



SSE RIGA

Bachelor Thesis

**Demographic Decline and Pension Adequacy:
The Impact of Probabilistic Fertility and Migration
Outlooks in Latvia**

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Table of Contents

Abstract	3
1. Introduction	4
2. Literature Review	6
2.1. Latvia's Demographic History and Outlook.....	6
2.2. Core Demographic Metrics: TFR and NMR.....	6
2.3. Pension System Structure and Adequacy in Latvia.....	7
2.4. Probabilistic Demographic Inputs and Pension Outcomes.....	9
2.5. Research Questions and Hypotheses	13
2.6. Probabilistic Demographic Outlooks for Pension Analysis	14
2.7. Expected Contribution	15
2.8. Summary	16
3. Methodology	18
3.1. Demographic Projection Framework	18
3.2. Data for the Demographic Model.....	20
3.3. Structure and Assumptions of the Demographic Model	20
3.4. Pension Accumulation Framework	22
3.5. Data for the Pension Model	24
3.6. Structure and Assumptions of the Pension Model.....	25
3.7. Limitations of the Demographic and Pension Models.....	27
3.8. Summary	30
4. Analysis of Results and Discussion	31
4.1. Net Migration Rate Outlooks.....	31
4.2. Total Fertility Rate Outlooks	36
4.3. Answers to the Research Questions and Evaluation of the Hypotheses.....	40
4.4. NMR Intervention Scenarios.....	41
4.5. TFR Intervention Scenarios.....	44
5. Conclusion.....	48
6. References	50
7. Appendices.....	56
Appendix A. Historical Evidence on Chosen Assumptions in the Demographic and Pension Models	56
Appendix B. Summary of Assumptions Used in the Final Model Results.....	56

Abstract

Latvia faces persistent demographic decline driven by low fertility, sustained emigration, and a shrinking working-age population, increasing pressure on pension adequacy in a system whose first pillar depends closely on the contributor base. This thesis addresses a gap in the literature by linking probabilistic demographic uncertainty directly to pension adequacy in Latvia, focusing on how variation in the total fertility rate (TFR) and net migration rate (NMR) shapes future pension replacement rates.

The thesis develops a transparent partial equilibrium framework combining demographic projections with a pension capital accumulation model. United Nations probabilistic projections are used to analyse fertility and migration separately, while stylized intervention scenarios based on approximated Eurostat baseline trajectories are used to test the sensitivity of pension adequacy to demographic change.

The results show that migration affects pension adequacy mainly in the short and medium term, while fertility matters primarily in the long run. Within the central 80% probability interval, migration uncertainty produces large differences in future population size but a relatively narrow range of long-run replacement rate outcomes, whereas fertility uncertainty produces only negligible adequacy differences over the coming decades. Overall, demographic improvements alone are unlikely to restore pension adequacy in Latvia without complementary pension-system adjustments.

1. Introduction

Population ageing and demographic decline are increasingly shaping the adequacy of pension systems across developed economies. Latvia represents a particularly relevant case, as it has experienced persistently low fertility, substantial emigration, and a shrinking working-age population. These demographic trends place pressure on contribution-based pension systems, especially the first pillar, where benefits depend directly on the size and productivity of the contributor base. This is particularly important in Latvia, since its first pillar follows a notional defined contribution structure, a design used only in a limited number of countries rather than being the global norm. As a result, concerns about future pension adequacy have become central to both academic research and policy discussions.

This thesis examines how Latvia's pension adequacy develops under different probabilistic outlooks for the net migration rate (NMR) and total fertility rate (TFR). Using probabilistic demographic projections within a transparent partial equilibrium pension modelling framework, it traces how alternative demographic trajectories affect population and pension replacement rate outcomes. In doing so, the study is both explanatory and evaluative, explaining how fertility and migration shape pension outcomes while assessing what those outcomes imply for the adequacy of future retirement income.

While existing studies often rely on deterministic scenarios or standardized demographic projections, relatively little research directly connects probabilistic demographic uncertainty to pension adequacy, especially in Latvia. This thesis addresses that gap through a transparent framework combining probabilistic fertility and migration outlooks with a pension capital accumulation model, making it possible to trace how demographic uncertainty feeds through population dynamics and the contributor base into replacement rate outcomes. The probabilistic approach also adds value by distinguishing more plausible paths from more extreme outcomes and by showing how different demographic variables matter for pension adequacy across time horizons.

The framework developed in this thesis is relevant for both research and policy. It provides a transparent way to connect demographic uncertainty with pension adequacy outcomes in Latvia and helps clarify which demographic channels matter most for future adequacy. Its practical relevance is illustrated by the fact that a version of the pension model developed in this thesis, together with its demographic component, is currently used by the Bank of Latvia to analyse how changes in

underlying assumptions, including but not limited to demographic factors, may influence future pension outcomes.

At the same time, the analysis should be interpreted with several limitations in mind. The models rely on simplifying assumptions regarding demographic behaviour, labour-market dynamics, and institutional rules of the pension system. Moreover, the projections assume that the overall structure of Latvia's pension system remains unchanged over the projection horizon. Pension reforms, economic developments, and policy interventions may alter the system in ways that are not captured by the model. The results should therefore be interpreted not as precise forecasts but as a tool for understanding the mechanisms through which demographic change can influence pension adequacy.

The remainder of the thesis is structured as follows. Section 2 reviews the relevant literature on demographic change, pension system design, and probabilistic demographic projections, and formulates the research questions and hypotheses. Section 3 presents the methodology, describing the demographic and pension models, the data used, and their main assumptions and limitations. Section 4 provides analysis of results and discussion, examining fertility and migration outlooks, evaluating their impact on pension adequacy, and addressing the research questions and hypotheses. Section 5 concludes.

2. Literature Review

2.1. Latvia's Demographic History and Outlook

Latvia's demographic decline reflects both historical disruption and more recent structural change. Earlier population shocks related to war, occupation, and forced migration helped establish migration as a persistent demographic force in Latvia (Hazans, 2019; Zvidrins, 2021). Since independence, however, demographic contraction has been driven primarily by sustained low fertility and net emigration.

Fertility declined as part of the broader Second Demographic Transition in Europe, keeping Latvia's total fertility rate persistently below replacement level (Varpina, 2018). At the same time, Latvia's joining of the EU in 2004 accelerated emigration, particularly among young and working-age individuals, and the 2008 financial crisis reinforced more permanent emigration patterns (Hazans, 2019; Zvidrins, 2021). Together, these trends have reduced the working-age population and intensified population ageing.

Forward-looking evidence suggests that these demographic pressures will persist. Fertility is projected to rise only modestly, from 1.53 in 2022 to around 1.70 by 2070, remaining well below the fertility replacement level throughout the projection horizon (European Commission, 2024, Statistical Annex - Latvia). Because fertility affects the labour force only with a long delay, even an improvement in birth rates would take decades to strengthen the contributor base (World Bank, 2015).

Migration poses a more immediate challenge. Persistent net emigration has disproportionately reduced the number of young and working-age contributors, weakening the financing base of social protection systems (World Bank, 2015). As a result, Latvia's old-age dependency ratio is projected to increase from 36% in 2022 to 59% by 2050 (European Commission, 2024, Statistical Annex - Latvia). These demographic trends are especially important in a country where old-age poverty is already high, with Latvia recording the second-highest rate among OECD countries at 27% (OECD, 2018, p. 40). Taken together, low fertility and sustained emigration point to continuing demographic pressure on the adequacy of Latvia's pension system.

2.2. Core Demographic Metrics: TFR and NMR

The two key demographic indicators used in this thesis are the total fertility rate and the net migration rate. Together, they capture the main drivers of population change and therefore form the core demographic inputs for evaluating Latvia's future pension adequacy.

The Total Fertility Rate represents the average number of children a woman would have over her lifetime if current age-specific fertility rates remained constant and women did not die during their reproductive years (UN, 2024b, p. 63). In the context of this thesis, TFR is important because it determines the long-term size of future working-age cohorts and thus shapes the contributor base of the pension system over time.

The Net Migration Rate, referred to by the United Nations as the Crude Net Migration Rate, measures the number of immigrants minus emigrants per 1,000 inhabitants in a year (UN, 2024b, p. 58). In this thesis, NMR is expressed as a percentage of the population, that is, per 100 inhabitants. Unlike fertility, migration affects total population size immediately, but its effect on pension adequacy is stronger in the short term when migrants are predominantly of working age, since this more quickly changes the size of the contributor base.

Because TFR and NMR influence population dynamics through different channels and over different time horizons, they provide the most relevant basis for analysing how demographic change translates into pension adequacy outcomes in Latvia. For this reason, the demographic model developed in this thesis focuses specifically on variation in these two indicators, while other demographic factors are held constant or treated as background assumptions. This approach makes it possible to isolate the distinct effects of fertility and migration on future pension adequacy.

2.3. Pension System Structure and Adequacy in Latvia

Pension systems are commonly assessed through two related dimensions: adequacy and financial sustainability. In this thesis, the primary focus is on adequacy, which Holzmann and Hinz (2005, p. 55–56) define in terms of a pension system's ability to prevent old-age poverty and support a basic standard of living after retirement. In the same discussion, they suggest a benchmark net replacement rate of around 40% of pre-retirement earnings as sufficient for basic consumption smoothing and poverty prevention. However, this benchmark should be interpreted cautiously, since adequacy depends not only on the replacement rate itself but also on wage levels, pension and wage taxation, household needs, and the broader cost of living. At the same time, adequacy cannot be fully separated from financial sustainability, since higher benefits require greater financing capacity. Measures aimed at improving financial sustainability often work by restraining or reducing benefits (Holzmann & Hinz, 2005, p. 56–57).

In this context, the replacement rate refers to the extent to which pension income replaces pre-retirement earnings. The gross replacement rate is typically understood as the ratio of the average initial pension received by those retiring in a given year to the average wage at retirement, before accounting for taxes and other deductions (Stabina & Fromholde, 2023, p. 19). By contrast, a net replacement rate compares pension income and earnings after taxes. Because pensions are generally taxed less than wages, net replacement rates are typically higher than gross replacement rates. In this thesis, all replacement rate results are presented as gross replacement rates unless stated otherwise. Furthermore, replacement rates serve as the main indicator of adequacy for this study, although their specific advantages and limitations are discussed later in the literature review.

Latvia's public pension system has a three-pillar structure. The first pillar is a mandatory pay-as-you-go (PAYG) notional defined contribution (NDC) scheme. The second pillar is a mandatory funded defined-contribution scheme. The third pillar consists of voluntary private retirement savings (Stabina & Fromholde, 2023, p. 6). The first pillar is particularly important in this thesis because, unlike many traditional public pension arrangements in developed economies, it does not operate as a classic defined-benefit system. Instead, it records individual contributions in notional accounts and links pension benefits to lifetime contributions (Barr & Diamond, 2009, p. 8), while pension capital is indexed to the size of the contributor base. Although overall retirement income depends on all three pillars combined, this makes the first-pillar especially important for analysing how fertility and migration affect pension adequacy.

Existing evidence suggests that Latvia's pension system already faces significant adequacy challenges. OECD (2018, p. 40) evidence shows that Latvia has the second-highest old-age poverty rate among OECD countries, while the World Bank (2015, p. 125) reports that 12.3% of pension recipients have pensions below the poverty line and that 36% of people aged 65 and over are at risk of poverty or social exclusion. Forward-looking projections point in the same direction: although the gross replacement rate at retirement was 56% in 2022, it is projected to decline to 28% by 2040, implying a substantial weakening of retirement income protection (Stabina & Fromholde, 2023, Table 9). At the same time, the pension system dependency ratio is expected to rise from 0.6 in 2022 to 1.0 pensioners per employed person by 2060, indicating growing pressure on the contributor base that supports public pensions (Stabina & Fromholde, 2023, Table 10).

Taken together, this literature suggests that Latvia's pension adequacy is already under pressure and is likely to weaken further as demographic ageing continues. For the purposes of this thesis, the key question is therefore not whether

demographics matter for pension outcomes, but how changes in fertility and migration translate into adequacy outcomes within a pension system whose first pillar is closely tied to the size of both the contributor and beneficiary base. This, in turn, implies that the methodology must capture not only changes in total population size, but also how demographic developments affect the future contributor base that determines pension accumulation and adequacy.

2.4. Probabilistic Demographic Inputs and Pension Outcomes

This section identifies the main research gap addressed in this thesis. Pension outcomes depend on long-term changes in population structure, which makes them highly sensitive to assumptions about fertility, migration, and ageing. When such assumptions are selected arbitrarily, projected adequacy outcomes may reflect the modeler's choices more than plausible demographic developments. This issue is particularly relevant in Latvia, where demographic decline has been persistent and where standardized projection frameworks may not fully capture country-specific risks. In this context, the use of transparent and well-justified demographic outlooks becomes especially important.

Within the Latvia-specific literature reviewed for this thesis, we did not identify studies that link probabilistic demographic inputs directly to pension adequacy outcomes. Stabina and Fromholde (2023) provide a limited form of scenario analysis for Latvia by varying assumptions such as migration, fertility, and life expectancy in the context of public pension expenditure projections. However, this exercise is designed for a standardized European Commission reporting framework and does not provide a broader probabilistic assessment of pension adequacy. As a result, it does not fully address how demographic uncertainty may translate into adequacy outcomes in the Latvian case.

Although relatively few studies incorporate demographic uncertainty into pension analysis, international literature does provide several relevant examples. Notably, these studies vary in methodology but share a common justification for moving beyond deterministic high and low scenarios. Several authors argue that scenario-based approaches do not assign probabilities to outcomes and often bundle demographic assumptions into rigid "high" or "low" combinations that may not reflect realistic relationships between fertility, mortality, and migration. Therefore, they provide a weaker basis for evaluating long-run pension risk.

One group of studies models demographic uncertainty mainly through stochastic forecasting methods applied directly to demographic variables. Hardle and

Mysickova (2009), for example, develop a stochastic population forecast for Germany in which mortality is projected using the Lee-Carter method, while fertility is projected using a related stochastic approach. Migration is treated separately through immigration and emigration processes, with migrant age distributions estimated statistically. The resulting demographic forecasts are combined in a cohort-component population model. The authors justify this approach by arguing that deterministic scenarios cannot assign probabilities to outcomes and may generate inconsistent forecast ranges. In pension terms, their model does not focus primarily on pension adequacy but rather on the contribution rate required to maintain the current pension level and, alternatively, on the pension level that would result if the contribution rate is fixed. Their results show that demographic uncertainty widens over time and that the German PAYG pension system remains strongly exposed to ageing pressures.

Vanella et al. (2022) also analyze Germany, but with a different objective and modelling strategy, forecasting the future number of old-age and disability pension recipients. Their approach combines a fully probabilistic population forecast with age- and sex-specific pension receipt rates; uses Principal Component Analysis to identify the main patterns in historical pension receipt across age and sex; and applies time-series methods together with Monte Carlo simulation to generate probability ranges for future outcomes. The authors explicitly argue that probabilistic forecasting is valuable because it generates distributions of future outcomes rather than a limited set of deterministic scenarios with unknown likelihoods. At the same time, their core output remains the projected number and distribution of pension recipients, rather than adequacy metrics.

A second group of studies derives demographic uncertainty more explicitly from historical forecast errors and simulation-based population forecasting frameworks. Ahn et al. (2005) use the Alho and Spencer method in combination with the Program for Error Propagation (PEP) for stochastic population forecasting, generating predictive distributions of the future Spanish population by age and sex. In their framework, uncertainty in fertility, mortality, and migration is propagated through repeated cohort-component simulations. The authors explicitly criticize deterministic scenario methods for overriding the stochastic nature of demographic processes and for failing to show the probability range within which future population outcomes are likely to fall. Their pension outputs focus on contributors, pensioners, and pension expenditure, together with broader fiscal indicators.

Habermann and Fehr (2004) combine stochastic population forecasts generated with PEP with a model of the German economy. Their main contribution is to show how demographic uncertainty interacts with pension reform and how this affects

welfare and risk across generations, which is more closely related to the adequacy evaluation of this study. In particular, they compare alternative reform schemes and examine how they alter pension contribution rates, future pension benefit levels, and the distribution of demographic risk across cohorts. This makes the paper more relevant to adequacy-type questions than studies focused only on pension expenditure or the number of beneficiaries.

Lassila and Valkonen (2008) take a somewhat broader approach. They synthesize evidence from stochastic population simulations and discuss how demographic uncertainty should be incorporated into pension policy analysis. Methodologically, their focus is less on one specific pension model and more on what stochastic population projections reveal about long-run pension risk. Their central argument is that long-run pension projections are inherently highly uncertain and that this uncertainty is substantially larger than what is typically conveyed by deterministic high-low scenario variants. Drawing on country studies that use stochastic population projections, they show that demographic uncertainty alone can make long-term pension outcomes highly uncertain. They also argue that analysing the fiscal stability of pension systems requires a very long horizon, suggesting that 100 years should be regarded as a minimum. While seemingly a very long forecast, such a horizon should rather be considered as an extended risk simulation, than an unreliable forecast far away in the future. They emphasize that stochastic population projections are useful both for showing forecast errors in long-run demographic outcomes and for capturing demographic risk in pension systems. Their contribution is therefore mainly in clarifying why modelling uncertainty matters, rather than evaluating pension metrics.

Taken together, these studies show that modelling demographic uncertainty can provide a richer understanding of pension risk than deterministic scenario variants alone. At the same time, they also reveal a broader methodological difficulty: in one form or another, most of these approaches still rely on past variability, past forecast errors, or historically estimated stochastic processes as the basis for future uncertainty. This is a limitation in a country such as Latvia where demographic decline is structural and persistent. However, it is also difficult to avoid entirely. Long-run demographic forecasting necessarily requires some basis for assigning plausible future uncertainty, and historical patterns remain one of the most transparent and systematic foundations available for doing so. The central challenge, therefore, is not to remove this dependence completely, but to use it in a way that is credible, transparent, and appropriate to the research question.

A further limitation of the literature using probabilistic assessments is that the pension metrics used are not consistent across studies. This limits their comparability.

Given the diversity of pension indicators used in previous research, this thesis focuses on a single core metric: the gross replacement rate at retirement. In the remainder of this thesis, the term “replacement rate” refers to the gross replacement rate unless stated otherwise. This choice follows from the thesis objective, which is to assess adequacy rather than fiscal sustainability. The replacement rate directly captures the extent to which pension income replaces pre-retirement earnings and therefore provides a clear indicator of retirement income protection. Relative to expenditure-based or contribution-rate measures, it provides a more direct connection between demographic change and the adequacy of retirement income. The gross replacement rate is also more suitable for the present analysis than the net replacement rate, since incorporating taxation would add an additional layer of complexity while giving little additional value to this study.

At the same time, the replacement rate has important limitations. It is an average earnings-related measure and therefore does not show the distribution of pension outcomes across individuals. As a result, it cannot reveal inequality among pensioners, identify which groups face the lowest pension outcomes, or indicate how many retirees remain below the poverty line. A higher replacement rate also does not necessarily imply lower old-age poverty, since poverty depends on absolute pension levels, household composition, housing costs, other sources of income, taxation, and the poverty threshold used. Similarly, replacement rates cannot assess distributional adequacy, since they do not show whether pensions are sufficient for low-income workers, women, individuals with interrupted contribution histories, or other vulnerable groups. The measure also abstracts from differences in household needs, living costs, wealth, and non-pension income, all of which may affect actual living standards in retirement. In this thesis, replacement rates are therefore used only as an indicator of average pension adequacy and of the direction in which demographic change affects retirement-income replacement. They should not be interpreted as direct evidence of old-age poverty, pensioner inequality, or the adequacy of pensions for specific social groups.

In summary, the literature shows that incorporating demographic uncertainty can add important value to pension analysis, especially relative to purely deterministic high and low scenario approaches. At the same time, existing studies differ substantially in methodology, country context, and pension metrics, which limits their direct comparability and their applicability to Latvia. This creates a clear research gap. Latvia requires a transparent and context-appropriate framework that links probabilistic demographic inputs, particularly fertility and migration, to pension adequacy outcomes. Addressing this gap is the central contribution of this thesis.

2.5. Research Questions and Hypotheses

Latvia's demographic situation poses significant challenges to its pension system, particularly within the first pillar, which operates on a pay-as-you-go notional defined contribution model. As discussed earlier, Latvia has experienced persistent population decline driven by low total fertility rates and long-term emigration, especially among young and working-age individuals. This has contributed to a shrinking contributor base and a rising old-age dependency ratio. At the same time, pension adequacy in Latvia is already low with high old-age poverty levels. Both OECD (2018) and Primus (2025) suggest that pension adequacy in Latvia is likely to weaken further unless supported by pension-system reforms and broader improvements in labour-market and economic performance.

The demographic literature further indicates that fertility and migration influence pension systems differently across time. Fertility shapes the size of the labour force in the long run, while migration affects the working-age population more immediately. In Latvia's case, the long-term decline in TFR has limited the regeneration of future contributor cohorts, while sustained emigration has reduced the size and productivity of the current workforce. Because the first pillar directly links contributions to benefits, demographic pressures translate into lower contribution flows, higher dependency ratios, and declining adequacy.

These insights lead directly to the research questions of this thesis. To understand how demographic change influences pension outcomes, it is necessary to isolate the effects of fertility and migration and examine how changes in these variables affect pension adequacy over time. This thesis does not vary life expectancy because the aim is to focus on the two demographic factors under analysis. In Latvia's case, the main source of demographic pressure examined here is the shrinking working-age population and the resulting weakening of the contributor base. Life expectancy is therefore held constant as a background assumption, while other demographic factors are also kept fixed and no structural changes to the pension system are assumed. This approach makes it possible to identify more clearly the extent to which changes in TFR and NMR can alter pension system performance in Latvia.

Research questions

1. How does Latvia's pension adequacy evolve under different probabilistic net migration rate outlooks?

2. How does Latvia's pension adequacy evolve under different probabilistic total fertility rate outlooks?

In addition to examining gradual demographic shifts, this thesis also evaluates the potential effects of sudden or policy-driven changes in TFR and NMR. Such scenarios will be referred to as demographic intervention scenarios. These hypothetical cases are considered capable of altering TFR and NMR more rapidly than trends alone would allow. The purpose of these scenarios is to illustrate the relationship between demographic change and pension adequacy and to support a clearer conceptual understanding of the pension system's sensitivity to policy intervention.

Hypotheses

1. A higher net migration rate increases pension adequacy in the short and medium term primarily by expanding the number of contributors and strengthening first-pillar capital accumulation, while the funded pillars remain less directly affected by demographic change.

2. A higher total fertility rate improves pension adequacy primarily in the long term. Only when larger birth cohorts reach working age and enter the labour force do contribution flows strengthen. In the short and medium term, increased fertility has no direct positive effect on pension adequacy.

2.6. Probabilistic Demographic Outlooks for Pension Analysis

The United Nations World Population Prospects (UN, 2024a) provides probabilistic projections for fertility, mortality, and migration for a wide range of countries, including Latvia. These projections include median trajectories as well as 80% and 95% probability intervals, representing the distribution of simulated demographic futures. As noted earlier, this thesis uses only the probabilistic outlooks for fertility and migration. In the absence of a publicly available, nationally calibrated probabilistic population projection framework for Latvia, the UN projections provide a credible and transparent basis for forward-looking pension analysis. They are internationally recognized, methodologically consistent, and offer explicit probability intervals that can be incorporated into a pension model.

A similar institutional approach appears in NZIER (2025), a report prepared for New Zealand's Retirement Commission, which presents demographic and labour-force projections alongside probability intervals in a retirement-income policy context. Its relevance here is that it shows how central projections can be interpreted together with

uncertainty bands when assessing future developments that matter for pension outcomes.

In the empirical analysis, TFR and NMR are not varied jointly within the same probabilistic outlooks. Instead, each is examined separately while the other is held constant at its median path. Joint probabilistic combinations, such as simultaneous use of an upper-bound fertility and upper-bound migration path, are harder to interpret in a clear analytical way. When both variables vary together, it becomes difficult to determine how much of the resulting pension outcome is driven by fertility and how much by migration. By isolating them, the analysis allows the distinct transmission mechanisms of each demographic factor to be interpreted more clearly.

Using these probabilistic demographic inputs in a transparent pension model makes it possible to show how Latvia's pension adequacy may evolve under a range of plausible demographic paths, and how sensitive pension outcomes are to uncertainty in fertility and migration. This provides a clearer understanding of demographic risk and its implications for the adequacy of Latvia's pension system.

2.7. Expected Contribution

This thesis contributes to the literature by developing a transparent and reproducible projection framework for Latvia that links probabilistic outlooks for fertility and migration to future pension adequacy. By tracing how variation in the total fertility rate and net migration rate feeds through population structure and contributor dynamics into replacement rate outcomes, it provides a Latvia-specific assessment that goes beyond deterministic demographic variants and standardized approaches not designed to isolate adequacy effects. In this way, the thesis makes demographic uncertainty explicit and shows how it shapes pension outcomes in a form that can be reused, adapted, and extended in future research and policy analysis.

The projection horizon extends to 2100 in order to capture the full long-run effects of demographic change, especially fertility, whose effect on pension outcomes emerges only gradually as new cohorts are born, age, and enter the labour force. A shorter horizon would miss an important part of the demographic mechanisms. At the same time, the results should not be read as a forecast of an unreformed pension system until 2100, but as an analysis of the long-run demographic forces affecting pension adequacy if the core system structure remains constant. The findings are best interpreted as showing the dynamics across different outlooks rather than as precise predictions of future pension outcomes.

The framework is relevant for several stakeholder groups. For researchers, it provides a transparent way to connect demographic uncertainty with pension adequacy outcomes in a small, demographically vulnerable country. For policymakers, it helps clarify which demographic channels matter most for future pension adequacy and how sensitive the system is to different fertility and migration developments. For public institutions engaged in long-term policy analysis, it offers a practical basis for scenario evaluation. In particular, a variation of the models developed by the authors, presented in Section 3, is being used by the Bank of Latvia to examine alternative policy outcomes and support recommendations to decision-makers. More broadly, the framework can also contribute to public discussion by making long-run pension implications easier to interpret and compare.

The expected contribution is therefore twofold. First, the thesis provides a demographically probabilistic assessment of pension adequacy in Latvia that is more closely tailored to the country's specific demographic challenges than deterministic alternatives. Second, it delivers a practical modelling tool that helps quantify how different demographic paths may affect future pension adequacy and makes the mechanisms behind these outcomes more transparent.

2.8. Summary

The literature reviewed in this chapter shows that Latvia's pension adequacy challenge is closely tied to persistent demographic decline. Sustained low fertility and net emigration continue to weaken the future contributor base, while the structure of Latvia's pension system makes these pressures especially important. Because the first pillar follows a pay-as-you-go notional defined contribution design, demographic change affects pension outcomes primarily through its impact on the size and productivity of contributors. Existing evidence further suggests that adequacy is already under strain, as reflected in high old-age poverty, low pension income for many retirees, and projected declines in replacement rates.

The literature reveals a clear methodological gap. We did not identify a Latvia-specific study that links probabilistic demographic inputs directly to pension adequacy outcomes within a transparent analytical framework. International studies do incorporate demographic uncertainty, but they vary substantially in methodology and often focus on fiscal indicators, contribution rates, or beneficiary counts rather than adequacy. At the same time, the reviewed literature suggests that probabilistic approaches provide a stronger basis for analysing demographic uncertainty than deterministic scenario variants, which do not assign probabilities to outcomes.

Taken together, these findings motivate the approach adopted in this study. By focusing on fertility and migration as the key demographic drivers, isolating their effects, and linking probabilistic demographic outlooks to replacement rate outcomes, the thesis seeks to provide a more transparent and policy-relevant assessment of how demographic uncertainty may shape future pension adequacy in Latvia.

3. Methodology

To study how different demographic outlooks influence pension adequacy in Latvia, a tool is needed that connects demographic inputs with pension outcomes. This tool must allow different paths for the total fertility rate and net migration rate to be introduced and show how these changes affect the replacement rate. For this purpose, two related models are developed: a demographic model, which projects how the population changes over time under given assumptions, and a pension model, which uses the population projections to estimate pension adequacy outcomes.

3.1. Demographic Projection Framework

The starting point for any demographic analysis is the demographic balancing equation, expressed as:

$$P_{(t+1)} = P_{(t)} + B - D + M,$$

where the population at time t+1 equals the population at time t plus births, minus deaths, plus net migration (Preston et al., 2001, p. 2). This identity is not itself a model, but a basic accounting framework for describing population change. To use it for projections, assumptions must be made about future fertility, mortality, and migration. In practice, it underpins the cohort-component method, which is widely used for population forecasting. More broadly, the equation shows that any projection depends on assumptions about future demographic behaviour, and that small changes in these inputs can accumulate into very different long-term outcomes (O'Neill et al., 2001, p. 210–211).

The most widely used method for turning the balancing equation into projections is the cohort-component approach, which advances each age and sex group year by year. New cohorts are generated through fertility assumptions, existing cohorts are reduced by mortality, and migration flows are added or subtracted. Its main strengths are transparency and flexibility, which explain why it is the standard method used by institutions such as Eurostat and the United Nations (O'Neill et al., 2001, p. 210–211; Preston et al., 2001, p. 119–121).

Other approaches are less suitable for the present purpose. Time-series extrapolation is simple but ignores age structure, microsimulation produces highly detailed results but is data-intensive and harder to communicate clearly, and system dynamics models are generally too stylized for detailed national demographic projections (O'Neill et al., 2001, p. 213–215).

In recent decades, two important developments have shaped the field. First, multi-state cohort-component models extend the basic method by adding characteristics such as education or region of residence, allowing projections to better reflect heterogeneity in demographic behaviour (Lutz et al., 2018, p. 8). Second, there has been a shift from traditional outlook-based projections toward probabilistic methods. Outlook-based approaches, such as high, medium, and low variants, remain widely used because they are simple and intuitive, but scholars such as Raftery et al. (2012) argue that they understate the full extent of demographic uncertainty. Probabilistic methods, often Bayesian, address this by generating distributions of outcomes and prediction intervals rather than a limited set of fixed scenarios. At the same time, Lutz (2021, p. 135) argues that such models should not rely only on past statistical patterns but should also reflect the causal drivers of demographic change. The debate therefore reflects a broader methodological tension between probabilistic precision and causal explanation.

To understand how these theoretical approaches are applied in practice, it is useful to look at the major producers of population projections. These include the United Nations, Eurostat, the International Institute for Applied Systems Analysis (IIASA), and national statistical offices (O'Neill et al., 2001, p. 206). The World Bank also produced long-term projections until the mid-1990s but later discontinued them. The US Census Bureau has historically published global projections, although credible information on its current methodology could not be identified. Among these institutions, Eurostat is especially important for Latvia, as its standardized demographic projections provide the baseline against which the thesis model outputs are later compared.

The United Nations relies on the cohort-component method, but uses Bayesian hierarchical models for fertility and mortality, producing probabilistic ranges around a central “medium” outlook (UN, 2024b, p. 1). This makes the UN projections globally consistent but somewhat “black box,” since causal mechanisms are less explicit. Eurostat, by contrast, employs a convergence pathway for European countries: short-term national trends are projected using time-series models, but in the long run, fertility, mortality, and migration are assumed to move toward common EU-wide values (Eurostat, 2023b, p. 6–9). This ensures comparability across member states, though it sometimes diverges from national expectations. IIASA has pioneered multi-state projections, especially those including education. Their Shared Socioeconomic Pathways (SSPs) integrate demographic projections with education and migration profiles, reflecting education’s influence on fertility and mortality (Lutz et al., 2018, p. 8). National statistical offices, including those in the Baltics, typically produce simpler

deterministic scenario-based projections tailored to local policy debates, with variants for high and low fertility or migration.

The literature and institutional practices suggest that the cohort-component model remains the most suitable approach because it offers the best balance between realism and transparency. While probabilistic methods express uncertainty more precisely and multidimensional models can incorporate factors such as education, these approaches are also less transparent or more data intensive. As Lutz (2021, p. 131) notes, the inclusion of education depends on the purpose of the projection. For Latvia, where the main concern is the balance between contributors and beneficiaries, an age- and sex-based model is sufficient and most transparent.

3.2. Data for the Demographic Model

The demographic model uses population and mortality data to project Latvia's population using an age and sex matrix from 2025 to 2100. This year range is aligned with the Eurostat projection horizon, and when the model was developed, data for 2025 were not yet available. The baseline population dataset provides the population distribution by single-year age groups and sex for 2024. This dataset serves as the starting point of the projection and determines the initial size and structure of each cohort before demographic changes begin to take effect (Eurostat, 2024).

The mortality datasets contain annual age-specific death probabilities for females and males, covering the projection period from 2025 to 2100. Sourced from Eurostat, these probabilities reflect expected changes in mortality over time and are used as fixed inputs throughout the model, allowing realistic survival patterns to be applied to each cohort (Eurostat, 2023a).

Together, these datasets provide the demographic foundation of the model by fixing the initial population structure and the mortality path over the projection horizon. Births and migration are then determined by user-defined assumptions for the total fertility rate and net migration rate, allowing alternative demographic paths to be tested rather than relying on fixed projections from large institutions.

3.3. Structure and Assumptions of the Demographic Model

The demographic model works as a year-by-year population simulation that follows a standard rule: the population in a given year equals the population from the previous year plus births, minus deaths, and plus net migration as given by the previously established demographic equation (Preston et al., 2001, p. 2). Each year, the model applies these steps in the same order. First, people die according to their

age- and sex-specific death rates; second, the remaining population moves one year older; third, new births are added; and finally, net migrants are distributed across age groups.

The model starts with an initial population matrix with age and sex dimensions, and it uses official data on mortality probabilities to make sure survival patterns are realistic over time. Births are calculated using a chosen mean TFR together with a normally shaped fertility curve that represents the likelihood of women giving birth at different ages. In the model, this curve is hardcoded for ages 15 to 49, which is a widely used reproductive age range in demographic analysis (UN, 2019, p. 1). This childbearing age pattern is based on a normal distribution, so that most births occur around the average childbearing age, with fewer births occurring at ages further from the mean. This shape is supported by both historical Latvian data (Figure A.1.) and academic findings showing that, while the exact curve form has a limited effect on final population projection outcomes, the TFR and the mean childbearing age (along with the standard deviation) are key parameters for accuracy (Ediev, n.d. p. 1). Hence, these parameters are made customizable within the model. The number of newborns is then split into males and females using a fixed sex ratio at birth which can also be customized by the user.

Migration is modelled through a user-defined NMR, expressed as a percentage of the previous year's population. Net migrants are distributed evenly across a user-specified working-age band, consistent with historical evidence showing no clear age pattern of migration (Figure A.2) and are then split by sex according to a chosen share. Because the model uses net migration, it captures only the combined effect of immigration and emigration, and for simplicity focuses on permanent flows relevant to long-term pension dynamics. A safeguard is also included to prevent extreme emigration assumptions from reducing any age group below zero.

Fertility and migration pathways can be specified as constant values, changing trends, detailed yearly inputs, or combinations of different phases, allowing the model to capture a wide range of demographic scenarios. The simulation produces annual results by age, sex, and year, together with summary outputs for births, deaths, migration, and total population, as well as a graph of total population over the projection horizon. The demographic model is implemented in R, and the underlying code is available from the authors upon request. The model is designed to make its assumptions transparent and to generate outputs that can be analysed on their own or used directly as inputs in the pension model.

3.4. Pension Accumulation Framework

To link demographic scenarios with old-age pension outcomes, it is necessary to explain how pension capital accumulates across working life and where demographic developments enter this process. Latvia's current pension system began in 1996 with only the first pillar in place, to which all social security contributions (SSC) were directed. The voluntary third pillar was added in 1998, and the mandatory funded second pillar followed in 2001, redirecting part of SSC into market-based savings (Latvian Ministry of Welfare, 2018). This distinction matters because demographic decline affects the first pillar most directly through the contributor base, whereas the funded pillars depend primarily on investment returns.

The discussion begins with the first pillar, which operates as a pay-as-you-go system. This means that the pensions paid out today come directly from the contributions made by the current workforce. The key to understanding this pillar lies in how the Latvian government calculates capital indexation, which determines how the accumulated pension capital grows over time. In a person's first year of work, their accumulated capital is calculated as:

$$K1_{(t)} = \textit{Average Wage}_{(t)} * \textit{First Pillar SSC}_{(t)}.$$

However, for people who started working before 1996, no capital was officially accumulated until that year, since the current pension system only began then. To account for those earlier working years, such individuals receive a lump sum that represents contributions made before 1996:

$$\textit{Lump sum}_{(1996)} = (1996 - \textit{Start Year}) * \textit{Average Wage}_{(1996-1999)} * 0.2.$$

A minor complication arises for individuals who retired between 1996 and 1999, as they were subject to a special transitional treatment of pre-1996 pension rights. However, this special case is not modelled separately, since it has little relevance for the present analysis and does not affect projections for future retirees. After the first working year, first-pillar pension capital evolves according to the following formula:

$$K1_{(t)} = K1_{(t-1)} * \textit{Capital Indexation}_{(t)} + \textit{Average Wage}_{(t)} * \textit{First Pillar SSC}_{(t)}.$$

This means that previously accumulated capital is adjusted (indexed) each year, and new contributions are added on top. The capital indexation formula is:

$$Capital\ Indexation_{(t)} = \frac{Average\ Wage_{(t)} * Employment_{(t)}}{Average\ Wage_{(t-1)} * Employment_{(t-1)}}.$$

In these formulas, the average wage in the contribution term refers to the earnings of the representative worker, whereas in the capital indexation formula it refers to the country's average wage. In the model, however, these coincide, since individuals are represented by average earnings.

The capital indexation formula implies an important insight: for first-pillar capital to keep pace with wage growth, total employment must remain at least at the same level as in the previous year. Employment is calculated as:

$$\begin{aligned} Employment_{(t)} &= Working\ Age\ Population_{(t)} * Labor\ Participation_{(t)} \\ &* (1 - Unemployment_{(t)}) \end{aligned}$$

If employment declines, the first pillar's contribution base shrinks, reducing the growth of pension capital. This highlights a direct link between demographic trends, like ageing or emigration, and pension adequacy (Likumi.lv, 2025).

The second and third pillars work differently because they are funded systems that invest money in financial markets. The second pillar is mandatory for most workers, while the third pillar is voluntary. Although participation in the second pillar was phased in gradually, evidence shows that most workers have joined, so in this model we treat it as mandatory for all contributors (Latvian Ministry of Welfare, 2018). In a person's first working year, the second and third pillar capital is calculated as:

$$K2_{(t)} = Average\ Wage_{(t)} * Second\ Pillar\ SSC_{(t)} * Yield_{(K2,t)}^{0.5},$$

and

$$K3_{(t)} = Average\ Wage_{(t)} * Third\ Pillar\ Rate_{(t)} * Yield_{(K3,t)}^{0.5}.$$

The factor of 0.5 reflects that people contribute throughout the year, so on average, contributions earn half a year's investment return. In later years, the accumulated capital continues to grow according to:

$$K2_{(t)} = K2_{(t-1)} * Yield_{(K2,t)} + Average Wage_{(t)} * Second Pillar SSC_{(t)} * Yield_{(K2,t)}^{0.5}$$

and

$$K3_{(t)} = K3_{(t-1)} * Yield_{(K3,t)} + Average Wage_{(t)} * Third Pillar Rate_{(t)} * Yield_{(K3,t)}^{0.5}$$

In other words, existing savings grow at the full annual yield, while new contributions grow at half the yield for that year. At the point of retirement, total pension capital is the sum of the balances accumulated in all three pillars:

$$K_{(t)} = K1_{(t)} + K2_{(t)} + K3_{(t)}.$$

Here, retirement in year t is treated as occurring once the capital accumulation process for that year has been completed. As a result, the balances in all three pillars are taken at time t , and no further accumulation is assumed after retirement. Instead, the total pension capital is immediately converted into pension income by distributing it across the remaining expected years of life. This rule, combined with the assumptions described above, forms the core of the Latvian pension model. The key insight is that year-to-year demographic changes affect the flow of contributions into the system and therefore influence the total capital accumulated across all pillars at retirement (Likumi.lv, 2025).

3.5. Data for the Pension Model

The pension model uses a combination of historical data, economic assumptions, and population projections to estimate future pension outcomes for Latvia. Since the demographic model can directly feed into the pension model, the population-related data used there are also relevant here. In particular, population structures by age and sex are essential for calculating the working-age population, retirees, and future contributors to the pension system.

In addition, three main datasets are used in the pension model. The first dataset contains historical data from 1995 to 2024 on the average wage subject to insurance contributions, capital indexation, and historical contribution rates for each pension pillar. Historically, the combined contribution rate of the first and second pillars has

remained constant at 20%, although the proportion allocated between them has changed. These variables provide the historical trends and calibration values used in the model (Official Statistics of Latvia, 2024; State Social Insurance Agency of the Republic of Latvia, 2024; VSAA, 2023).

A second dataset provides projections for key labour-market and macroeconomic variables from 2024 to 2100, including labour participation rates, unemployment rates, labour productivity growth, life expectancy at age 65, and contribution rates to the first pension pillar. These assumptions are consistent with Eurostat’s long-term scenarios and ensure that wage and employment projections evolve in line with broader economic expectations Eurostat (2023a). The third dataset provides projected population data by age and sex from Eurostat (2023a).

This setup allows the pension model to function effectively while still offering flexibility in the degree of customization applied. The historical data provides the foundation of the model, ensuring that it operates correctly and reflects observed past trends. The other two datasets, containing Eurostat-based economic projections and population data, allow users either to rely on preloaded official assumptions or to replace them with custom inputs in order to test alternative economic or demographic scenarios. In this way, the model serves both as a transparent policy tool grounded in established data and as a flexible simulation framework for exploring “what-if” cases. For the probabilistic UN values used for the total fertility rate and net migration rate, the custom-input option is applied.

3.6. Structure and Assumptions of the Pension Model

The pension model links economic behaviour with demographic change to estimate future pension outcomes. It starts by projecting average wages forward from the last year observed using a simple rule:

$$Av. Wage_{(t)} = Av. Wage_{(t-1)} * (1 + Labour Productivity Changes_{(t)} + Inflation_{(t)})$$

,

monthly wages are then annualized. With wages projected, the model estimates employment as follows:

$$\begin{aligned} Employment_{(t)} &= Working Age Population_{(t)} * Labor Participation_{(t)} \\ &* (1 - Unemployment_{(t)}) \end{aligned}$$

If users keep the “baseline” setting, the working-age population is imported from Eurostat projections; if they choose “custom”, it is generated by the demographic model and can reflect any fertility and migration path specified by the user. Retirement age can remain at its default or follow a user-defined path, and the default working-age interval (20-65) automatically expands if the retirement age is raised. From wages and employment, the model uses the previously described capital-indexation factor that tracks how the contribution base evolves over time:

$$Capital\ Indexation_{(t)} = \frac{Average\ Wage_{(t)} * Employment_{(t)}}{Average\ Wage_{(t-1)} * Employment_{(t-1)}}$$

Capital then accumulates separately in the three pillars, as described in the previous section. At retirement, the model sums the three balances accrued up to year t for a person retiring that year:

$$K_{(t)} = K1_{(t)} + K2_{(t)} + K3_{(t)}, \text{ (Likumi.lv, 2025).}$$

Monthly pensions are then calculated by dividing this capital by life expectancy at 65, adjusted if the retirement age differs from 65:

$$Monthly\ Pension_{(t)} = \frac{K_{(t)}}{Adjusted\ Life\ Expectancy_{(t)} * 12}$$

Finally, the gross replacement rate is calculated as the ratio of the projected monthly pension to the projected average wage of employees, adjusted for income that does not fully generate mandatory social insurance contributions and for shorter-than-full contribution careers.

$$Replacement\ Rate_{(t)} = \frac{Monthly\ Pension_{(t)} * (1 - Contribution\ Duration\ Adjustment_{(t)})}{Projected\ Av.\ Wage_{(t)} * (1 + Non-Contributory\ Income\ Share_{(t)})}$$

The Non-Contributory Income Share variable is included in the replacement rate formula to account for income that does not generate mandatory social insurance contributions. This includes both undeclared income and earnings that are only partially subject to contributions. The shadow economy component is estimated annually by experts (LTRK, 2025), while partial contribution cases reflect situations in which social

insurance contributions are paid only in part. By incorporating this non-contributory income into the denominator of the replacement rate, the model reduces the measured replacement rate relative to calculations based solely on declared income. Although this lowers the estimated result, it improves the realism of the measure by aligning pre-retirement earnings more closely with total actual income rather than only the portion used for pension accumulation. In this sense, the variable represents a design element developed for the Bank of Latvia model variation to capture the gap between actual earnings and the contribution base underlying pension accumulation. The Contribution Duration Adjustment parameter accounts for the fact that individuals may not complete the full 45 years of contributions assumed in the model. In practice, employment interruptions and periods outside the labour force reduce the effective number of contribution years, meaning that pension benefits calculated under a full-career assumption would otherwise be overestimated. In the current model specification, this adjustment is set at 20%, reflecting the difference between the full contribution period assumed in the model (45 years) and the observed average contribution duration of 35.8 years. This parameter therefore scales projected pension outcomes to better reflect realistic contribution histories observed in practice (Latvian Ministry of Welfare, 2025).

Like the demographic model, the pension model is implemented in R, and the underlying code is available upon request. Throughout the model, users can choose how much to customize: the model will run on historical series and official projections out of the box, but every major assumption, including labour participation, unemployment, productivity, contribution rates, investment returns, retirement age, and the population path, can be switched to fixed values or user-supplied trajectories. The model produces a results table that can include many of the variables used throughout the calculation, but its main outputs are total and pillar-level replacement rates, together with a plot of replacement rates over the projection horizon, suitable for policy analysis or reporting.

3.7. Limitations of the Demographic and Pension Models

Demographic change and pension system development are difficult to model precisely because they depend on human behaviour and future external conditions that cannot be fully anticipated. For this reason, both models rely on simplifying assumptions intended to preserve transparency and interpretability rather than produce exact forecasts. Sections 3.7.1 and 3.7.2 discuss the main limitations of the demographic and pension models.

3.7.1. Limitations of the Demographic Model

First, several parameters in the demographic model are hardcoded throughout the simulation. The projection horizon is fixed at 2025–2100, the maximum age at 100, and the female fertile age range at 15–49. These choices are standard and appropriate for the present analysis, but they also limit flexibility. If future mortality improvements lead to a larger population surviving beyond age 100, or if childbearing continues to shift to older ages, the current parameterization may become less realistic without manual adjustments to the code.

Second, the model assumes that age-specific fertility and migration patterns remain stable over time. Fertility is represented by a normal age curve based on historical Latvian data (Figure A.1), while migration is distributed evenly across a user-defined age band because the available data do not show a clear and consistent age-specific migration pattern (Figure A.2). Although users can adjust key parameters such as the mean and standard deviation of the fertility curve, the migration age band, and the sex composition of migrants, these values are held constant throughout the projection period. As a result, the model does not capture possible future shifts in fertility timing or migration behaviour that differ from past patterns.

Third, the model simplifies the process through which births occur. Fertility is determined solely by applying age-specific birth probabilities to the female population, while the male population does not play a role in determining the number of births. As a result, the only ways to increase the number of births in the model are through higher fertility rates or a larger number of women of childbearing age. Other important factors that influence fertility decisions, such as education, income, family policies, or cultural norms, are not explicitly included. In this sense, the demographic model operates as a partial-equilibrium framework, as it does not capture all behavioural feedback mechanisms present in real-world demographic systems. While this limits the model's realism, it helps maintain clarity and computational efficiency, which is appropriate given the model's purpose of supplying transparent demographic inputs for the pension adequacy analysis.

Fourth, migration in the model is represented using a simplified and specific profile. This approach is aligned with the main purpose of the demographic projection model, which is to provide inputs for the pension model. The migration considered in the model refers to individuals who arrive in or leave the country permanently, as these are the migrants who can contribute to the labour market if they are of working age. In the case of immigration, a working-age migrant is defined as a person who arrives in Latvia with the intention of staying and working there permanently during their working

life for the same average wage as locals. If the model later simulates emigration, this individual may leave the country, but in that case, they are treated in the same way as the local population and may be randomly selected among potential emigrants. For simplicity, and as mentioned earlier, the model focuses only on net migration, since the resulting number of working-age individuals is the main variable of interest. As a result, the model treats migration in a simplified and narrowly focused way that is suitable for the purposes of this analysis.

3.7.2. Limitations of the Pension Model

First, the pension model operates as a partial-equilibrium framework. It focuses on how demographic developments influence pension outcomes, but it does not model feedback effects between the pension system, the labour market, and the wider economy. Variables such as labour-force participation, unemployment, productivity growth, and wages are treated as exogenous inputs rather than as outcomes that respond to demographic change or pension policy. As a result, the model may either underestimate or overestimate the true impact of demographic trends on pension adequacy, since potential adjustments in the labour market or macroeconomic environment are not captured.

Second, the model is based on a representative-worker assumption. Pension outcomes are calculated for a stylized individual or cohort using average wage levels and average contribution histories. This approach abstracts from heterogeneity across individuals, such as differences in career length, employment interruptions, part-time work, gender-specific wage gaps, or income inequality. Consequently, the results should be interpreted as indicative of average pension adequacy rather than as a description of outcomes for specific population groups. Additionally, it does not allow examination of inequality in wages and pensions, for example, how many pensioners remain below the poverty line.

Third, the model is built around the current institutional structure of the Latvian pension system and its core rules. While users can customize several parameters, including contribution rates, retirement age, and investment yields for the funded pillars, the fundamental design of the first pillar remains unchanged throughout the simulation. This implies that the model does not account for potential structural reforms to the pension system, such as changes in benefit formulas or indexation rules, which could significantly alter future pension outcomes.

Fourth, returns in the second and third pension pillars are modelled in a simplified manner. In reality, contributions to funded pension pillars are made

continuously, typically on a monthly basis, and each contribution earns a different amount of investment return depending on when it is paid. To avoid excessive complexity, the model assumes that new annual contributions earn, on average, half of the yearly investment return, reflecting the idea that some contributions are made earlier in the year and others later. While this approximation is commonly used and reasonable for long-term projections, it abstracts from short-term market volatility and timing effects that may influence individual pension outcomes.

3.8. Summary

This section has presented the methodological framework used to examine how demographic uncertainty affects pension adequacy in Latvia. Two connected models were developed for this purpose. The demographic model projects Latvia's population using a cohort-component structure driven by assumptions about fertility, mortality, and migration, while the pension model translates these population dynamics into pension outcomes through the capital accumulation mechanisms of Latvia's three-pillar pension system. Together, these models create a transparent analytical tool that allows different demographic pathways, particularly variations in the total fertility rate and the net migration rate, to be translated into replacement rate outcomes.

The modelling approach prioritizes transparency and interpretability over excessive complexity. Key demographic and economic inputs can be modified to explore alternative scenarios, allowing the analysis to isolate how specific demographic developments influence pension adequacy. At the same time, the models rely on several simplifying assumptions, such as fixed behavioural patterns, representative workers, and exogenous macroeconomic variables. These assumptions limit the ability of the framework to capture all real-world dynamics but make it possible to clearly identify the mechanisms through which demographic change affects pension outcomes.

4. Analysis of Results and Discussion

This chapter presents the results of the probabilistic demographic analysis and evaluates how alternative fertility and migration outlooks translate into population dynamics and pension adequacy outcomes. The first part focuses on outcomes derived from United Nations probabilistic projections and directly addresses the research questions and hypotheses. The second part examines stylized intervention scenarios in order to provide additional insight into the sensitivity of pension adequacy to demographic change and the underlying mechanisms driving it.

4.1. Net Migration Rate Outlooks

The median trajectories presented in Sections 4.1 and 4.2 are identical, since both analyses use the UN median projections for the total fertility rate and the net migration rate. In both cases, the model is driven by the same median demographic input combination, which produces identical population and replacement rate paths. These results are nevertheless examined separately because each section isolates a different source of demographic uncertainty. In this section, the analysis focuses on variation in net migration while holding fertility constant at its median level.

4.1.1. NMR Probability Bands

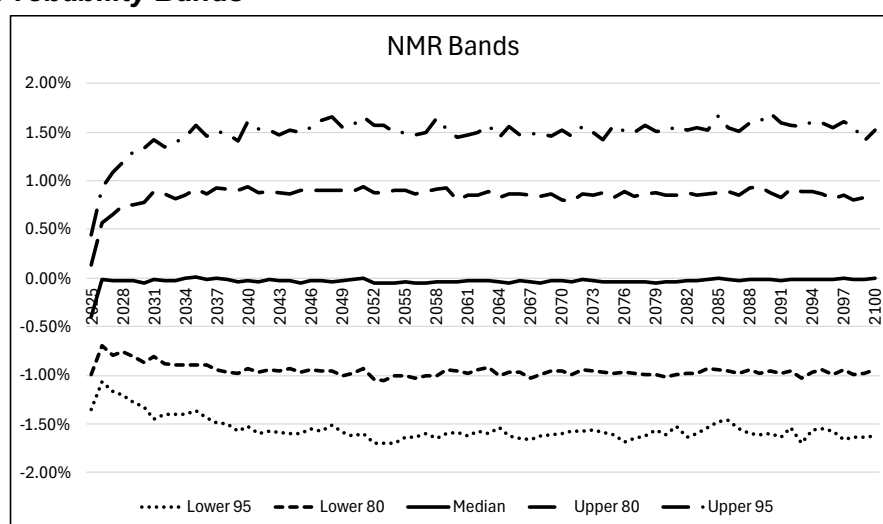


Figure 1: Net migration rate probability bands for Latvia, 2025–2100. Created by authors. (UN, 2024a).

The probabilistic net migration rate bands show a clear pattern of early adjustment followed by long-run stabilization. All trajectories initially display an increase in the NMR during the early projection period, indicating that net migration becomes

less negative in the short term compared to recent historical levels. From approximately 2040 onward, each probability band converges toward a stable long-run level around which only limited year-to-year fluctuations occur.

Using long-run averages from 2040 onward, the lower 95 band stabilizes around -1.60% (with a maximum spread of 0.14 percentage points), the lower 80 band around -0.97% (spread of 0.08 pp), the median around -0.03% (spread of 0.03 pp), the upper 80 band around 0.87% (spread of 0.08 pp), and the upper 95 band around 1.54% (spread of 0.15 pp). In practical terms, the median UN projection implies that after 2040, Latvia experiences a net migration rate very close to zero.

For the analysis that follows, attention is restricted to the 80% probability interval (lower 80, median, upper 80). This choice reflects a focus on more realistic demographic outcomes. The lower and upper 95 bounds represent extreme cases, with only a 2.5% probability that NMR falls below the lower bound or 2.5% probability that it exceeds the upper bound. Focusing on the 80% interval therefore keeps the analysis centered on the most relevant range for interpreting likely pension adequacy outcomes.

4.1.2. Population Outcomes under NMR Outlooks

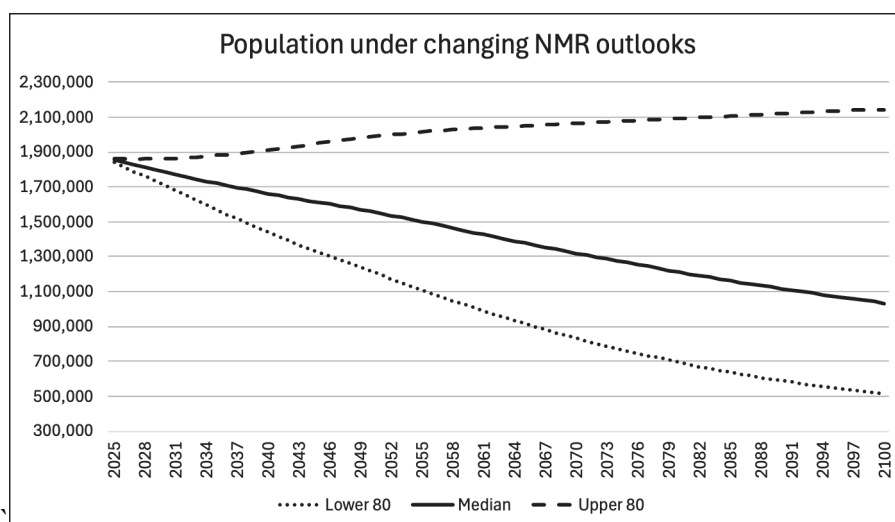


Figure 2: Population projections under alternative net migration rate outlooks for Latvia, 2025–2100. Created by authors.

When these migration paths are applied to the demographic model, population outcomes diverge substantially even within the 80% probability range. By 2050, Latvia’s population varies between approximately 1.22 million under the lower 80 trajectory and 1.99 million under the upper 80 trajectory. By 2100, this range widens

further, from around 0.51 million to 2.14 million. This implies that even outcomes considered statistically likely by the UN generate a population spread of roughly 1.63 million people by the end of the projection horizon.

Despite this wide uncertainty, the median projection still indicates persistent demographic contraction. When the median UN demographic inputs are introduced into the model, Latvia's population declines from roughly 1.85 million in 2025 to 1.56 million by 2050 and further to approximately 1.03 million by 2100. This confirms that even under the most probable migration path, the model produces a long-term depopulation trajectory.

A useful way to benchmark this median result is to compare the resulting model output with the European Commission baseline population path. Using ten-year intervals from 2030 to 2070, the European Commission projects population levels of roughly 1.7 million, 1.6 million, 1.5 million, 1.4 million, and 1.3 million (European Commission, 2024, Statistical Annex - Latvia), while the corresponding model outputs under the median UN demographic inputs are approximately 1.8 million, 1.7 million, 1.6 million, 1.4 million, and 1.3 million. The model output is therefore slightly higher, but the two trajectories converge by the second half of the century. This suggests that the population dynamics generated by the model under median UN inputs are broadly plausible relative to another major institutional benchmark.

An important modelling assumption behind these results is that migrants are distributed across the 17–69 age range (Table B.1). This means migration mainly affects the working-age population. As a result, changes in the net migration rate directly and immediately influence the number of contributors to the pension system, making pension outcomes particularly sensitive to migration changes.

This has an important substantive implication. Migration uncertainty creates very large differences in total population size, but these differences are especially relevant because they are concentrated in age groups that matter for employment and contributions.

4.1.3. Replacement Rate Outcomes under NMR Outlooks

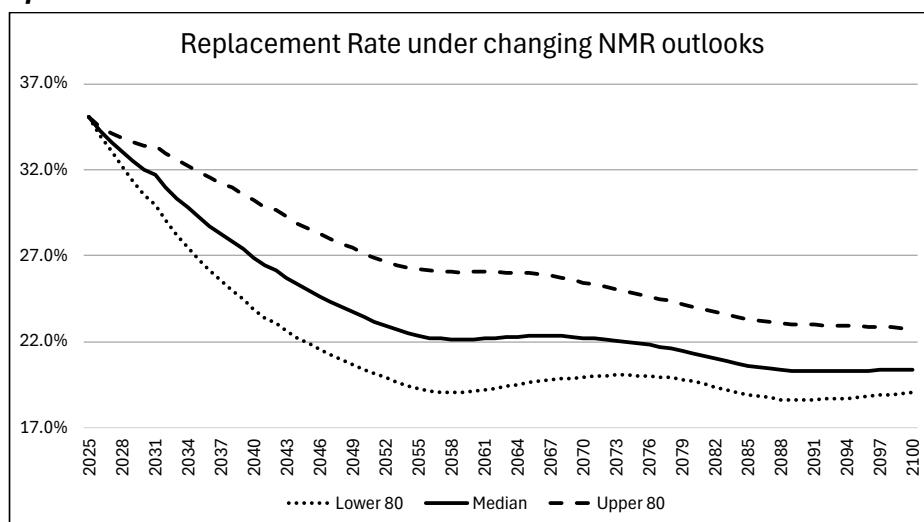


Figure 3: Replacement rate projections under alternative net migration rate outlooks for Latvia, 2025–2100. Created by authors.

Despite the very large dispersion in population outcomes, pension replacement rates do not diverge to the same extent. Instead, the lower 80, median, and upper 80 migration outlooks produce three clearly separate but similarly shaped replacement rate trajectories. Because migration affects the working-age population and contribution flows immediately, replacement rate paths begin to diverge from the start of the projection horizon.

In all cases, replacement rates decline substantially over time. In 2025, the replacement rate is 35.1% across all outlooks. By 2050, it ranges from 20.4% under the lower 80 migration outlook to 23.4% under the median outlook and 27.1% under the upper 80 outlook. By 2100, the range narrows to 19.0%, 20.4%, and 22.7%, respectively. Interpreted probabilistically, this implies that, if Latvia’s net migration rate remains within the UN’s central 80% probability interval, the replacement rate in 2100 would be expected to fall within a relatively narrow range of 19.0% to 22.7%.

The median replacement rate path can be compared with the European Commission baseline as a plausibility check on the model output under median UN demographic inputs. The European Commission projects gross replacement rates of 39.5% (2030), 27.7% (2040), 23.8% (2050), 22.6% (2060), and 23.7% (2070) (European Commission, 2024, Statistical Annex – Latvia), while the corresponding model outputs under the median UN demographic inputs are approximately 32.0%, 26.9%, 23.4%, 22.1%, and 22.2%. The largest gap appears in 2030, where the model estimate is notably lower. This likely reflects differences in modelling structure. Whereas the European Commission projection is embedded in a broader institutional

macro-demographic framework, the present model isolates demographic transmission more directly through contributor dynamics. From mid-century onward, however, the two paths become very similar, suggesting that the replacement rate dynamics generated by the model under median UN inputs are broadly plausible, even if they imply a somewhat sharper early decline.

The divergence between migration paths is largest around mid-century, peaking around 2055, after which the spread gradually narrows. Replacement rates fall most sharply in the early projection period and later stabilize into flatter trajectories. This pattern is shaped by the initial population structure used in the model, which already reflects many years of low fertility. When migration paths are varied, fertility is held constant at the UN median trajectory, which remains well below replacement level throughout the projection horizon. As a result, too few young people enter the workforce regardless of whether migration is relatively low or high. Even stronger immigration therefore cannot fully offset the shrinking size of younger cohorts entering working age. The contributor base grows much more slowly than wages, which causes replacement rates to fall sharply in the early decades across all migration outlooks, with the strongest decline occurring under the most negative migration path.

The later-stage convergence of the replacement rate trajectories can be explained by both the long-run stabilization of the demographic outlooks and the institutional design of Latvia's first pension pillar. From around 2040 onward, the UN NMR outlooks stabilize around long-run levels and fluctuate only slightly. As a result, differences in population growth across the migration paths begin to narrow, cohort sizes evolve more gradually, and employment dynamics become increasingly similar across the different outlooks.

This pattern is reinforced by the way first-pillar pension capital is indexed in the Latvian pension system. As discussed earlier, capital indexation depends on the relative change in the contribution base rather than on its absolute level:

$$Capital\ Indexation_{(t)} = \frac{Average\ Wage_{(t)} * Employment_{(t)}}{Average\ Wage_{(t-1)} * Employment_{(t-1)}} .$$

This means that maintaining a permanently higher level of employment through migration does not, in itself, produce lasting gains in pension outcomes. Migration can improve replacement rates when it increases the contributor base relative to the previous period, but this effect weakens over time as migrant cohorts age and eventually retire themselves. At that point, continuing inflows are increasingly required merely to sustain the existing contributor base rather than to generate further gains in

adequacy. If inflows slow or stop, the improvement in replacement rates may also weaken or reverse. In this sense, migration can alleviate demographic pressure, but it does not eliminate the underlying structural problem.

Because replacement rates in the model depend on how the contributor base evolves relative to wage growth, the increasing similarity of demographic and employment dynamics across the outlooks translates into flatter replacement rate trajectories and gradual convergence toward the end of the projection horizon. These results therefore clarify the substantive role of migration in Latvia's pension system. Migration uncertainty matters greatly for pension adequacy in the short and medium term because it directly affects the number of contributors. However, the long-run convergence of the replacement rate paths suggests that migration alone is not sufficient to reverse structurally low adequacy if fertility remains persistently below replacement level. Migration therefore appears to function primarily as a timing and cushioning mechanism rather than as a full long-run solution to Latvia's pension adequacy problem.

4.2. Total Fertility Rate Outlooks

As in Section 4.1, the median trajectories are identical because both analyses are based on the UN median projections for the total fertility rate and the net migration rate. However, this section isolates fertility uncertainty while holding migration constant at its median level, allowing the effects of variation in fertility to be evaluated more clearly.

4.2.1. TFR Probability Bands

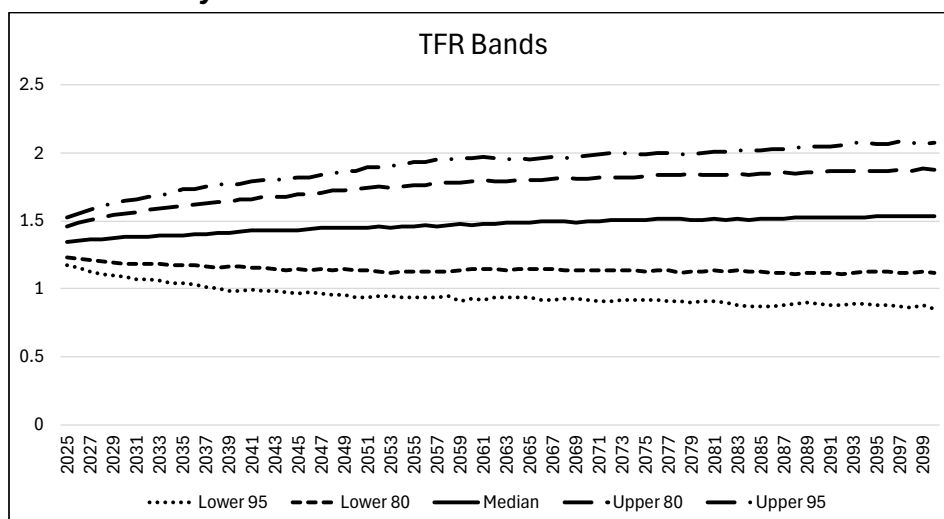


Figure 4: Total fertility rate probability bands for Latvia, 2025–2100. Created by authors. (UN, 2024a).

In contrast to migration, fertility projections do not converge toward a fixed long-run value. Instead, all TFR paths exhibit gradual upward or downward movement throughout the projection horizon. According to the UN projections, there is a 95% probability that Latvia's TFR lies between approximately 0.94 and 1.87 by 2050, and an 80% probability that it lies between 1.14 and 1.73, with the median projection indicating a value of around 1.45. By 2100, the corresponding ranges widen to 0.85–2.08 (95%) and 1.12–1.87 (80%), with a median value of approximately 1.53.

The median trajectory implies that fertility is expected to increase moderately over time but remain well below the replacement level of around 2.1 children per woman. Even in the upper 95% band, fertility does not reach this threshold, peaking at 2.08 by 2100. This implies that, according to the UN probabilistic projections, the probability of Latvia reaching replacement-level fertility at any specific year is extremely low, below 2.5%. In earlier years, this likelihood is even smaller, as projected fertility levels remain further below the replacement level.

The relatively wide uncertainty range already visible in the early projection years may appear surprising given the short time horizon. However, in a probabilistic framework, uncertainty is present not only in distant outcomes but also in recent and near-term demographic trajectories.

As with migration, the analysis focuses on the lower 80, median, and upper 80 trajectories, which represent the most plausible fertility outcomes. This choice keeps the interpretation centered on the most relevant probability range while avoiding overemphasis on highly extreme tail outcomes.

4.2.2. Population Outcomes under TFR Outlooks

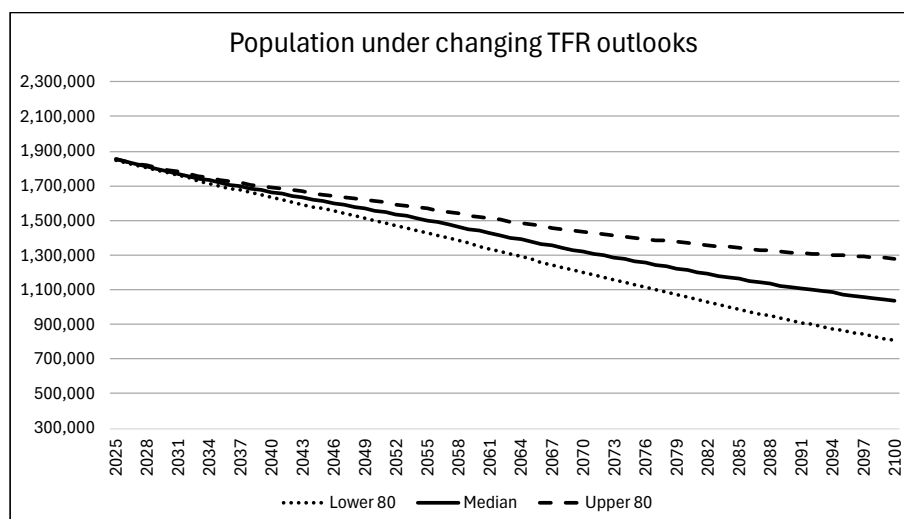


Figure 5: Population projections under alternative total fertility rate outlooks for Latvia, 2025–2100. Created by authors.

When fertility variation is introduced while holding migration at its median path, population outcomes show substantially less dispersion than under migration uncertainty. By 2050, population ranges from approximately 1.50 million to 1.61 million across the 80% fertility interval. By 2100, this range widens to roughly 0.81 million to 1.28 million. The spread therefore reaches only about 0.47 million people by the end of the century, compared with 1.63 million under NMR variation.

This difference reflects the distinct timing of fertility and migration effects. Migration changes population size immediately, whereas fertility affects demographic outcomes more gradually through cumulative intergenerational processes. Because all fertility trajectories considered here remain below replacement level, while migration is held at its median path, population declines under all fertility outlooks and the dispersion across outcomes remains substantially smaller than under migration uncertainty, especially in the first decades of the projection horizon. These results suggest that fertility uncertainty is important for Latvia’s long-run demographic outlook, but much less powerful than migration in shaping population outcomes over the coming decades.

4.2.3. Replacement Rate Outcomes under TFR outlooks

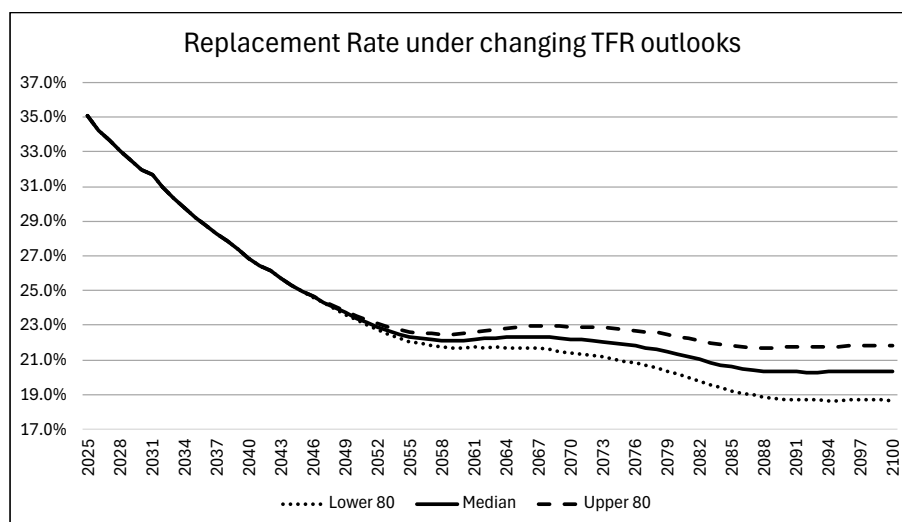


Figure 6: Replacement rate projections under alternative total fertility rate outlooks for Latvia, 2025–2100. Created by authors.

Replacement rates decline from 35.1% in 2025 to approximately 25.0% by 2045, after which divergence across fertility paths begins. By 2100, replacement rates reach 18.7% under the lower 80 path, 20.4% under the median path, and 21.8% under the upper 80 path, implying a spread of 3.1 percentage points within the 80% fertility interval. Under migration variation, the corresponding spread is slightly larger at 3.7 percentage points (19.0% to 22.7%), indicating that in the long run UN fertility and migration uncertainty produce broadly similar ranges of pension adequacy outcomes. However, this convergence masks much larger differences in the coming decades. By 2050, replacement rates under migration variation range from 20.4% to 27.1%, a spread of 6.7 percentage points, whereas under fertility variation they range only from 23.3% to 23.5%, a negligible spread of 0.2 percentage points. This highlights that migration uncertainty has a substantially stronger short- and medium-term impact on pension adequacy, while fertility effects materialize more gradually and remain comparatively limited in the near future.

More specifically, replacement rate dynamics under fertility uncertainty display a different timing structure from those under migration uncertainty. Across all fertility paths, replacement rates remain identical to one decimal place until 2045. This reflects the demographic lag inherent in fertility effects. While fertility trajectories diverge immediately from the start of the projection period, newborn cohorts only begin entering the labour force two decades later. As a result, contribution flows remain unaffected by fertility differences during the first part of the projection horizon, and

replacement rate paths separate only once these cohorts start contributing to the pension system.

Replacement rate trajectories under fertility variation then follow a wave-like pattern, with an initial decline, a period of modest stabilization or partial rebound, and then renewed downward pressure. This reflects the interaction between cohort ageing and the delayed labour-market entry of new generations. Once fertility differences begin to affect the size of entering working-age cohorts, higher fertility paths provide some temporary support to the contributor base and therefore to replacement rates. However, because all probabilistic fertility outlooks remain below replacement level, this support is limited and does not prevent renewed long-run decline. The results therefore suggest that fertility matters for pension adequacy mainly through delayed and only partial support rather than through any near-term reversal of the broader downward trend.

4.3. Answers to the Research Questions and Evaluation of the Hypotheses

The results directly address the two research questions formulated in Section 2.5 and support the corresponding hypotheses.

Regarding migration, the findings show that higher net migration improves pension adequacy immediately by expanding the contributor base and strengthening contribution revenues, but that this effect weakens over time as migration flows stabilize and migrant cohorts themselves age.

Regarding fertility, the findings show that higher fertility affects pension adequacy only with a substantial delay, since larger birth cohorts begin to matter only once they enter the labour force. As a result, fertility differences have almost no effect on pension adequacy in the short and medium term, and even in the long run their effect remains limited within the plausible probabilistic range.

Taken together, these results show that migration and fertility influence pension adequacy through different channels and time horizons: migration is much more important over the coming decades, while fertility matters mainly through delayed and only partial long-run support. At the same time, across all fertility and migration outlooks, replacement rates remain well below the adequacy benchmark of approximately 40% of pre-retirement earnings (Holzmann & Hinz, 2005, p. 55–56). Even under the more favourable trajectories within the UN's central 80% probability interval, long-run replacement rates remain below 23%. This indicates that demographic improvements alone, within realistic projection ranges, are insufficient to restore pension adequacy to that benchmark. Instead, Latvia's pension system

remains structurally constrained by population ageing and a shrinking contributor base, so demographic uncertainty mainly affects the timing and severity of adequacy decline rather than reversing its overall direction.

4.4. NMR Intervention Scenarios

The second part of the analysis focuses on intervention scenarios based on simple and transparent demographic trajectories, such as fixed input values over a given period or clear trends that persist throughout the projection horizon. These scenarios are based on Eurostat’s baseline projections for both migration and fertility, but their trajectories are approximated using smooth trends in which each variable starts from an initial value and then changes by a constant amount or percentage each year. This simplification makes the transmission from demographic inputs to population structure and replacement rate outcomes more direct and easier to interpret, while also serving as a robustness and validation exercise by helping to verify that the models behave as intended under stylized assumptions.

4.4.1. Population Outcomes under Intervention NMR Scenarios

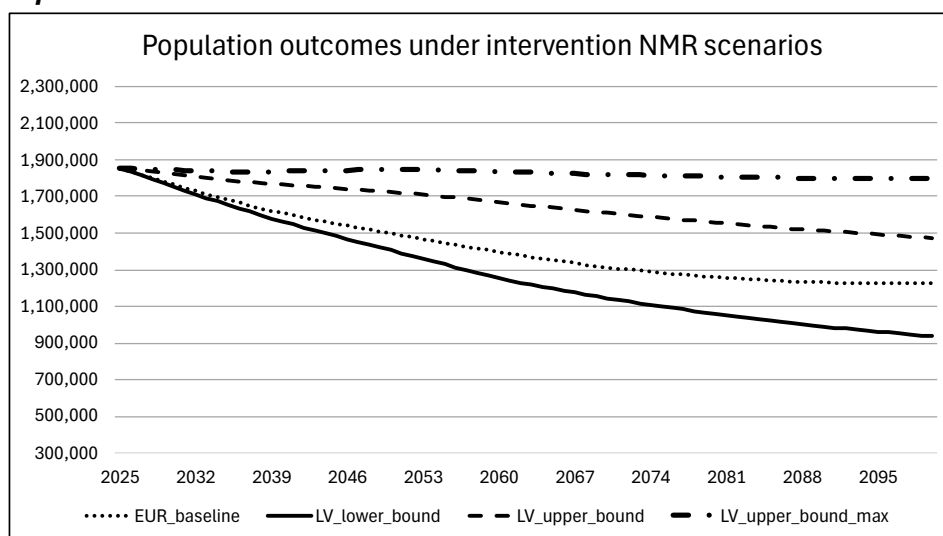


Figure 7: Population projections under intervention net migration rate scenarios for Latvia, 2025–2100. Created by authors.

Figure 7 presents four migration scenarios: EUR_baseline, the Eurostat baseline; LV_lower_bound, a pessimistic path with NMR at -0.5% for most of the period; LV_upper_bound, an optimistic path with NMR at 0.25% for most of the period; and LV_upper_bound_max, a more optimistic path with NMR at 0.5% for most of the period.

Population outcomes under these scenarios diverge substantially over time. The lowest trajectory reflects sustained net emigration throughout the projection horizon, while the highest trajectory reflects persistent net immigration. Under the most adverse scenario, population declines sharply in the first decades and reaches a minimum of around 0.8 million people by 2100. This outcome is driven by strong net emigration in the earlier period, with -0.5% of the previous year's population leaving annually between 2025 and 2060, followed by a milder but still negative flow of -0.25% per year from 2061 to 2100.

At the other extreme, the most optimistic scenario assumes a constant net migration rate of 0.5% per year over the entire period from 2025 to 2100, resulting in a population just below 1.9 million by 2100, close to Latvia's population level in 2024. The intermediate optimistic scenario, with NMR at 0.25% for most of the period, produces a more moderate population path that still substantially exceeds the pessimistic and baseline outcomes by the end of the century. Meanwhile, the Eurostat baseline produces continued population decline, but at a slower pace than the lower-bound scenario.

These results illustrate that migration has a strong and immediate effect on total population size. Large and persistent net immigration can, in principle, offset the effects of Latvia's ongoing low fertility, while sustained net emigration accelerates demographic contraction. At the same time, the magnitude required to stabilize population is substantial: maintaining population size under low fertility would require net inflows on the order of 10,000 migrants per year. While the relationship between migration and total population size is relatively direct, its implications for pension outcomes are less straightforward and are examined in the following subsection.

4.4.2. Replacement Rate Outcomes under Intervention NMR Scenarios

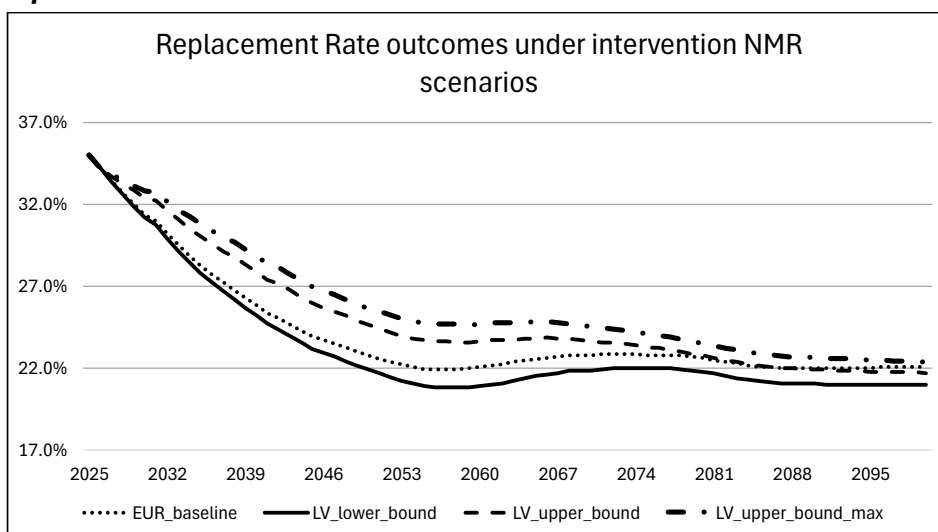


Figure 8: Replacement rate projections under intervention net migration rate scenarios for Latvia, 2025–2100. Created by authors.

As under the UN probability bands, the migration intervention scenarios show that even large differences in net migration assumptions produce only limited long-run differences in pension adequacy, with replacement rates eventually converging to around 21%. The added value of the intervention analysis is that it makes the mechanism behind this result more transparent. In particular, the Eurostat baseline converges toward a similar long-run outcome despite beginning from net emigration, which shows that long-run pension adequacy in the model depends less on the absolute scale of migration inflows than on how migration affects the growth of the contributor base from one period to the next. This follows from the structure of the first pillar, where capital indexation depends on relative changes in wage-adjusted employment rather than on the absolute number of contributors alone.

As a result, a large one-time migration improvement can raise replacement rates temporarily, but its effect fades as that improvement becomes embedded in the new baseline and migrant cohorts themselves age. By contrast, a gradual and persistent improvement in migration remains relevant for longer, because it continues to support contributor-base growth across successive periods. The intervention scenarios therefore clarify that, within this pension framework, the sustainability of migration improvement matters more for long-run adequacy than the short-term scale of inflows alone.

4.5. TFR Intervention Scenarios

As in Section 4.4, the analysis is based on the approximated Eurostat baseline trajectory, but here the alternative scenarios are constructed by varying TFR while holding NMR constant.

4.5.1. Population Outcomes under Intervention TFR Scenarios

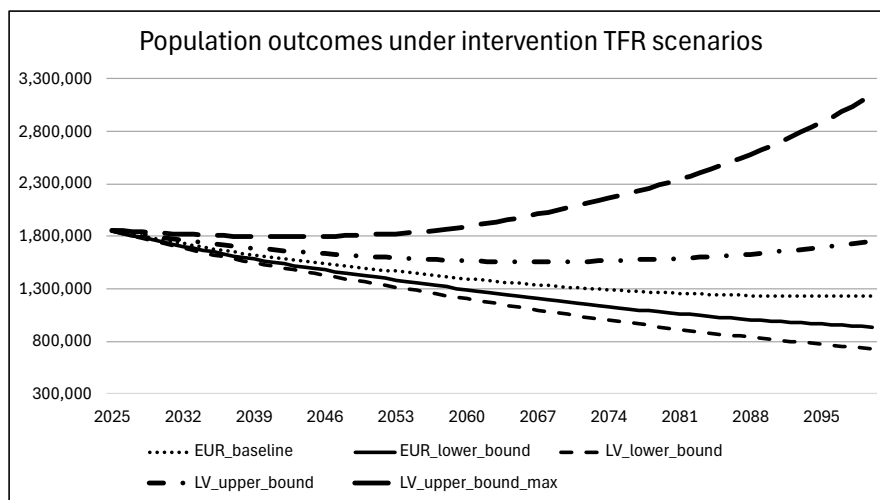


Figure 9: Population projections under intervention total fertility rate scenarios for Latvia, 2025–2100. Created by authors.

Figure 9 presents five fertility scenarios: EUR_baseline, the Eurostat baseline; EUR_lower_bound, the Eurostat pessimistic scenario; LV_lower_bound, a pessimistic path in which TFR is set at 1 for most of the projection horizon; LV_upper_bound, an optimistic path in which TFR is set at 2.1 for most of the period; and LV_upper_bound_max, a more optimistic path in which TFR is set at 3 for most of the period.

Turning from migration to fertility, a clear contrast emerges. Under these scenarios, fertility variation produces much larger long-run differences in population size than migration variation. In the most optimistic fertility scenario, where the total fertility rate is fixed at 3 throughout 2025–2100, population expands rapidly and reaches approximately 3.2 million by 2100, implying a strong reversal of Latvia's current demographic trajectory. At the opposite extreme, a pessimistic scenario with TFR fixed at 1 leads to continuous population decline, with total population falling to around 0.8 million by 2100.

The intermediate scenarios produce correspondingly more moderate outcomes. The Eurostat baseline and pessimistic Eurostat paths both imply continued long-run population decline, while the scenario with TFR at 2.1 generates a much more stable

trajectory by bringing fertility close to replacement level. Taken together, these results show that fertility has the potential to reshape population dynamics much more fundamentally than migration when changes are large and sustained over time.

These scenarios should be interpreted as stylized interventions rather than as equally plausible futures. In particular, the path with TFR fixed at 3 lies far outside the realistic probabilistic range and is therefore mainly illustrative. Its value is to show that, from a purely demographic perspective, sustained fertility changes can alter long-run population development more fundamentally than migration, even though migration remains important.

4.5.2. Replacement Rate Outcomes under Intervention TFR Scenarios

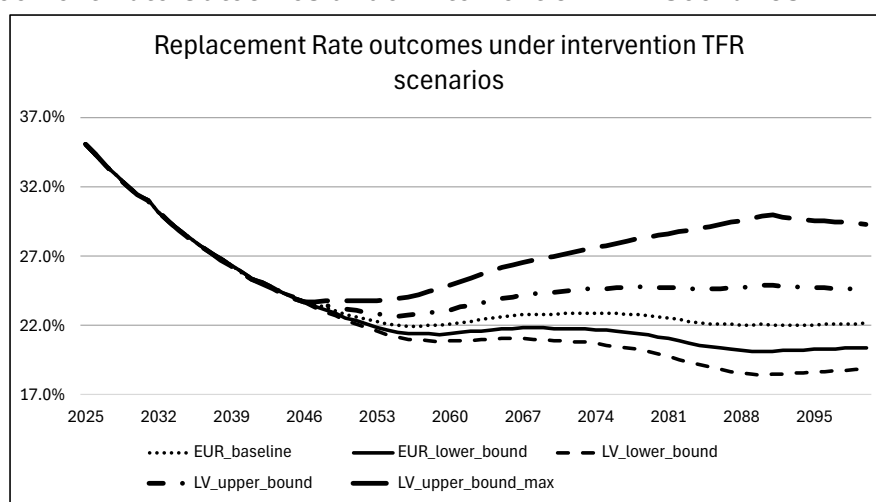


Figure 10: Replacement rate projections under intervention total fertility rate scenarios for Latvia, 2025–2100. Created by authors.

The fertility intervention scenarios add two insights that are less visible in the probabilistic analysis. First, they show more clearly that even very large and sustained fertility increases do not improve pension adequacy quickly, because the transmission mechanism is structurally slow. Larger birth cohorts affect the pension system only once they begin entering the labour force. Second, they show that even when fertility is raised to extreme levels, the effect on replacement rates is not unlimited. Replacement rates eventually stabilize rather than rising continuously, because first-pillar capital accumulation depends on changes in the contributor base relative to the previous year, not simply on the absolute size of the population. The intervention scenarios therefore clarify that the main constraint is not only whether fertility increases, but also how slowly and through what institutional mechanism such increases translate into pension outcomes. This makes the added value of fertility policy lie primarily in sustained long-run support, rather than in any rapid improvement in pension adequacy.

4.5.3. Sensitivity Analysis of Underlying Assumptions in Intervention Scenarios

Sensitivity analysis				
Scenario	Replacement rate (2050)	Replacement rate (2070)	Replacement rate (2100)	pp. Δ against baseline
EUR_baseline	22.8%	22.8%	22.1%	0.00
Earlier fertility	22.7%	22.8%	22.1%	-0.05
Later fertility	22.9%	22.8%	22.1%	0.00
Concentrated fertility	22.8%	22.8%	22.2%	0.05
Wider fertility	22.8%	22.8%	22.1%	-0.04
Lower sex ratio	22.8%	22.8%	22.2%	0.03
Higher sex ratio	22.8%	22.8%	22.1%	-0.02
Narrower migrant age band	22.7%	22.9%	22.2%	0.10
Prime-age migrants	22.5%	23.1%	22.5%	0.32
Lower male migrant share	22.8%	22.8%	22.1%	-0.05
Higher male migrant share	22.8%	22.8%	22.2%	0.05

Table 1: Results summary for baseline replacement rate projection sensitivity to alternative underlying assumptions about migration and fertility. Created by authors.

The sensitivity analysis suggests that the baseline results are generally robust to reasonable changes in the underlying demographic assumptions, with the alternative parameter values for each scenario reported in Table C.1. Most alternative specifications produce only negligible changes in projected replacement rates, indicating that the overall conclusions of the analysis are not highly dependent on specific parameter choices. The largest effects emerge from assumptions related to the age distribution of migrants. Concentrating migrants within prime working ages slightly strengthens the contributor base and increases long-run replacement rates. However, even in this case, the effect remains modest and does not materially alter the broader conclusion that demographic improvements alone are insufficient to restore pension adequacy.

These results should also be interpreted considering the labour-market assumptions used in the model. The current specification assumes that permanent working-age migrants enter the Latvian labour market and earn the same average

wage as the resident population. It also applies common labour-market assumptions rather than separately modelling alternative participation or employment profiles for migrants. Therefore, the migration-related results can be understood as reflecting a relatively favorable integration assumption. If migrants entered employment with a delay, had lower earnings profiles, or participated less consistently in the labour market, the positive effect of migration on the contributor base would be weaker. In that case, the replacement-rate gains from higher migration would likely be smaller than those shown in the baseline intervention scenarios. This limitation is especially relevant for the short and medium term, where migration has the strongest effect on pension adequacy.

Overall, the sensitivity analysis supports the robustness of the thesis findings. Alternative demographic specifications affect the exact replacement-rate values, but they do not change the main conclusion that fertility and migration improvements can cushion demographic pressure but are unlikely, on their own, to restore pension adequacy in Latvia.

5. Conclusion

This thesis examined how demographic uncertainty affects pension adequacy in Latvia by analysing alternative probabilistic outlooks for the total fertility rate and the net migration rate. Using a transparent modelling framework that combines a demographic projection model with a pension capital accumulation model, the study assessed how different demographic trajectories influence the contributor base and, ultimately, pension replacement rates.

The results show that both demographic variables affect pension adequacy, but through different mechanisms and over different time horizons. Migration matters mainly in the short and medium term, as migrants are typically of working age and immediately affect the size of the contributor base. Higher net migration therefore temporarily supports replacement rates, but this effect weakens over time as migrant cohorts age and enter retirement themselves. The probabilistic analysis refines this result by showing that, although uncertainty in NMR leads to very large differences in future population size, it produces a much narrower range of long-run pension adequacy outcomes within the central 80% probability interval. This indicates that migration is most important for short- to medium-term pension sensitivity, while its long-run effect on adequacy is more limited.

Fertility, by contrast, affects pension adequacy mainly in the long run, since changes in fertility influence the labour force only after new cohorts are born and reach working age. Persistently low fertility therefore remains one of the main structural drivers of declining pension adequacy in Latvia. The probabilistic analysis shows that, across plausible fertility paths, TFR remains below replacement level throughout the projection horizon. As a result, fertility uncertainty produces only negligible differences in pension adequacy over the coming decades, with divergence emerging only much later. This clarifies that, although fertility remains highly important for raising replacement rates by strengthening the long-run demographic base of the pension system, relying on TFR improvements to achieve this would be highly unrealistic within the central 80% interval.

Taken together, the findings support the central hypotheses of the thesis. Higher net migration improves pension adequacy in the short and medium term, while higher fertility strengthens adequacy primarily in the long term. The intervention scenarios further suggest that sustained and gradual improvements in these demographic indicators are more effective than one-time changes that are not maintained. At the same time, neither factor alone is sufficient to offset Latvia's long-term demographic pressures. Even under relatively optimistic outlooks, replacement

rate trajectories remain comparatively low, suggesting that demographic improvements alone are unlikely to produce favourable pension outcomes without complementary changes elsewhere in the pension system.

These results should be interpreted with caution, as the model does not capture all possible demographic, economic, or policy developments and assumes that the overall structure of Latvia's pension system remains unchanged over time. The findings should therefore be understood not as precise forecasts, but primarily as evidence of how sensitive pension adequacy is to demographic uncertainty and of the channels through which this sensitivity operates.

Future research could build on this framework by examining the policy mechanisms that may influence fertility and migration in Latvia, including family support, childcare, housing, labour-market conditions, and migration and integration policy. The model could also be extended to incorporate behavioural responses, alternative labour-market scenarios, and possible changes to pension system parameters. This would allow for a broader analysis of how demographic and policy developments jointly shape long-term pension adequacy in Latvia.

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Acknowledgement

The only artificial intelligence tool used in the preparation of this thesis was ChatGPT. It was primarily employed as a supporting tool for literature exploration, particularly through its deep research functionality, which helped identify niche and relevant academic sources related to demographic projections, pension adequacy, and probabilistic modelling. ChatGPT was also used to assist in understanding complex concepts from research papers, to help critique our findings, and to support the interpretation of results by highlighting discussion points that may otherwise have been overlooked. In addition, it was used to improve and refine the R code underlying the demographic and pension models, helping strengthen the structure, clarity, and

functionality of the modelling process. It also contributed to improving the coherence, clarity, and academic tone of the written text, helping ensure a professional and readable presentation of the research. All material produced with the assistance of ChatGPT was carefully reviewed, edited, and verified by the authors to ensure accuracy and to fully reflect their own analysis, interpretation, and academic work.

7. Appendices

Appendix A. Historical Evidence on Chosen Assumptions in the Demographic and Pension Models

Figure A.1. Historical data on number of births according to mother's age in Latvia (Eurostat, 2024). Created by authors.

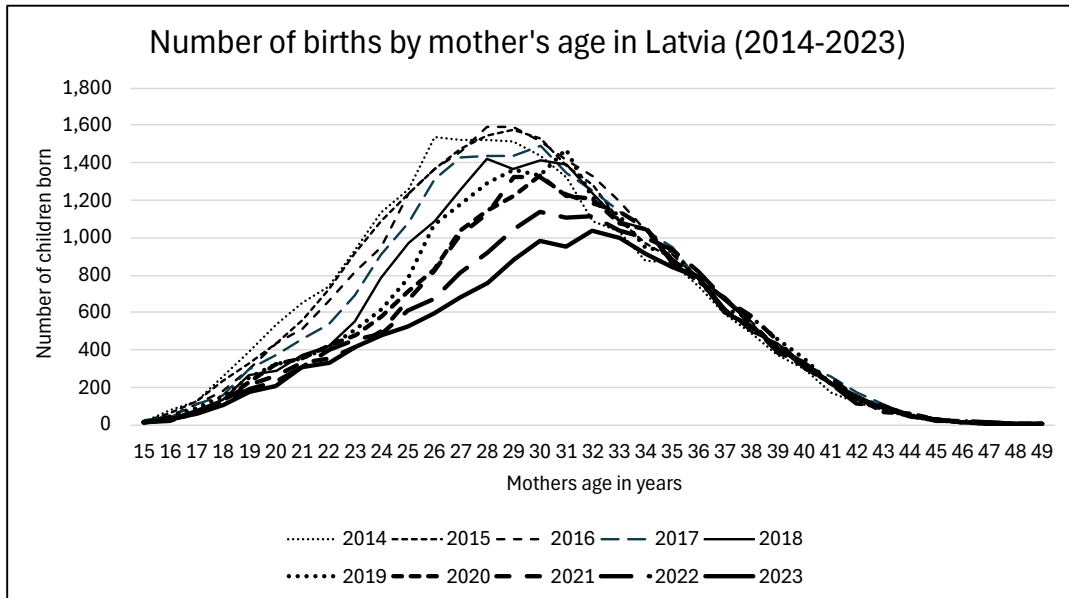
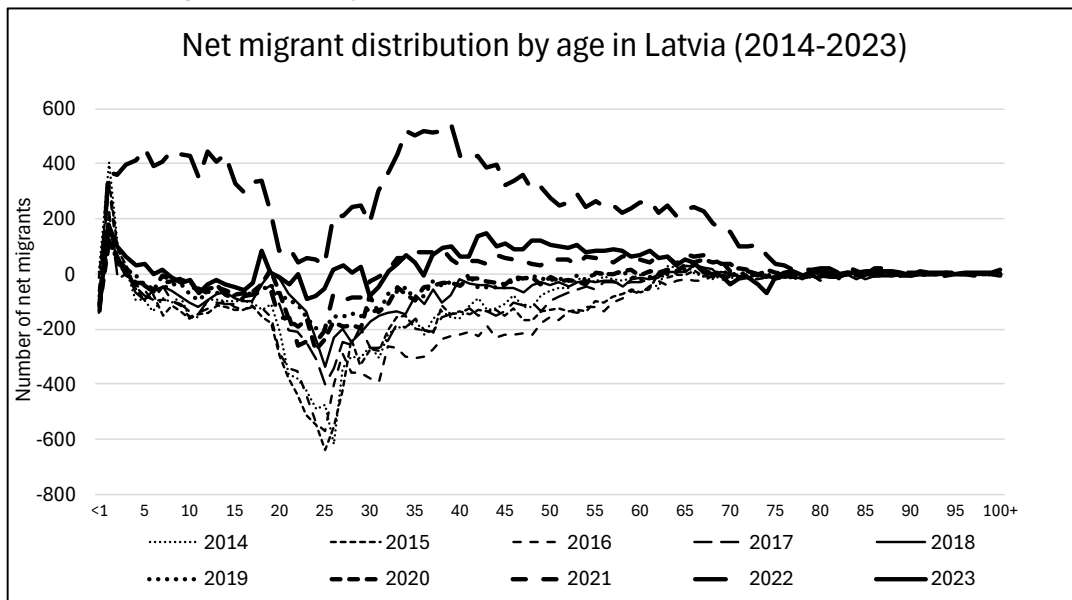


Figure A.2. Historical data on net migrant distribution by age in Latvia (Eurostat, 2024). Created by authors.



Appendix B. Summary of Assumptions Used in the Final Model Results

Table B.1. Assumptions made about fertility and migration based on historic data from Eurostat (2023a) and Trading Economics (2023). Created by authors.

Underlying assumptions		
Assumption	Chosen value	Source
Mean age for women giving birth	30.0	Eurostat (2023a)
Standard deviation for age at which women are giving birth (spread of the distribution)	5.4 (95% of births occur between age 19 and 41)	Eurostat (2023a)
Sex ratio at birth	1.064	Trading Economics (2023)
Age band for migrants	17 - 69	Eurostat (2023a)
Male share for migrants	58.0%	Eurostat (2023a)

Appendix C. Summary of Assumptions Used in the Sensitivity Analysis

Table C.1. Assumptions made about fertility and migration to test sensitivity of baseline replacement rate projections in intervention scenarios. Created by authors.

Underlying assumption sensitivity					
Scenario	Mean birth age	Birth age standard deviation	Sex ratio	Migrant age band	Male migrant share
EUR_baseline	30.0	5.4	1.064	17–69	58%
Earlier fertility	28.0	5.4	1.064	17–69	58%
Later fertility	32.0	5.4	1.064	17–69	58%
Concentrated fertility	30.0	4.5	1.064	17–69	58%
Wider fertility	30.0	6.5	1.064	17–69	58%
Lower sex ratio	30.0	5.4	1.050	17–69	58%
Higher sex ratio	30.0	5.4	1.075	17–69	58%
Narrower migrant age band	30.0	5.4	1.064	20–64	58%
Prime-age migrants	30.0	5.4	1.064	25–54	58%
Lower male migrant share	30.0	5.4	1.064	17–69	50%
Higher male migrant share	30.0	5.4	1.064	17–69	65%