

Population projections for migration scenarios, human capital development, and sustainable integration

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Executive summary

The most important economic asset of a population is its human capital: the skills, educational level, and wellbeing of citizens. Educational expansion and international immigration can increase human capital and mitigate the negative consequences of population ageing. Attracting skilled migrants is key for increasing productivity, and their integration in a way that promotes social cohesion involves new demands to the educational system, social services, and society at large. This challenge is shared by all high-income countries but is especially acute in Finland, with its stalling productivity and educational levels, ultra-low fertility, modest recent history of immigration, and stark concentration of immigrants to the capital region. At the same time, Finland remains a stable and democratic country with high population wellbeing and is increasingly attractive to international talent. Our globally pioneering role as the first wealthy welfare state with a highly aged population provides an opportunity to benchmark best practices in data-driven immigration and labour policies.

The proposed consortium responds to these challenges and opportunities by exploring how human capital and productivity may evolve in Finland under various educational, migration, and integration scenarios. We present a set of multidimensional population projections for Finland between 2025 and 2070, study integration processes and human capital prerequisites, employ methodological innovations, and enhance capacity to use projection tools in education, policy, and research. Specifically, we address the following questions: What are the likely future scenarios of human capital development in Finland, given different types of migration and educational policies, and how do they compare to other high-income countries? How do different scenarios, taking into account uncertainty as well as possible future migration 'shocks', affect labour force productivity, public expenditure, and especially the Finnish pension system? How can Finland compete internationally given the intensifying 'war for talent', and successfully integrate skilled immigrants and their descendants in different regions? How can services and education ensure all children and youth enter adulthood with optimal capabilities, the starting point for a productive and flourishing adult life and healthy ageing?

To answer these questions, MigScene brings together an internationally renowned PI with leading Finnish expertise in data science, economics, demography, and the social sciences, and an international network of population projection centres and experts. The project feeds on constant and systematic interaction with key ministry and policy stakeholders and the major cities in Finland and promotes coordinated and skilled use of population policies and projections. Scientific breakthroughs are sought regarding the scope and indicators of human capital. AI is deployed to enhance the development and use of human capital indicators and adoption of projection tools.

MigScene will present population scenarios and policy recommendations on national and regional levels, and for immigrants' skill development and sustainable integration in different regions of Finland, with a focus on younger generations. We create a new Finnish microsimulation system aimed for general use, employ other national and international microsimulation databases, and develop macro-level projections using a rich array of high-quality survey and register data. In cooperation with Statistics Finland and relevant stakeholders, we aim to synergise the current disparate, uneven and overlapping use of population scenarios in ministries and municipalities and strengthen the use and easy adaptation of this key policy tool.

The core aim of the consortium is to promote sustainable population development (Lutz 2014, Rotkirch 2021), which we measure through economic sustainability, citizen wellbeing and social cohesion, and as resilience to outside shocks. MigScene commits to principles of the National Board on Research Integrity (TENK) at all stages and the principles of open science. This entails making results reproducible through sharing code and also data whenever possible; publishing open access; and disseminating popularised results in local languages. For some of the data, such as individual register-data, sharing is not permitted, but AI tools can assist with providing synthetic data that allows for replication. Teamwork aims to foster ecological and social sustainability, with an even gender and age composition, well-planned personal meetings, and minimal use of flights.

1 Central idea of project and answers to programme questions A–E

Question A. On what challenges defined in the programme is the project focused?

The Finnish population has been rapidly ageing since the 2010s, with notable effects on economic growth and public finances (Kotamäki & Lehtonen 2024). The country is currently characterised by old baby boomers, ultra-low fertility, a modest recent history of immigration, and concentration of immigrants to the capital region. Finland also is a politically stable and democratic country with high wellbeing, increasingly attractive to international talent.

State-of-the-art population projections are key for policy, planning and evaluation and encompass the educational, labour force and migration policies mentioned in the Call. However, current national and regional population projections are unevenly utilised and do not take into account the dynamic and changing nature of migration trends or human capital developments. The existing Finnish microsimulation databases (ELSI, SISU, Kela) are useful for population projections, but are limited by scant data on immigration backgrounds, integration, and wellbeing. They also have restricted access and are difficult to use.

To combat these challenges the consortium will provide four types of new knowledge. First, we develop a *new microsimulation model* suited for labour force, immigration and population projections, as well as *stochastic macro-level population projections*; both projection tools will be accessible to all interested non-commercial parties through a user-friendly interface. Second, we investigate the *effects of different immigration and educational scenarios* on dependency ratios, labour force participation, productivity, and pensions, and compare likely Finnish trajectories with other high-income countries, which enables identification of policy opportunities. We also separately investigate impacts of unexpected ‘migration shocks’ due to e.g. political or natural disasters which cannot be included in regular projections. Third, we investigate *integration patterns of immigrants* over several generations, with a particular emphasis on regional effects and family networks. How immigration contributes to the labour force depends on retention rates, internal migration, and family formation – factors that feed into the structure of the next generations in different parts of Finland. We consider all types of migrant populations including intra-EU mobility and return migration (all types that are available in Finnish register data). Fourth, we investigate *childhood human capabilities*. Many scenarios of future productivity assume improved capabilities and higher human capital in the future, yet such optimism no longer seems self-evident, and we also explore less optimistic scenarios. We integrate key indicators of child and youth wellbeing in different groups. This will be useful for research and policy and contribute to the outcomes of multidimensional projections.

B. How foster cross-disciplinary understanding and conditions addressing challenges?

Multidimensional scenario analyses combine demography with economics, other social sciences and data science. Our cross-disciplinary team members are experts in population projections, microsimulation techniques, forecasting methods, register data analysis, and wellbeing indicators. The MigScene team has pioneered the development of multidimensional population projections. Such projections have two main advantages. We use high-quality microsimulation models, which are not confined to age, sex, and place of residence like traditional forecasts, but can also incorporate variables such as education, migrant background, family status, and labour participation. We also develop probabilistic forecasting methods that indicate the likelihood that any given scenario actually materializes. This is particularly important for migration, which tends to be even more volatile than fertility and mortality. We also involve experts in political science and migration. This allows us to pay attention to immigrant retention and internal migration, trends which are typically omitted in current forecasts. Another innovative step is the proposed integration of youth capabilities into human capital projection variables.

C. How do research fields and interaction partners support achieving solutions?

MigScene brings together an internationally renowned PI, the best available Finnish expertise and key policy stakeholders. Main national partners in research are the Finnish Centre for Pensions, the Urban Research and Statistics Unit (City of Helsinki), and Statistics Finland. Main interaction partners are three major cities Helsinki, Turku, Tampere, and Tampere city region. Confirmed stakeholders include the Prime Minister's Office, Ministry of Finance, Ministry of Economic Affairs and Employment and Ministry of Education and Culture. These are invited to appoint representatives to the national Steering Group which also includes leading macro-economists. Main international partners in research are the International Institute for Applied Systems Analysis (IIASA), the Max Planck Institute for Demographic Research, and the Netherlands Interdisciplinary Demographic Institute (NIDI). The Scientific Advisory Board includes leading EU and international experts on projections. Altogether, this allows for a focused, concerted and ambitious project.

D. Role of AI in relation to the research design and the societal challenges

The use of Artificial Intelligence (AI) is present throughout MigScene in different ways. First, *machine learning techniques* are deployed to identify variable combinations with the largest explanatory power in research with register data and survey data. This pertains to studies of immigrant-native kin networks and their impact on integration, education and labour force participation (WP3, see below), and in relation to capabilities in childhood and youth (WP4). Second, consistent with our commitment to open science and reproducibility, we provide *research replication packages* throughout the project. There are two key bottlenecks in achieving this: code sharing and data sharing. We reduce barriers to both bottlenecks by using AI to optimize code for sharing (White 2024) and by using AI to generate synthetic data in instances where the underlying real data cannot be shared, which is the case for example with register data (Goyal, et al. 2024). Third, we will generate a *learning companion for the new microsimulation system* that we develop in the project. Microsimulation is an exceptionally powerful tool for exploring the possible futures of population dynamics, their causes, and consequences. Microsimulation tools, however, tend to be complex, and their use requires expert knowledge. The scientists in the project (Lutz, Marois, Myrskylä, Tikanmäki) have extensive expertise in developing and applying microsimulation tools. In MigScene, we will take a step further and develop a novel, easy-to-use microsimulation system for general use; and lower the barrier to adoption by generating an AI aided learning companion for

the users. Modern AI will enable also other rapid, interactive and cost-effective *interactions within the Projection Hub*. For instance, we develop a projection explorer app with a chatbot interface to share our findings.

Finally, the rapid development of AI will *alter the effects of education on employment and productivity* in some areas in the coming decades. One strength of our methodologies is that as these effects materialise, we can accordingly alter the parameters of the forecasts.

E. Concrete societal impact of the project

MigScene will develop new knowledge, indicators and a variety of projection tools that are handy for setting realistic goals for immigrant attraction, retention and integration, and youth wellbeing in an ageing society. In close cooperation with Statistics Finland and policy and regional stakeholders, we aim to streamline and synergise the use of key human capital indicators and population projections, using AI to facilitate their use and dissemination. Current national population forecasts rely largely on freeze rate or linear extrapolation projections but are being developed to include more uncertainty measures and alternative scenarios; we utilise and complement this process with regional projections and more detailed migration and educational assumptions.

Two separate approaches are adopted for microsimulation; these serve two different but equally important purposes. The first is to generate *a novel, easy-to-use general microsimulation system for the Finnish context*. We develop an IASA based new model tailored to the Finnish context that is easy to use, openly accessible, and comes with an AI-powered learning companion to reduce barriers to adoption. This model provides microsimulation-based scenarios and projections for key dimensions of population dynamics and human capital. We complement the open-access microsimulation tool by using the Finnish Center for Pensions' long-term pension simulation model ("ELSI"). This model, in contrast to the public-use model, provides a detailed accounting of the Finnish social security system, which has details on the Finnish social security/labour markets/retirements/pension regulations and allows us to *calculate financial trajectories for each potential population future*. ELSI is also the tool that produces "official" expenditure projections; and WP2 will work with ELSI to produce new insight on various expenditure paths, at the very detailed level and in a form that is already integrated into decision making. This two-pronged approach to microsimulation allows us to broaden the use of microsimulation among researchers and stakeholders and directly provide to the stakeholders and decision makers the financial overview of possible population futures.

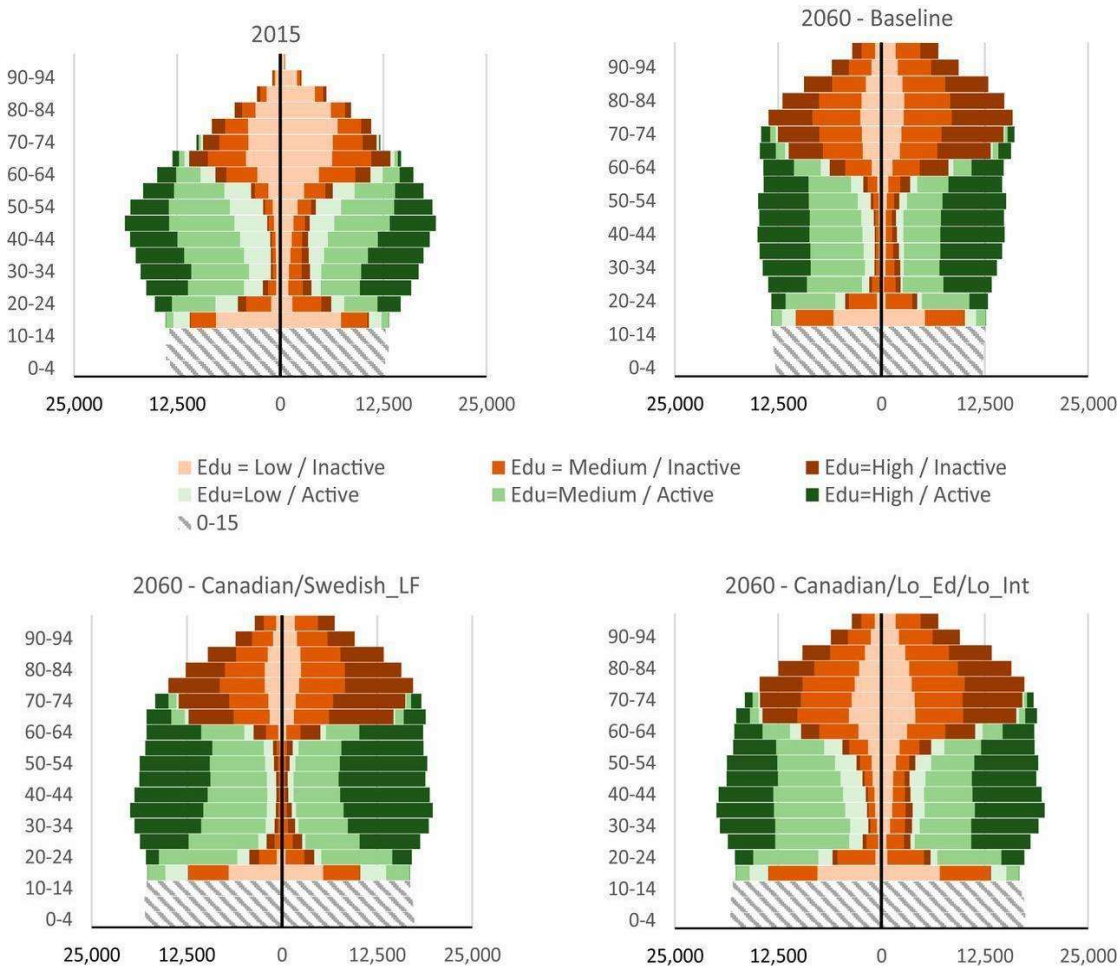
2 Scientific objectives and their justifications as well as objectives for interaction

Including heterogeneity in population projections—such as stratifying the population by educational attainment, labour force participation, place of birth, and their interactions—produces a nuanced and policy-relevant picture of human capital potential and population aging (Marois, Gietel-Basten, & Lutz 2021). The PI Lutz and IASA collaborator Marois have introduced such models to assess productivity effects of migration internationally. When such multidimensional projections are applied, conventional indicators like the age dependency ratio are shown to overstate the expected economic burden of aging, while more sophisticated indicators like the labour force dependency ratio and the productivity-weighted labour force dependency ratio reveal more moderate trends (Marois, Bélanger, & Lutz, 2020). Given stark improvements in the educational profile of the workforce, dependency burdens can remain stable or even decline.

The impact of migration also looks significantly different under these models: rather than the volume of immigration alone, it is the economic integration of immigrants—captured through labour market participation and education—that determines their effect on dependency ratios. High levels of immigration can even have negative consequences if newcomers are poorly educated or excluded from the labour market (Marois et al., 2020). Moreover, immigration can influence fertility patterns, both directly through the typically younger age profile and higher initial fertility of some immigrant groups, and indirectly by altering the educational composition of the reproductive-age population (Potančoková & Marois, 2020).

These findings emphasize the need for population projections that go beyond age and sex and instead incorporate the social and economic dimensions that shape demographic behaviour and policy outcomes. For instance, projection of the EU population to 2060 assuming increases in labour force participation to Swedish levels and / or attraction of skilled migrants with Canadian-style policies show remarkable differences (Figure 1), with impacts on individual member states even starker.

Figure 1. Age pyramids disaggregated by labour force participation and education for the EU-28 in 2015 and 2060 under different scenarios (thousands).



Source: Marois, Bélanger and Lutz (2020) PNAS

Finnish WP leaders have been the first to adapt multidimensional projections to Finland. Results indicated that dependency ratios will worsen in Finland, however they are measured. However, the consequences of population ageing appear less dramatic for economic productivity, if the current

gender gap in educational achievement would disappear and were Finnish men to become as educated as Finnish women (Marois, Rotkirch & Lutz, 2021). Another projection indicated that smaller age cohorts may not harm long-term economic sustainability in Finland if there is robust investment in younger generations (Myrskylä et al., 2024). The considerable interest this work generated in national and regional policy makers provided the impetus for the MigScene proposal.

Research questions. We have four main research questions.

- RQ1. What are the likely future scenarios of human capital development in Finland over the next 50 years, given different types of migration and educational policies? How do these compare to scenarios from other European and high-income countries?
- RQ2. How do different scenarios of human capital development affect public expenditure? How can such macro-level scenarios better consider uncertainty as well as migration 'shocks' due to natural or political events abroad?
- RQ3. What are the prospects for attracting and retaining skilled immigrants, and of integrating them and their descendants in different regions?
- RQ4. How is the wellbeing of children and youth developing among those with migrant and native backgrounds? What indicators can best capture the capabilities, or prerequisites for human capital, among young adults? Are these indicators helpful additions to projections?

We study these goals with a variety of statistical methods: microsimulations, econometric methods including synthetic control methods, machine-learning techniques, and Bayesian methods.

Theoretically, MigScene deploys *unified growth theory* in combination with theories of *human capital, demographic dividend, migration, and youth capabilities*. Decreased population growth can be combined with sustained income growth, as outlined in unified growth theory (Galor 2011). Building on this approach, PI Wolfgang Lutz showed how economic demographic dividends specifically benefit from education (Lutz et al., 2019). We further test and refine these assumptions. Potential for scientific breakthroughs relate to better understanding of productivity in the long run in ageing, multiethnic societies, and better understanding of wellbeing of children and youth in very aged societies. In particular, previous work did not assume ultra-low fertility for a prolonged period, which Finland may have entered (total fertility rate below 1.3 since 2023), and which boosts the need for skilled immigration. Previous forecasts also often assumed that youth wellbeing will improve, and that increases in education will raise productivity, which may be at least partly challenged by digitisation and AI.

Interaction goals. The interaction activities aim to enhance statistical infrastructures in Finland and strengthen knowledge-base and skills for population forecasting. We:

- expand population projections in multidimensional and probabilistic directions
- develop intuitive parametrizations for expected future migration, mortality and fertility, so that scenarios may be modelled with ease
- plan for user-friendly, AI-facilitated and interactive access to different academic and public bodies of publicly available microsimulation models and probabilistic forecasts
- disseminate quarterly migration and population updates
- build capacity to do population projections in regions, research institutes, and ministries, and train users within cities and administration
- train scholars in statistics, economy and social sciences, also within the SKILLS Programme
- invite migrant and youth organisations to participate with their own contents in yearly interactive Population Day, where MigScene results are also disseminated

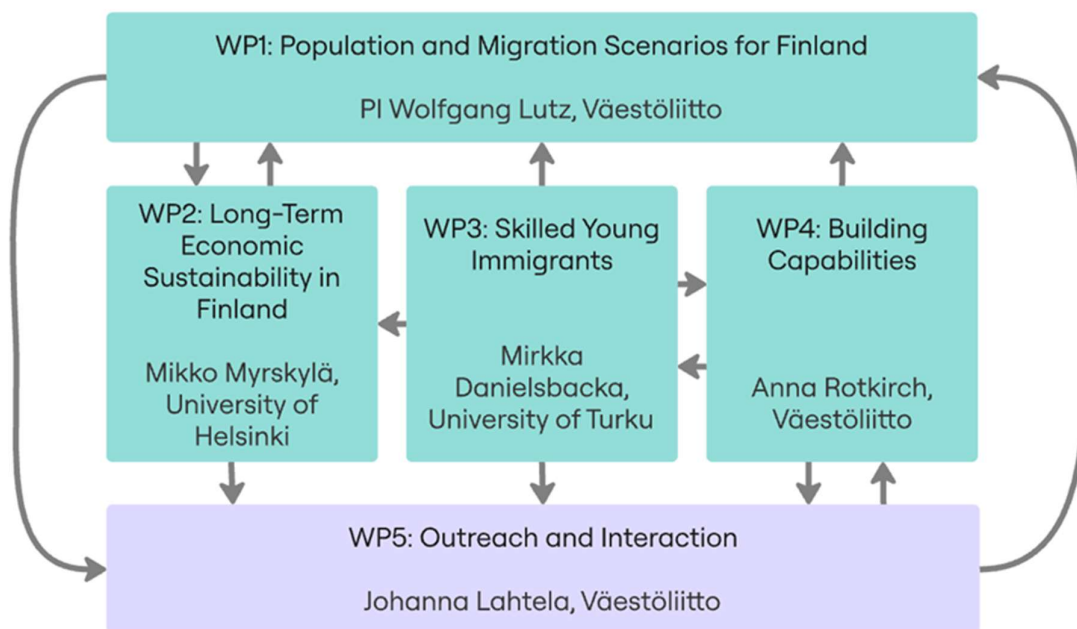
Publication plan: All scientific WPs will publish actively throughout the planned six years in top scientific journals from various disciplines (see Figure 4 Timetable for research activities). Results from international scientific articles will be disseminated to a wider audience through popularised highlights, media events, and short summaries and videos on the project's web pages. Code sharing for each work package research and making R packages developed in WP2 publicly available are also part of the publication plan.

We follow Open Science principles. All scientific results and codes are published open access. Forecasting tools, notably the new microsimulation model and coding for stochastic forecasting, will be made available to all interested parties (upon registration) and training is provided to use it, including AI-facilitated training and interaction.

3 Research implementation, methods and data, listed by work package

The four core research questions are tackled by four Work Packages (WP), with interaction as the fifth WP. The work packages are interlinked and feed key outputs to each other (Figure 2).

Figure 2. Work package output flowchart.



WP1 and WP5 are master work packages which collaborate with all others directly. WP1 and WP2 work with similar issues and methods regarding microsimulation but have different types of outputs, which are fed into Interaction. WP3 and 4 exchange expertise and results on immigration and youth, and their indicators are fed into projections within WP1-2. All WPs also contribute specific outcomes to WP5 and are interlinked in several other ways through methodological exchange, co-authorships and joint supervisions, shared summer schools and stakeholder requests. MigScene collaborator Guillaume Marois will be teaching microsimulation modelling and use of the new model to all MigScene researchers and to a wider student audience at the University of Turku and University of Helsinki. WP leaders (Lutz, Myrskylä, Rotkirch, Danielsbacka) will lead and supervise PhDs and postdocs across WPs.

WP1: Population and Migration Scenarios for Finland, led by Wolfgang Lutz (Population Research Institute, Väestöliitto). WP1 deploys a Finnish and an international microsimulation model to achieve four core aims.

1.1. We develop *a multidimensional population projection model for Finland* using microsimulation. The model will be based on the internationally recognized approach developed by Marois and KC (2021) and Bélanger and (2017), which has been applied in several demographic and policy contexts (van Hook et al. 2020; Marois, Bélanger & Lutz 2020; Gietel-Basten et al. 2024; Marois, Gietel-Basten, & Lutz 2021; Marois, Potancokova, & Gonzalez 2023). It will be *dynamic* and *time-based*—simulating year-by-year transitions in individual life trajectories. Starting from a detailed base population, the model will simulate life events such as mortality, fertility, migration, educational transitions, and labour force participation, using transition probabilities that vary with individual characteristics. Unlike most existing models that rely on public dataset from surveys or census data—often limited in sample size or scope—our model will use the rich Finnish civil registry, which allows the inclusion of many dimensions and their interactions. This enables modelling of immigrant integration processes, such as employment trajectories, geographic settlement, mobility, fertility patterns, and the educational attainment of their children.

1.2. Next, the model will produce *forecasts of the population* by age, sex, education, and labour force status at the national and sub-national level plus selected municipalities up to 2070 with possible extensions to 2100. In addition, it will support the testing of various policy-oriented scenarios, such as changes in immigration levels, educational attainment, or internal mobility, and assess their long-term impact on population outcomes at the subnational level. This part thus provides the core infrastructure for generating evidence-based insights to support strategic planning and regional development policies.

1.3. We use the international IASA microsimulation model, under direction of its developer, collaboration partner Guillaume Marois, for international comparisons. Here, we compare *Finnish scenarios with those of other high-income countries* under different migration assumptions. Similar scenarios were made a decade ago and will be updated.

1.4. We test scenarios with *different integration, retention, fertility and internal migration rates*, which has not been done before. Input from WP3.

1.5. We test the *explanatory value of adding indicators of young adult capabilities* to WP1.1-2, to potentially broaden microsimulation variables of human capital by adding a measure of childhood and youth development, with input from WP4.

Key WP1 collaborator is **Guillaume Marois** who runs the IASA microsimulation model and will train Finnish scholars in the methodology through teaching courses and research visits.

WP2: Long-Term Economic Sustainability under Uncertain Population Dynamics is led by Mikko Myrskylä (University of Helsinki) and consists of two interrelated modules, 1) Long-term economic sustainability and 2) Probabilistic population forecasting.

WP2 package puts forward probabilistic projections for public expenditure scenarios and demographic trends in Finland under alternative migration and human capital scenarios. Using ELSI, the computational microsimulation model developed by the Finnish Centre for Pensions (ETK) that includes a detailed implementation of the Finnish social security, pension, and labour market system (Tikanmäki & Lappo 2020), we analyse how migration-related scenarios affect long-term sustainability. The work with experts from Finnish Center for Pensions and their ELSI model builds on past successful collaborations that analyzed to what extent investments in human capital can compensate for the long-run negative economic impact of low fertility (Myrskylä et al. 2025).

However, this past work ignored the migration and uncertainty in population dynamics, a key focus of WP2.

To state the risk of scenarios occurring we *integrate probabilistic models of future population composition and migration flows with ELSI*. The construction of *probabilistic scenarios* is a key innovation. It allows us to not only test the robustness of Finland's economy under some fixed conditions, but to also state the likelihood of each scenario (Rafael & Selin 2014). The research team has extensive expertise on developing probabilistic forecasting models (Bohk-Ewald, Li, Myrskylä 2018; Hellstrand et al. 2021), and are already working together with Statistics Finland to implement these into official statistics production.

Module 1 “Long-term economic sustainability”, led by Dr. **Sanna Kailaheimo-Lönnqvist**, assesses the development of economic sustainability and public expenditures under various migration and human capital scenarios in Finland.

2.1. First, we evaluate *consequences for public expenditure of significant variations in net immigration*, and their potential impact on population-level employment, productivity, and sustainability of pension expenditures.

2.2. Second, using ELSI we explore the effects of varying *emigration rates* among the Finnish workforce, including migrants, focusing on the departure of highly versus low educated and skilled workers.

2.3. Third, using ELSI we estimate the effects of varying *immigrant integration patterns*, in relation to various initial skill levels, and ranging from rapid integration with high employment rates among immigrants to scenarios of poor integration, over generations

2.4 Fourth, we estimate macro-economic models of expenditure effects of *immigration ‘shocks’*. Abrupt changes in net immigration are often characterized by a sudden rise in unskilled immigration. Utilizing the examples from Sweden in 2006 and 2011-2020, we first apply impact estimates for Sweden to the Finnish context and then assess the effects of immigration shocks on GDP per capita, debt-to-GDP ratio, productivity, and long-term pension expenditure. Using the formalism of hidden Markov models, we specify a probabilistic simulation model for future immigration ‘shocks’. Such models are regularly used in finance to model the financial stress of market shocks on institutions (Soltani & Abbes 2023) and are naturally adapted to the domain of demographic ‘shocks’ (Hainaut 2012). Results allow us to test the microeconomic specifications in WP1 and WP2.1-3.

Additionally, WP2 Module 1 analyses factors like sex, family status, and age in both immigrants and emigrants, and how these affect economic sustainability. We also assess whether it is more advantageous for immigrants to settle in urban or rural areas (in collaboration with WP3) and collaborate with WP5 in creating the chatbot for the Projection Hub.

Module 2 “Probabilistic population forecasting”, led by Dr. **Julia Hellstrand**, focuses on methodological improvements in population forecasting in Finland.

2.5. We produce *probabilistic population forecasts for Finland*. It will integrate scenario-based specification of future fertility, migration, and mortality developments (similar to WP1) with historically and statistically informed uncertainty quantification around Finland's possible demographic trajectories. Specifically, we will:

- Develop and implement a state-of-the-art probabilistic population forecasting model in collaboration with Statistics Finland. The model should be able to produce stochastic simulations of future demographic trajectories which can be integrated into other models, especially the ELSI model in WP2.1-3.

- Adopt the framework of *conformal prediction* to probabilistic demographic forecasting which implements the principle that a prediction is only as good as similar predictions in the past turned out to be (Shafer & Vovk 2008).
- Develop *intuitive parametrizations* for expected future fertility, migration, and mortality so that scenarios may be modelled with ease.
- Develop and test *area-based specifications* of the probabilistic projections.
- Probabilistic scenario forecasting models will be made available in a documented and public R package. WP2 findings will also be shared and popularised through a chatbot interface.

Key collaborators in WP2 are ELSI microsimulation model specialists Dr. **Heikki Tikanmäki** and **Sampo Lappo** at the Finnish Centre for Pensions (WP2.1-3); macroeconomists **Mauri Kotamäki** and **Jonne Lehtomäki** (WP2.4); and Dr. **Jonas Schöley** at the Max Planck Institute for Demographic Research, **Markus Rapo** and Dr. **Anna Pärnänen** from Statistics Finland (WP2.5). Dr. **Aapo Hiilamo** at the Max Planck Institute for Demographic Research analyses the geographical effects (WP2.1-3).

WP3: Skilled Young Immigrants, led by Mirikka Danielsbacka (University of Turku).

One of the most effective ways of integration is to strengthen immigrant ties to the host country through family connections. WP3 studies *ways to attract and retain skilled immigrants* and their children, and the likely trajectories of employment, productivity and family formation of different immigrant groups and generations. WP3 will study all immigration groups (all ethnicities and educational groups) in the population, with a focus on highly skilled immigrants, and in particular those who have come to Finland to study for an academic degree (Mathies & Karhunen, 2021; Mosneaga & Winther, 2013). In 2023, over 30 000 international full degree students were enrolled in universities and universities of applied sciences, which is around 9% of all students.

WP3 has three main aims:

3.1. To analyse the *family and kin networks of all immigrants* in Finland during 1980–2025 using full population register data. The WP3 leader has developed a linked register of family and extended kin relations in the entire population, allowing comprehensive analyses of all migrant groups, including internal migration and emigration.

3.2 Use the same nation-wide register data to *assess which individual-, family- and regional level factors are related to higher retention rates* of immigrants.

3.3. To promote shorter term demand-supply matching and *integration of skilled immigrants*. Here we employ results from WP3.1-2 and investigate international students in Turku and their employment in Finland after graduation, in collaboration with the city of Turku.

Data: Full population register data with kin networks is accessible for WP3 leader via the INVEST research flagship centre (INVEST data (e17)). This data is ideal for studying kin networks of immigrants and the educational or occupational outcomes and retention rates of different immigrant groups (WP3.1-2) and to study retention rates of international degree students (WP3.3). The register data encompasses the whole population that lives in Finland and consists of different types of administrative register-based datasets, typically covering the entire population since the 1970 census. The data is more accurate from the 1980s onwards and for immigrants' kin networks newer data is more useful, since immigration to Finland was very low until then. Crucially, all kin members living in Finland have recently been linked to each other (up to 1st cousins) and thus it is possible to form a kin network for each ego or person. The data is longitudinal, so that it includes ego's relatives in Finland for each year ego is alive. Also living distance and travel time between kin members in Finland, variables related to their socioeconomic situation etc, are available. All these variables can influence how often kin interact with each other and thus provide an important asset

for the aims of MigScene. Such a large dataset with kin networks allows us also to compare different migrant groups and different regions and is internationally unique.

Methods: WP3 will take advantage of cutting-edge (supervised) interpretable machine learning (ML) methods to examine migrants' kin network (Molnar 2022). One of the most valuable assets of ML methods here is the non-parametric nature of the approaches (Hastie et al. 2009; Molina & Carip 2019). That is, they allow for complex non-linear associations and interactions between several predictors to obtain well-fitting models that produce accurate predictions. This flexibility is important here because we have multiple variables describing the kin network structure, which may further potentially interact with each other in an unpredictable manner. In addition to effective and automated variable selection, supervised ML will also rank the predictors in terms of their predictive ability. This provides information on what aspects of the kin network are the most important in influencing different outcomes considered here ("interpretable" versus so-called "black box" methods, Molnar (2022)). Being able to understand and communicate why and how ML predicts the outcomes helps to inform policies.

WP3 provides input to family scenario variables in WP1 and WP2. WP3 collaborates especially with WP4 on studying the capability building of young immigrants with register data and estimates demand and supply of skilled migrants regionally for WP5.

Key collaboration partners in WP3 are political scientist with expertise on Finnish and European immigration and integration, Senior Researcher **Minna Säävälä**, Professor **Bruno Arpino** from the Department of Statistical Sciences at University of Padua (machine learning methods), Senior Lecturer **David Coall** from School of Medical and Health Sciences at Edith Cowan University (effects of kin on minority groups' employment, retention rates and family formation) and researcher and data-experts from INVEST Research Flagship Centre, University of Turku (register data research).

WP4: Building Youth Capabilities, led by Anna Rotkirch (Population Research Institute, Väestöliitto).

WP4 adopts a *child-centred perspective* on cognitive and wellbeing outcomes. Different age cohorts and generations have different economic and family realities (*pace* Kalmijn & Leopold, 2021), which often get lost when statistics represent the current labour force. Many scenarios of future productivity in Europe assume stable or improved skills of younger generations. However, educational levels have stalled in Finland, and are now below the OECD average (33% for men and 46 % of 25–34 year old women in Finland hold a tertiary education, compared to 41% and 54% in the OECD. Also, mental health and youth deaths have deteriorated during the last decade. Finland also has comparatively high levels of societal exclusion of young men, especially men with a migrant background, as the first larger cohorts of second generation immigrants reach adulthood (OECD, 2024; Estévez & Rotkirch, 2024). Another starting point is that better use of the vast and existing knowledge base of families, children and youth is needed for cost-effective and timely policy decisions. We answer to RQ4 and assess *the wellbeing of children and youth among those with both native and migrant backgrounds*. The key focus of the WP is what indicators best capture the *capabilities among young adults*, the future adult generations. The concept of capabilities has received many different and varying applications. Here, we approach it as the potential for the development of manifest human capital in adulthood, and a new human capital indicator in projections. In other words, capabilities denote the social, cognitive and developmental prerequisites for the "freedom to lead different types of life" (Sen, 1993) at the threshold of adulthood.

We plan to:

4.1. *Compile relevant data on children and youth wellbeing*, building on previous national endeavours to compile childhood statistical indicators in which WP4 members have participated (Lahtela & Pärnänen, 2023).

4.2. Building on 4.1, we identify the best general predictors of *human capabilities* at age 18–20, applying both theory-driven and machine-learning techniques (Pelt et al. 2024). This work is the core contribution of WP4 to MigScene and its focus during the first stage of the consortium.

4.3. Next, we build *scenarios of socio-economic and wellbeing* for natives and immigrants, nationally and regionally, together with WP1 and WP2. We test and assess whether human capabilities contribute meaningfully to multidimensional projections of future human capital.

4.4. Within Interaction activities, we can test which ingredients of 4.1. indicators best capture differences between children and youth of different immigrant backgrounds and of different migration generations. We aim to develop *immigrant integration and childhood indicators* from the perspective of younger generations, in collaboration especially with the City of Helsinki as well as Turku, Tampere, and Nordregio. While cities use many indicators of regional segregation and socioeconomic diversity (Vilkama et al. 2023), demographic and child indicators have not yet been more systematically incorporated (cf Pisarevskaya & Scholten, 2025).

4.5. In sync with 4.3 and 4.4, we investigate *effects on retention and integration of various indicators affecting families and children*, together with WP3.

Data: To assess and create key capability variables we employ all available high-quality and systematically collected survey and register data in Finland. WP4 researchers have for decades worked with the wealth of high-quality, but often disparate data on children and youth, and contributed to their systematisation. We also incorporate new data on residence permits combined with extensive individual-level register data maintained by Statistics Finland, and developmental data on children and their families from maternity clinics (neuvola), which is currently being prepared for research utilisation. These will be valuable for research (WP3) and policy (Interaction WP5), and for projections in WP1-2.

Methods: We deploy advanced statistical tools to identify their predictors across different domains of childhood and youth. As in WP3, WP4 will take advantage of interpretable machine learning (ML) methods to identify most useful summary variables. These methods can identify variables in childhood predicting early adulthood outcomes (for an example see Pelt et al., 2024)

Key collaboration partners in WP4 are **Anna Pärnänen** from Statistics Finland (family and migrant statistics, WP4.1-2), senior researcher and Väestöliitto CEO **Tiina Ristikari** (childhood exclusion and poverty, WP4.2-4.), Adjunct Professor **Pasi Saukkonen** and Chief Specialist **Tuuli Anna Renvik** from the Urban Research and Statistics Unit (various integration and wellbeing measures, City of Helsinki (WP4.3), and Senior Researcher, Docent **Minna Säävälä**, Director of integration services at Ministry of Employment (WP4.4-6). Mutual research exchanges will take place with the team of **Helga de Valk** at NIDI.

WP5: Outreach and Interaction, led by Johanna Lahtela (Population Research Institute, Väestöliitto).

WP5 gathers all outreach and interaction and is also responsible for the internal coordination of the consortium (meetings, events, communication, reporting). WP5 is led by Johanna Lahtela (50% WP5) supplanted by a research coordinator (50%).

WP5 partners and target audiences consist of our interaction collaborators, stakeholders, and the general public. Committed **interaction collaborators**, who directly contribute to and adopt our end results, include the three major cities Helsinki, Turku, and Tampere and the Tampere city region,

Statistics Finland, and Finnish Centre for Pensions. **Stakeholders** represent other public bodies, institutes, and leading experts, and ministries (see answer C above). We also wish to disseminate knowledge for the SKILLS programme, promoting synergy and capacity building within it. The General public is accessed through dissemination and communication and events. See the Interaction plan below.

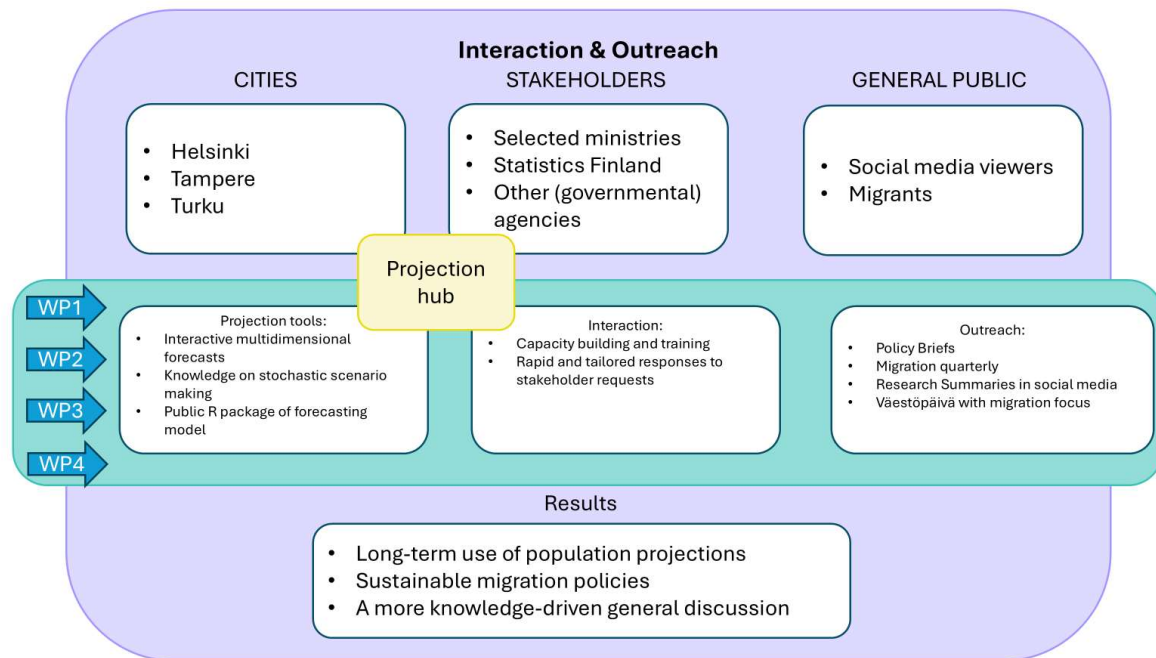
Research ethics: In all stages of the project, we are committed to the ethical principles of the Finnish National Board on Research Integrity. All data have received ethical approval. All users of register data sign Statistics Finland’s license and commit to follow their ethical rules.

Equality and non-discrimination: There is an even gender balance in the core research team and the PI is a non-native. We adhere to the Equality Plan of the Family Federation of Finland (Väestöliitto).

4 Implementation of interaction

The endpoint of each MigScene research step is the long-term use of population projections and sustainable migration policies. We aim for national capacity and infrastructure that persists after the project. This part of the interaction work package is called the **Projection Hub**. Other ways of interaction, popularisation, media contacts and outreach are here summarised under **Outreach** (Figure 3).

Figure 3. Interaction and Outreach flowchart.



Key consortium interaction bodies

Steering group. The national Steering Group includes 7–9 key stakeholders and leading economists. Participants include one representative from the Prime Minister’s Office, Ministry of Finance, Ministry of Economic Affairs and Employment, Ministry of Education and Culture, Statistics Finland and professor in macroeconomics **Niku Määttänen** (University of Helsinki and Helsinki Graduate School of Economics). The SG meets live for half a day once per year to discuss project progress, results, and eventual concerns. Extra meetings may be held if major geopolitical

events occur and create new demands for scenarios. Members can ask for consultation and information continuously.

Scientific Advisory Board meets yearly, **see point 6**.

Newsletter. *Population Quarterly* will be posted four times per year on the project website and distributed by e-mail and social media. It is a short visually appealing compilation of latest migration trends (immigration, emigration, and internal migration) and expert comments, and if shown to be useful, will continue it after the end of the consortium.

Policy briefs. MigScene creates scenarios, presents a set of likely future developments and policy choices for immigration and integration policies based on projection results. We also evaluate how different population scenarios will affect the pension system, and how unexpected outside increases in migration affect public expenditure.

Projection Hub. Our single main output is to improve migration and population **policy tools and statistical infrastructures** in Finland through the Projection Hub, which will benefit collaboration partners, policy makers, and scholars. The Projection Hub aims to

(i) provide *multidimensional population forecasts* and the capacity to use them

- spread knowledge of Finnish *microsimulation models* developed and used in the project, and knowledge of how to use them
- spread *knowledge of stochastic scenario* making
- provide the forecasting models in a documented and *public R package* that allows easy use of the forecasting approach within the scientific community and beyond.
- develop a *user-friendly chatbot*, using a conversational approach empowers users and helps them to better understand the assumptions, uncertainties and scenarios plausible via different policy pathways.

(iv) coordinate and provide *capacity building and training*: teaching students at MA, PhD and post doc levels through courses and summer schools at the University of Turku and its INVEST flagship, and the University of Helsinki, and through international exchange of visiting scholars to IIASA and Max Planck Institute

(v) create a *Population Quarterly newsletter*, which follows Statistic Finland releases on migration (March), births (June), ageing (September) and marriages (December). The Quarterly comments on the newest statistics, adds our own variables (e.g., migration retention rates, tempo-adjusted fertility rates, years of Good Life in ageing, and the gap between wishing for a partner and having one, as well as wishing to be a parent and actual fertility, in different population groups), and provides EU / OECD / global context to it.

(v) facilitate constant, *rapid and tailored responses to collaborator and stakeholder requests*. Experience shows that needs may arise in relation to a ministry report, a new initiative, or an unexpected event.

The first year is devoted to collecting requests and wishes regarding the Quarterly and planning the Quarterly and the technical implementation of the data services on the Hub; MigScene leaders have knowledge of similar formats from EU projects. Year 2 launches the Population Quarterly to email subscribers, the web page and on key social media platforms. Data on spread is collected, and year 3 gathers additional feedback on perceived usefulness and decides on optimal format to continue in years 4-6. Year 3 launches the pilot version of the new microsimulation model. Other consortia in the SKILLS programme are invited to participate in the Population Days.

Media and general public outreach. MigScene also disseminates knowledge to parties not directly interested in population policy tools or news. In addition to the Quarterly newsletters and policy briefs, 2–4 *short summaries* of research results and policy briefs are written monthly in Finnish and Swedish. We organise media brunches 2–3 times / year.

Population Day. The *Population Day*, organised each May by Väestöliitto since 2023, is a live and partly streamed full day of interactive events and short research highlights. Depending on its topic, we invite experts, organisations and policy makers to participate, e.g. as panel guests or as hosts of a pop-up spot. The Population Day is planned to focus on migration in the second, fourth, and final programme year of the consortium (2027, 2029, and 2031). Preliminary topics are population projections (2027), wellbeing of second generation of immigrants (2029), and family formation of immigrants (2031). Other consortia in the SKILLS programme are also invited to participate in Population Day.

All WP leaders will be involved in Outreach, aided by WP5 director **Johanna Lahtela** and a research coordinator NN. PI and WP1 leader **Wolfgang Lutz** is chair of the Steering Group and the Scientific Advisory Board. WP2 leader **Mikko Myrskylä** coordinates educational and summer school planning, implementation and evaluation. WP3 leader **Mirkka Danielsbacka** will coordinate the policy briefs. WP4 leader **Anna Rotkirch** is responsible for Population Day planning and media strategy of the consortium.

5 Consortium's responsibilities and competence as regards scientific and societal impact

The PI of the consortium **Wolfgang Lutz** is a world leading specialist in demographic analysis, population projections, and population and sustainable development. He was for 25 years head of IIASA's World Population Program and recently Interim Deputy Director General for Science of IIASA and Founding Director of the Wittgenstein Centre for Demography and Global Human Capital (IIASA, Austrian Academy of Sciences and Univ. of Vienna). The author and editor of 28 books and special issues and more than 300 refereed articles, Lutz has been elected to six Academies of Sciences (including US-NAS, TWAS, and Tiedeseura) and received several international prizes for his research. Lutz has a close and long-lasting connection to Finland. His PhD concerned Finnish fertility, and he is fluent in Finnish. Since 2024, Lutz is Distinguished Professor at the Population Research Institute, Väestöliitto. He also continues to work with IIASA, so that MigScene and the entire SKILLS programme could benefit from his experience and connections in population and migration studies. Lutz will devote 10% of working time to direct the consortium and participate in its events, supervision, and outreach. WP3 leader Danielsbacka will, in addition to leading her WP, devote 20% of her working time to support the PI with administration related to recruitment and reporting processes of the consortium.

WP2 leader **Mikko Myrskylä** is Director of the Max Planck Institute for Demographic Research, Professor of Social Data Science at the University of Helsinki, and previously Professor of Demography at the London School of Economics. Myrskylä is the PI of the ERC Synergy project BIOSFER: Untangling the causes of low fertility in modern societies, and Director of the Max Planck-University of Helsinki Center for Social Inequalities in Population Health. He has PhDs in Demography and Statistics, and his expertise covers forecasting, microsimulation, and labour demography.

WP3 leader **Mirkka Danielsbacka** works as a Professor of Sociology at the INVEST research flagship centre, University of Turku. An expert in family sociology, her publication list includes 109 peer-reviewed articles or book chapters and 12 books or edited volumes. Danielsbacka's main research themes are intergenerational family relations, health, wellbeing, and social networks. She is also leading an international MA programme at the University of Turku.

WP4 leader **Anna Rotkirch** is Research Professor and Research Director at the Population Research Institute, Väestöliitto - the Family Federation of Finland. She has also served as Demographic

Rapporteur to the previous and current Finnish governments. An expert on fertility, family relations, and population policies, she is internationally recognised for her scientific and policy work, with over 200 research articles and 10 academic and popular books. Her expertise includes internal migration and regional population indicators. She is skilled in science communication and popularisation in Finnish, Swedish and English languages and PRI has under her direction gained notable national and international visibility and policy relevance. Rotkirch is familiar with this funding instrument as Co-Pi of a previous STN consortium, NetResilience.

Outreach WP5 leader, **Johanna Lahtela**, MA of Social Science in Sociology, is Research Coordinator in Population Research Institute, Väestöliitto. Through her roles as Country Team Operator of SHARE Finland and working with child and population statistics at Statistics Finland, she has vast experience of interaction and stakeholder cooperation. She also has experience of working with migrant children and their families within the Finnish Red Cross and being a court appointed representative for unaccompanied asylum-seeking children.

Core MigScene researchers already have access to most of the datasets utilized in the project, so we can start to carry out the scientific research as soon as the project starts. It might be that for the recruited new researchers there is a small delay in starting data-analyses because the permissions to use Finnish register data are sometimes delayed but we have reserved time for them to apply the permission to use the data.

6 International collaboration and researcher mobility

Main international partners in research are International Institute for Applied Systems Analysis (IIASA), the Wittgenstein Centre for Demography and Global Human Capital, and the Max Planck Institute for Demographic Research.

In addition, MigScene has international collaboration with professors Bruno Arpino (University of Padua, Italy), David Coall (Edith Cowan University, Australia) and Helga de Valk (The Netherlands Interdisciplinary Demographic Institute, Netherlands).

Research mobility:

- up to 2 years research visit to IIASA to train Finnish researchers in microsimulations
- up to 3 months visit to Max Planck Institute for Demographic Research related to key themes such as demographic forecasting, migration, and labour market sustainability
- up to a full academic semester at a time visits to the Comparative Life Course and Inequality Research Centre (CLIC) in the Dept of Political and Social Sciences at the European University Institute (EUI)
- up to 4 research visits to the Stockholm University Demography Unit (SUDA)
- up to 6 months research visit to University of Padua (Arpino) and Edith Cowan University (Coall), which conduct related to studies on kin networks of immigrants,
- up to 4 months research visit to NID related to the studies on children and youth

International Scientific Advisory Board:

- **Anne Goujon**, Programme Director, Population and Just Societies, International Institute for Applied Systems Analysis (IIASA)
- **Fabrizio Natale**, Joint Research Center, European Commission
- **Thomas Nedomysl**, Research Directors, Nordic research centre for regional development and planning (Nordregio)
- **François Pelletier**, Chief, Demographic microsimulation projection section (DEMOSIM), Statistics Canada
- **Helga de Valk**, Professor, Research Director, The Netherlands Interdisciplinary Demographic Institute

- **Pieter Vanhuyse**, Professor of Political Economy and Public Policy, Department of Political Science and Public Management, University of Southern Denmark

7 Schedule and cost estimate

Schedules for research and interaction activities are presented in Figures 4 and 5. The project starts on 1st October 2025 and ends on 30th September 2031. All WPs run for the whole funding period, including WP5 (interaction) (Fig 4). Research activities and timetable for WP1 - WP4 are described in more detail in WP descriptions.

Figure 4. *Timetable for research activities*

	25	2026		2027		2028		2029		2030		2031	
	II	I	II	I	II	I	II	I	II	I	II	I	II
WP1 Population and Migration Scenarios for Finland													
WP1.1													
WP1.2													
WP1.3													
WP1.4													
WP1.5													
WP2 Long-Term Economic Sustainability under Uncertain Population Dynamics													
WP2.1													
WP2.2													
WP2.3													
WP2.4													
WP2.5													
WP3 Skilled young immigrants													
WP3.1.													
WP3.2													
WP3.3.													
WP4 Building capabilities													
WP4.1													
WP4.2													
WP4.3													
WP4.4													
WP4.5													
WP4.6													

Figure 5. *Timetable for interaction activities*

	25	2026		2027		2028		2029		2030		2031	
	II	I	II	I	II	I	II	I	II	I	II	I	II
MigScene Interaction and Outreach													
Steering group													
Scientific advisory board													
Dissemination & Capacity Building													
Population Quarterly													
Result summaries													
Media brunch													
Population Day at PRI													

Consortium cost estimate

The total applied budget of the consortium for the whole six year period is 5 999 740€. Budget for the first funding period is 2 999 870€ and 2 999 870€ for the second period.

Salaries (including indirect employee costs and overheads, and yearly inflation of 2%): 5 246 682€. The PI will be salaried for 10% of working time for the entire funding period. In WP5 the interaction specialist is budgeted for 50% and the project coordinator 50% of working time for the duration of the project. In all WPs at least one postdoc is working full time and for most of the time two postdocs are working simultaneously. Senior scholars are differently salaried for periods I and II depending on their opportunities to take full time off for this project, but they will all be participating in meetings and supervision throughout the project. There is also joint supervision of postdocs by PI and WP leaders. The first recruitments will be conducted immediately after we receive the funding decision. The salaries, computed according to the standard salary levels of the host and partner institutions in equivalent jobs, take by far the biggest part of the project.

Travel expenses: 623 507€. We have budgeted 1-2 international conference trips for all scholars working in the project. Travel expenses also include travel costs related to research visits and mobility allowances. We have budgeted funding in order to invite our international research collaborators to work with the consortium, mainly to cover the travel and housing expenses. We have budgeted 1-2 international visitors per year, and they are expected to spend 2-10 weeks in the project. Also travel costs for international collaborators who participate in academic/scientific seminars are budgeted.

Equipment: 40 545€. Equipment costs are mainly computer and statistical software costs.

Materials: 110 221€. Costs from using the register data, as well as use of AI tools.

Services: 220 932€. Paying for publication in open access journals and language checking as well as online visualisation, interactive features and publication for the Projection Hub in Interaction and Outreach WP5.

Other costs: 153 999€. Other expenses are related to academic/scientific seminars, costs related to the Steering Group, Scientific Advisory Board, and other core stakeholder group seminars and visits, press conferences, social media campaigns, MigScene visual appearance and website.

Costs arising from interaction activities: WP leaders, post doc and PhD contributions to interaction are budgeted in Salaries. Licenses for visualisation and AI tools are budgeted in Services. Other interaction costs include yearly visits to Turku and Tampere regions à 3 days yearly, educational summer schools (every second project year or 3 times), 1-2 press launches yearly, the Väestöpäivä / Population Day event every 2nd project year, and preparation for its materials and interactive programme with selected migrant organisations.

8 Bibliography

- Bélanger, A. & P. Sabourin (2017) *Microsimulation and Population Dynamics* Cham: Springer Nature.
- Bohk-Ewald, C., L. Peng & M. Myrskylä (2018). Forecast accuracy hardly improves with method complexity when completing cohort fertility. *PNAS* 115(37), 9187-9192.
- Galor, O. (2011). *Unified Growth Theory*. Princeton University Press.
- Gietel-Basten, S., Marois, G., Torabi, F. & Kabiri, K. (2024). Reframing policy responses to population aging in Iran. *Genus* 80, 8.
- Goyal, M. & Mahmoud, Q. H. (2024). A systematic review of synthetic data generation techniques using generative AI. *Electronics* 13(17), 3509.
- Grund, S., Lüdtke, O., & Robitzsch, A. (2022) Using synthetic data to improve the reproducibility of statistical results in psychological research. *Psychological Methods* 29(4), 789–806.
- Estévez, J. L., & Rotkirch, A. (2024). Challenges in the pathway to parenthood and their part in explaining depressed fertility among migrant descendants. SocArXiv.
- Hellstrand, Julia, et al. (2021) Not just later, but fewer: Novel trends in cohort fertility in the Nordic countries." *Demography* 58(4), 1373-1399.

- Kalmijn, M., & Leopold, T. (2021). A new look at the separation surge in Europe: Contrasting adult and child perspectives. *American Sociological Review*, 86(1), 1-34.
- Kotamäki, M. & Lehtimäki, J. (2024) *Getting too old for this: Economic effects of ageing population in Finland*. No. 168. Aboa Centre for Economics (ACE), Discussion paper 168.
- Lahtela, J. & Pärnänen, A. (2023) Knowledge about children - Current status and development needs. Final report on Measure 24 of the National Child Strategy. Statistics Finland.
- Lutz, W., Crespo Cuaresma, J., Kebede, E., Prskawetz, A., Sanderson, W. C., & Striessnig, E. (2019). Education rather than age structure brings demographic dividend. *PNAS*, 116(26), 12798-12803.
- Marois, G. & Potančoková, M. (2020). *Scenarios of labor force participation and employment integration of immigrants in the EU: demographic perspective*. Publications Office of the EU.
- Marois, G. & Samir, KC (2021). *Microsimulation Population Projections with SAS*. London: Springer Nature.
- Marois, G., Bélanger, A., & Lutz, W. (2020). Population aging, migration, and productivity in Europe. *PNAS*, 117(14), 7690-7695.
- Marois, G., Gietel-Basten, S., & Lutz, W. (2021). China's low fertility may not hinder future prosperity. *PNAS*, 118(40), e2108900118.
- Marois, G., Potancokova, M., & Gonzalez-Leonardo, M. (2023). Demographic and labor force impacts of future immigration flows into Europe: does an immigrant's region of origin matter? *Humanities and Social Sciences Communications*, 10(1), 1-10.
- Marois, G., Rotkirch, A., & Lutz, W. (2022). Future population ageing and productivity in Finland under different education and fertility scenarios. *Finnish Yearbook of Population Research*, 137-160.
- Mathies, C., & Karhunen, H. (2020). Do they stay or go? Analysis of international students in Finland. *Globalisation, Societies and Education*, 19(3), 298-310.
- Molina, M., & Garip, F. (2019). Machine learning for sociology. *Annual Review of Sociology*, 45, 27-45.
- Molnar, C. (2022). Interpretable machine learning: A guide for making black box models explainable. Leanpub.
- Mosneaga, A. & Winther, L. (2013) Emerging talents? International students before and after their career start in Denmark. *Population, Space, and Place*, 19: 181-195.
- Myrskylä, M., Hellstrand, J., Lappo, S., Lorenti, A., Nisén, J., Rao, Z., & Tikanmäki, H. (2025). Declining fertility, human capital investment, and economic sustainability. *Demography*, 62(2), 489-514
- Myrskylä, Mikko, Julia Hellstrand, Sampo Lappo, Angelo Lorenti, Jessica Nisén, Ziwei Rao, and Heikki Tikanmäki. "Declining fertility, human capital investment, and economic sustainability." *Demography* (2025).
- OECD (2024) Education at a glance: Country Notes – Finland.
- Pelt, D. H., ... & Bartels, M. (2024). Building machine learning prediction models for well-being using predictors from the exposome and genome in a population cohort. *Nature Mental Health*, 2(10), 1217-1230.
- Pisarevskaya, A. & Scholten, P. (2025). *Cities of Migration: Understanding the Diversity of Urban Diversities in Europe* (p. 216). London: Springer Nature.
- Ramírez, R., & Selin, C. (2014). Plausibility and probability in scenario planning. *Foresight*, 16(1), 54-74.
- Rotkirch, A. (2021) Population policy guidelines for the 2020s. Executive summary, Linjauksia 2020-luvun väestöpolitiikalle, VNK 2021:2.
- Sen, A. (1993). Capability and well-being. In Nussbaum, M. / Sen, A. (1993, eds) *The Quality of Life*. Oxford: Clarendon Press.
- Shafer, G., & Vovk, V. (2008). A tutorial on conformal prediction. *Journal of Machine Learning Research*, 9(3).
- Soltani, H. & Abbes, M. B. (2023). The predictive power of financial stress on the financial markets dynamics: Hidden Markov model' *Journal of Economics and Finance* 47, 1, 94-115.
- Tikanmäki, H. & Lappo, S. (2020). ELSI: The Finnish Pension Microsimulation Model. Centre for Pensions 08.
- van Hook, J., Bélanger, A., Sabourin, P., & Morse, A. (2020). Immigration selection and the educational composition of the US labor force. *Population and Development Review*, 46(2), 321-346.
- White, M., et al. (2024) The model openness framework: Promoting completeness and openness for reproducibility, transparency, and usability in artificial intelligence. *arXiv preprint arXiv:2403.13784* (2024).
- Vilkama, K., Högnabba, S., Bernelius, V. & Henriksson, R. (eds, 2023). Segregation ennalta ehkäiseminen ja lieventäminen Helsingin kaupungissa. City of Helsinki Memoranda 2023:1.