outcomes to be evaluated across individuals and population groups.

The main contribution of the dissertation is therefore not the replacement of existing aggregate models, but their extension by an individual-level perspective. The microsimulation approach complements the Slovak Pension Model used in the Ageing Report framework and the medium-term pension forecast used for budgetary purposes. It is especially useful for analysing policy questions where the effects of pension rules differ across income groups, between men and women, or across different pension trajectories.

The current version of the model also has limitations. Some pension categories, especially disability pensions, survivor pensions and minimum income mechanisms, are modelled in a simplified way due to data limitations. The second pillar is represented mainly through its effect on first pillar pensions, while funded pension income is not modelled in full detail. These limitations create space for future development, especially through better administrative data, more detailed modelling of pension transitions and a fuller treatment of funded pension savings.

Overall, the dissertation shows that dynamic microsimulation is a useful tool for analysing the Slovak pension system. It allows the assessment of long-term sustainability, pension adequacy and distributional effects within one consistent framework and can therefore support more detailed evaluation of future pension policy reforms.

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## 9. Summary

Population ageing creates long-term pressure on public finances and makes the pension system one of the key areas of fiscal and social policy in Slovakia. Since pensions are the main source of income in old age, pension policy must be assessed not only from the perspective of expenditure and fiscal balance, but also from the perspective of benefit adequacy and distributional outcomes. This dissertation therefore focuses on modelling the sustainability and adequacy of the Slovak pension system using a dynamic microsimulation approach.

The work extends the Slovak Labour Market Model (SLAMM) with a pension module. The module links simulated labour market histories with the institutional rules of the Slovak pension system and calculates old age, early old age, disability and survivor pensions, as well as selected minimum income mechanisms. It reconstructs missing pension-relevant histories retrospectively and simulates future pension entitlements prospectively.

The results show that the developed model produces aggregate pension expenditure projections broadly comparable with existing official projection tools, especially for the main pension categories. The model is compared with the medium-term forecast of the Committee for Tax Forecasts and with the long-term projections of SLOPEM used in the Ageing Report. Its main added value lies in the ability to evaluate pension adequacy and distributional effects at the individual level.

Overall, the dissertation shows that dynamic microsimulation can complement existing aggregate pension models by linking sustainability, adequacy and heterogeneity within one consistent framework. It therefore provides a useful analytical tool for evaluating future pension policy reforms in Slovakia.

## 10. Extended Abstract in the Slovak Language

Dizertačná práca sa zaoberá modelovaním udržateľnosti a adekvátnosti dôchodkového systému na Slovensku pomocou dynamického mikrosimulačného modelu. Slovenský dôchodkový systém čelí výrazným demografickým tlakom, ktoré súvisia so starnutím populácie, predlžovaním strednej dĺžky života a postupnou zmenou pomeru medzi počtom prispievateľov a poberateľov dôchodkov. Z pohľadu verejných financií patrí dôchodkový systém medzi najdôležitejšie výdavkové oblasti citlivé na demografický vývoj. Zároveň však dôchodky predstavujú hlavný zdroj príjmu v starobe, a preto je potrebné hodnotiť nielen ich dlhodobú finančnú udržateľnosť, ale aj adekvátnosť poskytovaných dávok.

Cieľom práce je posúdiť, do akej miery možno slovenský dôchodkový systém hodnotiť pomocou prístupu, ktorý ponúka dynamický mikrosimulačný model. Práca nadväzuje na existujúci Slovak Labour Market Model (SLAMM), vyvinutý v Ekonomickom ústave Slovenskej akadémie vied, a rozširuje ho o penzijný modul. Tento modul prepája príjmové histórie jednotlivcov vychádzajúce z ich simulovanej historickej kariéry s legislatívnym nastavením slovenského dôchodkového systému. Umožňuje tak analyzovať nielen agregátne dôchodkové výdavky, príjmy a saldo systému, ale aj individuálne dôchodkové nároky, mieru náhrady, podiel dávok a distribučné výsledky podľa vybraných skupín populácie.

Metodologicky práca kombinuje inštitucionálnu analýzu dôchodkových pravidiel, modelovanie príjmov ako osobných mzdových bodov, retrospektívnu rekonštrukciu chýbajúcich pracovných trajektórií a prospektívnu simuláciu budúcich dôchodkových dávok. Penzijný modul modeluje starobné dôchodky, predčasné starobné dôchodky, invalidné dôchodky, pozostalostné dôchodky (bez sirotských dôchodkov) a vybrané minimálne príjmové mechanizmy v starobe.

Empirická časť práce porovnáva výsledky modelu s existujúcimi oficiálnymi projekčnými nástrojmi. V krátkodobom a strednodobom horizonte sú výsledky porovnané s prognózou Výboru pre daňové prognózy. V dlhodobom horizonte je model porovnaný s projekciami modelu SLOPEM používaného v rámci Správy o starnutí (Ageing Report). Výsledky ukazujú, že vytvorený mikrosimulačný nástroj poskytuje stabilné a rádovo porovnateľné projekcie hlavných dôchodkových výdavkov. Najlepšia porovnateľnosť sa dosahuje pri starobných a predčasných starobných dôchodkoch, ktoré tvoria najväčšiu

časť dôchodkových výdavkov. Väčšie rozdiely sa objavujú pri invalidných a pozostalostných dôchodkoch, kde sú výsledky citlivejšie na dostupnosť údajov a na zjednodušenia použitých modelových postupov.

Práca zároveň ukazuje, že hlavná pridaná hodnota mikrosimulačného prístupu nespočíva v nahradení existujúcich agregátnych projekčných modelov, ale v ich doplnení o individuálnu a distribučnú perspektívu. Model umožňuje hodnotiť adekvátnosť dôchodkov podľa pohlavia, veku a príjmových skupín. Distribučná analýza ukazuje, že slovenský dôchodkový systém vďaka solidarizačným prvkom vo výpočte dôchodkovej dávky komprimuje rozdiely medzi dôchodkovými dávkami v porovnaní s rozdielmi v celoživotných príjmoch. Nízkopríjmové skupiny dosahujú relatívne vyššie miery náhrady, zatiaľ čo vysokopríjmové skupiny majú vyššie dôchodky v absolútnej hodnote, ale nižšie miery náhrady.

Súčasťou práce je aj analýza alternatívnych scenárov vybraných legislatívnych nastavení. Analyzované sú scenáre rýchlejšieho rastu aktuálnej dôchodkovej hodnoty, odstránenia druhého piliera a zjednotenia dôchodkového veku mužov a žien. Výsledky ukazujú, že mikrosimulačný model dokáže konzistentne premietiť zmeny parametrov dôchodkového systému do výdavkových, príjmových a adekvátnostných ukazovateľov. Scenáre zároveň ilustrujú napätie medzi udržateľnosťou a adekvátnosťou: opatrenia zvyšujúce dôchodkové dávky môžu zlepšiť príjmovú situáciu dôchodcov, ale vytvárajú dodatočný tlak na dlhodobé výdavky systému.

Záverom možno konštatovať, že dynamická mikrosimulácia predstavuje vhodný doplnkový nástroj na hodnotenie slovenského dôchodkového systému. Umožňuje analyzovať dlhodobú udržateľnosť, adekvátnosť a distribučné dôsledky dôchodkových pravidiel v jednom konzistentnom modelovom rámci. Práca zároveň identifikuje obmedzenia súčasnej verzie modelu, najmä pri modelovaní invalidných a pozostalostných dôchodkov, minimálnych príjmových mechanizmov a plného príjmu z druhého piliera. Napriek týmto obmedzeniam model poskytuje analytický základ pre podrobnejšie hodnotenie budúcich dôchodkových reforiem a ich dopadov na verejné financie aj na jednotlivcov.