Mapping the co-evolution of policy frameworks and modelling systems: A comparative approach

Quantitative modelling frameworks increasingly shape how policymakers understand, value, and manage ecosystem services. Yet, the evolution of these modelling tools is rarely examined in relation to the policy environments that motivate their development. Existing scholarship has highlighted the importance of policy–model interactions (Bagstad et al., 2013; Johnson et al., 2025; Li and Goslee, 2025; Rounsevell et al., 2012) but comparatively little attention has been paid to how national and regional policy targets actively steer the trajectory of innovation in modelling. The aim of this study is to investigate the dynamic interplay between policy ambition and modelling infrastructure, focusing on how regional policy priorities influence the scope, structure, and methodological choices of ecosystem service modelling efforts.

By comparing modelling initiatives across regions with differing environmental objectives and regulatory pressures, this analysis identifies systematic patterns in how policy ambitions (or lack thereof) such as biodiversity conservation targets (CBD, 2020; IPBES, 2016), climate neutrality commitments (UNFCCC, 2022), and chosen policy instruments, drive innovation in modelling capabilities. For countries with stringent biodiversity and/or climate targets, we would expect their research institutions to develop modelling frameworks with higher spatial resolution, more explicit treatment of uncertainties, and stronger integration of biophysical and economic components. We conduct this analysis within the context of the European Union (EU) member states.

Methodological Approach

The study draws on two complementary datasets that have been recently compiled in a major research project aiming at understanding the transformation towards a Sustainable European Agricultural and Land use systems nicknamed SEAL (IFRO, n.d.). The first contains information on quantitative economic simulation models, including computable general equilibrium models, partial equilibrium models, and optimization models developed and/or used in EU member states. This dataset documents model architecture, data inputs, spatial and temporal resolution, and the degree to which various ecosystem services are integrated. The second dataset characterizes national policy environments and is based on an extensive review of approximately 675 strategy documents and more than 30,000 legislative texts, validated through consultation with national experts. It captures the policy targets and policy instruments used by 13 EU member states, as follows:

- Policy targets (e.g., ecosystem services targets around biomass provision, food provision, climate change mitigation, and biodiversity)
- Policy instruments utilized (market-based tools, financial schemes, regulatory standards, voluntary schemes etc.)

To uncover relationships between policy environments and model characteristics, the study applies a two-stage analytical strategy:

1. Cluster Analysis enabling the comparison of member states policy environments

Cluster analysis (Everitt et al., 2011) is used for grouping member states according to similarities in their policy profiles. Although the sample size is modest (13 countries), hierarchical clustering remains appropriate for exploratory pattern detection, particularly when the objective is to identify policy archetypes rather than to make statistical generalizations. Hierarchical clustering does not require large samples and is widely applied in small-N comparative research because it can reveal meaningful structure when supported by robustness checks and validation diagnostics

2. Correspondence Analysis (CA) between the policy archetypes and model attributes

Correspondence analysis (Greenacre, 2017) is then applied to explore associations between policy archetypes (revealed in stage one) and modelling attributes (found in the review of modeling architecture). CA is particularly suited for categorical and mixed-type data, enabling visualization of how modelling sophistication, data integration, and methodological choices align with different policy contexts. Variables included in the CA include:

- Spatial resolution (fine (field level or even more), medium (sub-national), coarse (country, regional, global))
- Temporal resolution (annual, decadal, scenario-based, timeline not specified)
- Integration of ecosystem service (none, partial, full, for the four ecosystem services: food provisioning, biomass provisioning, climate - GHG, biodiversity)
- Treatment of uncertainty (qualitative, probabilistic, scenario-based)
- Data sources (remote sensing, administrative datasets, survey-based inputs)
- Model type (IAM, CGE, PE , agent-based, etc.)

Several test will be used to assess the robustness of associations, and permutation tests evaluate the statistical significance of observed patterns.

Key Contribution

The findings highlight a reciprocal relationship: while models inform policy design and evaluation, policy frameworks themselves act as catalysts for expanding modelling complexity and infrastructure. Regions with ambitious ecosystem service targets tend to invest in more integrated, data-rich modelling systems, which in turn enable more nuanced policy evaluation. This feedback loop underscores the importance of understanding modelling evolution not merely as a technical process but as a policy-driven trajectory.

This work contributes to the GTAP community by clarifying how policy environments actively shape the evolution of quantitative modelling frameworks. This study provide empirical evidence on a topic that aligns closely with the GTAP community's long-standing focus on developing modelling tools that support policy analysis, while also reflecting on the potential danger of overfitting assessment tools with policy agendas, as regions with less strict policies may not have the developments in modelling infrastructure enabling an assessment of the negative environmental implications of enacted policies. The methodological approach, which combines cluster analysis with correspondence analysis, offers a replicable framework that GTAP researchers can use to compare modelling practice differences.

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