MOBI-TWIN

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Simulating regional futures: How spatial mobility shapes inequality and sustainability under the twin transition

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Key Messages

- **Effectively navigating regional decline requires shifting from reactive interventions to early, front-loaded transition investments.** Addressing digital and green capacity before demographic tipping points are reached prevents cumulative, irreversible drivers of long-term decay.

- **Ensuring demographic sustainability requires shifting from tracking total population to prioritizing youth and prime working-age retention.** Monitoring aggregate growth often masks the depletion of the 18–40 age group, which is vital for labor-force renewal and stability.

- **Combating spatial polarization requires shifting from broad regional aggregates to granular, subregional place-based policies.** Identifying specific municipalities at risk ensures that cohesion frameworks address internal core-periphery divergence rather than just pilot-level averages.

- **Achieving spatial justice requires shifting from standard demographic growth targets to independent, targeted distributional frameworks.** Since income equality does not mechanically follow population gains, policymakers must target distributional outcomes directly to prevent deepening inequality.

Background & Context

Europe's regions are undergoing profound structural transformation driven by the green and digital transitions. These processes reshape not only economic structures but also patterns of spatial mobility, influencing where people live, work, and invest their skills.

The **MOBI-TWIN project** investigates how these dynamics affect regional inequality, sustainability, and demographic trajectories. To explore potential future developments, the project developed **a spatial micro-simulation and agent-based modelling (ABM) framework** to simulate how individual mobility decisions interact with regional conditions and policy environments.

The model examines how alternative transition pathways and future scenarios influence population change and inequality in **five pilot regions**: Central Macedonia (Greece), Castilla-La Mancha (Spain), North & East Finland (Finland), Lombardy (Italy) and Northern Netherlands (Netherlands).

It simulates population dynamics over a ten-year horizon, representing individuals as agents whose relocation decisions depend on socioeconomic characteristics, residential preferences, and regional opportunities. By linking micro-level mobility behaviour with macro-level regional outcomes, it provides new evidence on how mobility can affect regional disparities.

MOBI-TWIN Evidence

1. The model: Agent-based simulation powered by spatial microsimulation

The MOBI-TWIN framework integrates spatial microsimulation and agent-based modelling, enabling the analysis of regional dynamics from the bottom up.

The approach operates in **three stages**:

1. **Synthetic population generation:** High-resolution regional populations are constructed using EU-SILC microdata combined with behavioural insights from the MOBI-TWIN survey.

2. **Behavioural modelling of mobility decisions:** Agents represent individuals whose migration or relocation decisions depend on factors such as income, education, age, employment status, and regional attractiveness.

3. **Scenario-based simulation of regional futures:** The model simulates monthly population changes over a ten-year horizon, allowing comparisons between alternative transition pathways and policy conditions.

This modelling architecture allows policymakers to explore counter-factual futures, how regions might evolve under different policy choices, economic conditions, and transition trajectories.

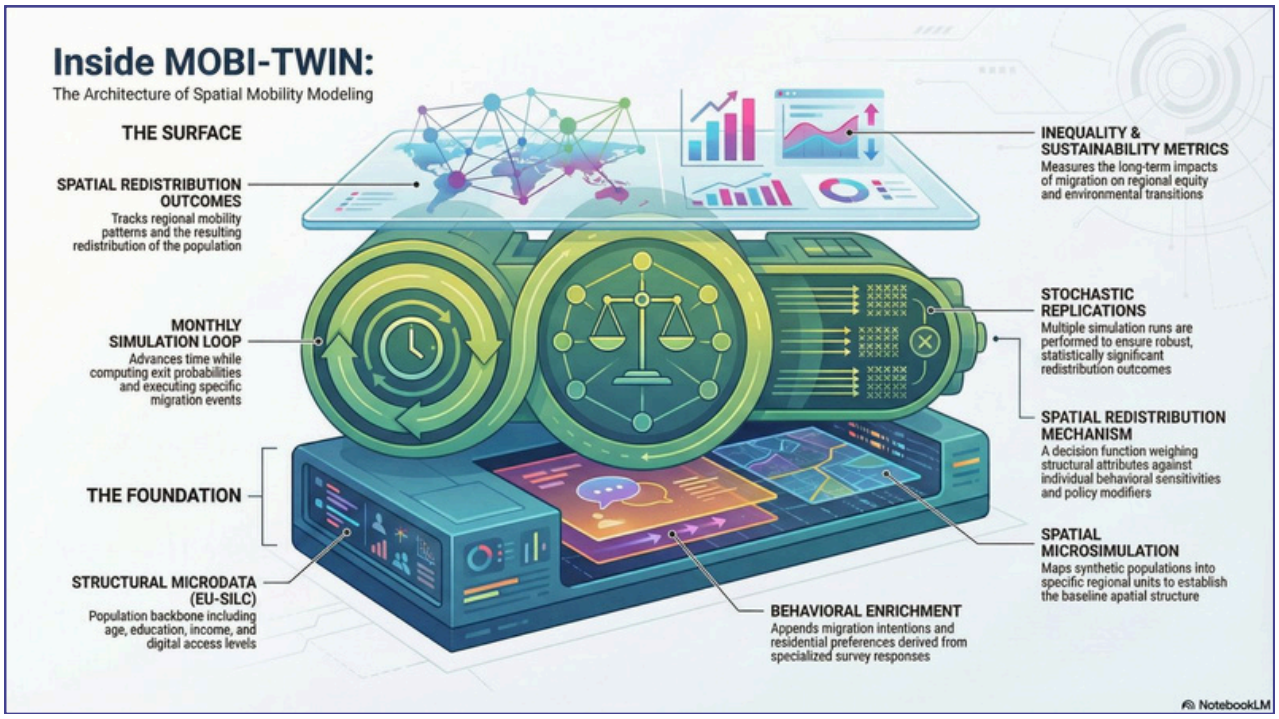


Figure 1. Schematic representation of the architecture of spatial mobility modeling. Generated with NotebookLM

2. Policy pathways and transition scenarios

The four policy pathways—No Transition, Digital Transition, Green Transition, and Twin Transition—reflect how the digital and green dimensions of the transition jointly or separately shape residential attractiveness. These **pathways are crossed with four narrative scenarios representing different macro-contexts shaping regional development**, ranging from rapid innovation-driven transformation to high-risk trajectories characterised by shocks and structural pressures:

Leapfrog
rapid regional advancement through proactive policy and innovation

Dark Horse
unexpected regional gains from niche strengths or external catalysts

Snail Pace
slow, uneven progress dominated by inertia and demographic decline

Lion's Den
high-risk trajectory with compounding shocks, geopolitical pressures, and vulnerability

Within the model, scenarios influence how strongly regional conditions affect mobility behaviour and population change. The model was calibrated against EU population projections (PROJ_19RP3) for the 2025–2035 period, ensuring a plausible baseline for each pilot before scenario experiments are applied.

3. A consistent scenario gradient across all pilots

Across all pilot regions, simulation results reveal a consistent and widening demographic gradient linked to scenario context. By the end of the 10-year horizon, **the gap between the most favourable (Leapfrog) and most adverse (Lion's Den) scenario exceeds 30%** points in Central Macedonia and Castilla-La Mancha, and remains substantial in all other pilots.

Across all pilots, scenario context—not just policy pathway—is the primary driver of long-run demographic outcomes. The widening divergence after mid-horizon signals cumulative compounding effects that are difficult to reverse without early intervention.

Key pilot-level outcomes at Year 10 under Twin Transition:

Central Macedonia — A structurally lagging and peripheral region, where adverse contexts generate persistent, compounding decline.

EL52

Leapfrog (+) 20.0%

Lion's Den (-) -12.5%

Castilla-La Mancha — An economy in structural transition, where only the most favourable scenarios consolidate demographic gains.

ES42

Leapfrog (+) 24.4%

Lion's Den (-) 6.6%

North & East Finland — A Balanced Innovator where baseline already trends negative; favourable scenarios offset structural headwinds rather than simply adding growth.

FI1D

Leapfrog (+) 17.6%

Lion's Den (-) 11.0%

Lombardy — Another economy in structural transition, where cumulative inflow and retention advantages compound sharply under Leapfrog.

ITC4

Leapfrog (+) 20.6%

Lion's Den (-) 6.8%

Groningen — A Balanced Innovator with an already-negative baseline (-2.1%), where the scenario ladder separates contexts that reverse vs. amplify underlying decline.

NL11

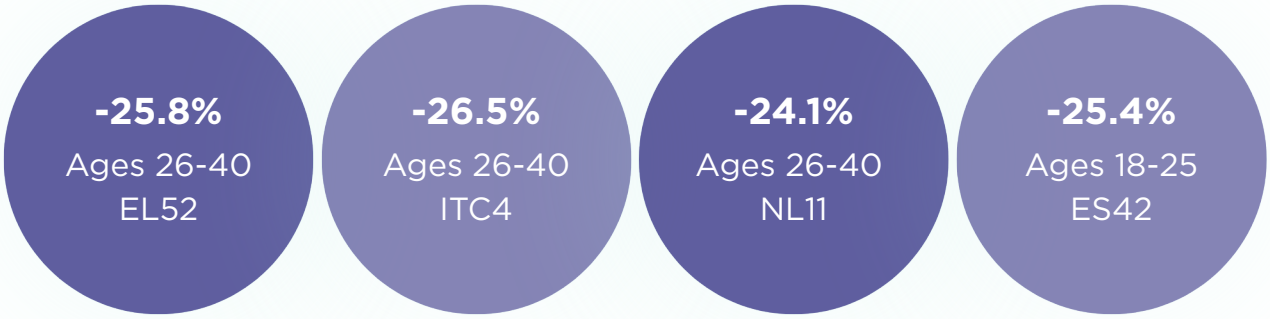
Leapfrog (+) 13.3%

Lion's Den (-) 7.6%

4. Cohort Dynamics: The hidden demographic risk

Total population trajectories alone obscure a more consequential finding: across all pilots, **adverse scenarios concentrate losses in the youngest and prime working-age cohorts**. The 18–25 and 26–40 age groups account for a disproportionate share of divergence, with consequences for labour-force renewal, welfare sustainability, and long-run demographic stability.

Lion's Den



Critically, favourable total-population outcomes do not always signal healthy age structure recovery. In Northern Netherlands, under Dark Horse (total +5.0%), ages 18–25 still fall 7.4%, and ages 26–40 fall 9.8%. In Finland, under Dark Horse, the totals are positive, but ages 26–40 remain negative. This means demographic sustainability risks can persist even when headline population figures improve.

Policymakers should treat working-age cohort retention as a primary indicator alongside total population, since regions can show 'positive' aggregate trajectories while experiencing sustained depletion of labour-force renewal cohorts.

5. Spatial heterogeneity: Beyond pilot-level averages

Scenario context does not shift population uniformly; it reshapes the internal geography of each pilot. Cross-scenario population change maps show that **favourable scenarios generate more spatially widespread positive change, extending gains beyond core urban centres**. Adverse scenarios produce more continuous zones of decline, leaving only localised pockets of relative resilience.

This territorial polarisation dynamic is particularly visible in Central Macedonia, where adverse scenarios form contiguous decline zones, and in Lombardy and Finland, where fine-grained heterogeneity across subregions reveals differentiated local trajectories even under the same scenario.

6. Distributional outcomes do not follow population patterns

A central finding across all pilots is that changes in income equality and other distributional indicators do not mechanically track population change. The **income equality maps are spatially heterogeneous across all scenarios**, including under Leapfrog, indicating that favourable demographic trajectories can coexist with uneven distributional adjustment.

Between-subregion inequality in income equality changes modestly in level but differs in direction across scenarios. **Adverse scenarios tend to widen spatial dispersion** in distributional outcomes, while the most **favourable scenario context in some pilots (notably FI1D and ES42) is associated with reduced between-subregion disper-**

sion. In Lombardy, dispersion tends to rise even under baseline scenario, highlighting that distributional divergence can emerge independently of aggregate demographic trends.

Regional equity policies must target distributional outcomes directly. Improving demographic totals without addressing compositional sorting and subregional distributional dynamics may leave spatial inequality unchanged or deepen it.

Policy Recommendations

1. Invest in transition capacity before demographic tipping points. The simulation results show that scenario differences compound over time, **becoming most pronounced in the second half of the 10-year horizon**. Early investment in digital and green transition capacity has an outsized long-run effect because it shapes the trajectory before cumulative mechanisms, such as out-migration, ageing, and reduced fiscal capacity, become dominant.

- **Target** ERDF, RRF, and cohesion investments to structurally lagging and peripheral regions (such as EL52) before baseline trajectories entrench demographic decline.
- **Design** transition investment packages that jointly address digital infrastructure, green energy, and skills, as the Twin Transition pathway consistently outperforms single-axis interventions in the model.
- **Use** the scenario ladder as a planning tool: regions currently resembling 'Snail Pace' conditions should treat 'Leapfrog' outcomes as reachable with proactive, coordinated investment rather than aspirational outliers.

2. Prioritise youth and prime working-age retention. Given that adverse scenarios concentrate disproportionate losses in ages 18–40, **regional strategies must address the specific drivers of early-**

career out-migration: employment quality, housing affordability, digital and green job opportunities, and quality-of-life conditions valued by younger cohorts.

- **Incorporate** cohort-specific demographic indicators (not just total population) into regional monitoring frameworks and programming targets for cohesion policy post-2027.
- **Design** place-based retention strategies for ages 18–40, including remote-work-enabling infrastructure, entrepre-neurship ecosystems, and green-skills training aligned with regional economic strengths.
- **Recognise** that a pilot showing positive total population growth can simultaneously be losing labour-force renewal cohorts. Re-gional strategies should screen for this asymmetry.

3. Address spatial polarisation within regions, not just between regions. The cross-scenario maps demonstrate that scenario context reshapes internal core-periphery dynamics, concentrating decline in peripheral subregions under adverse conditions. EU cohesion frameworks typically address disparities between regions, but **within-region territorial polarisation may be the more proxi-mate challenge in the next decade**.

- **Extend** place-based targeting to the subregional level, identifying municipalities and LAU-2 units at elevated risk of demographic decline within otherwise 'average' NUTS-2 regions.
- **Use** agent-based and spatial microsimulation outputs as evidence for within-region differentiation in Smart Specialisation Strategies and Just Transition Plans.

Pilot remote-work and green-economy relocation incentives that redirect inflows toward smaller and peripheral subregions, building on the remote-work mechanism tested in the MOBI-TWIN model.

4. Decouple demographic and distributional policy. The finding that distributional outcomes, particularly income equality, do not track population change means that **demographic policies alone are insufficient for equity objectives**. Compositional sorting, differential out-migration by income group, and subregional concentration of higher-income in-movers can all worsen distributional outcomes even as the headline population improves.

Track income equality and other distributional indicators at the subregional level as standard outputs of regional monitoring, not just at NUTS-2 aggregate level.

Design anti-displacement and mixed-income housing policies alongside mobility-attracting investments, particularly in regions experiencing inflows under Leapfrog conditions.

Include between-subregion inequality (Gini across subregions) as a supplementary cohesion indicator alongside standard convergence metrics.

5. Mainstream dynamic simulation into regional policy foresight. MOBI-TWIN demonstrates that agent-based simulation is operationally feasible at the EU regional scale and produces policy-relevant insights not accessible from aggregate projections. **The modular, scenario-based design supports systematic counterfactual comparison and transparent uncertainty communication**.

Integrate spatial microsimulation and ABM tools into EU regional monitoring frameworks, providing dynamic population projections that are sensitive to policy pathways rather than trend-based extrapolations alone.

Use the MOBI-TWIN modelling workflow as a template for post-2027 cohesion policy evaluation, particularly for ex-ante assessment of territorial impacts under alternative transition scenarios.

Build institutional capacity in national and regional statistical offices to apply and interpret dynamic microsimulation outputs alongside conventional Eurostat projections.

Conclusions

The **MOBI-TWIN modelling framework** provides some of the most **detailed quantitative evidence** yet available on how the twin transition will interact with residential mobility to reshape EU regional demographics, age structure, spatial distribution, and distributional outcomes. The findings are both encouraging and cautionary.

They are encouraging because they show that proactive, integrated transition investment, particularly under Twin Transition conditions, can generate sustained demographic gains, reverse baseline decline in lagging regions, and reduce between-subregion distributional divergence. The Leapfrog scenario is not utopian; it is achievable with coordinated, early acting policy.

They are cautionary because the simulation results demonstrate how adverse scenarios compound over time, how demographic losses concentrate in precisely the cohorts, such as young adults and prime working-age residents, that regions most need to retain, and how distributional outcomes can deteriorate even when aggregate population improves.

*The twin transition is not a passive backdrop to regional demographic change—it is an active driver. The **policy choices made in the next five years will determine which regions move toward Leapfrog trajectories and which are locked into Snail Pace or Lion's Den futures**. Evidence-based, place-sensitive, and proactively timed action is the decisive variable.*

MOBI-TWIN has demonstrated the feasibility and policy value of dynamic, place-based simulation for EU cohesion governance. **The next step is effectively integrating these tools within the regional policy cycle**, from programming through monitoring to evaluation, so that the precision of simulation evidence can routinely inform the ambition and targeting of EU regional strategy.

This Policy Brief was written by: Anastasia Panori, Elli Papastergiou (Aristotle University of Thessaloniki); Dimitris Ballas, Thanasis Ziogas (University of Groningen).

Layout: Elli Papastergiou (Aristotle University of Thessaloniki)

Consortium:

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