Simulation Models for Agricultural Policy Analysis and Assessment: Scope and Relevance

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* The presentation reflects personal views

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2. Scope (types and scales; policy areas covered)
3. Relevance (current use; alignment with current needs)
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1. Introduction

- What is an agricultural policy evaluation issue you would like to better understand through modelling?
- Examples of questions that simulation models CAN deal with:
  - What would be the impact of a new subsidy or climate policy on farm incomes? (ex-ante)
  - What would be the impact of a change in the types of farm subsidies on farm productivity? (ex-ante)
  - What would have been the economy-wide impacts of a greener policy mix in comparison to the impacts of the policy applied? (on-going / ex-post)
- Examples of questions that simulation models CANNOT deal with:
  - Will farmers feel more secure due to the introduction of a new subsidy?
  - What will be the exact weather conditions affecting crop yields ten years from now?
  - What unforeseen political events will disrupt agricultural markets in the next decade?
  - How will administrative inefficiency affect the implementation of an agricultural subsidy?
  - Which specific farms went bankrupt due to a tariff change?

1. Introduction

- Simulation models perform well at “what-if” analyses — like how a price support affects wheat supply — but falter on questions requiring exact predictions or unquantifiable human behavior. For these, complementary qualitative research or real-time monitoring is needed.
- So, what are they?
  - Quantitative tools that resemble agricultural (rural) systems to estimate policy outcomes
  - Quantitative, computer-based tools simulating real-world systems (crops, markets, etc.)
- Why they matter?
  - They are very important in providing evidence-based policy assessments, dealing with various policy domains (food security; sustainability; economic impacts).

1. How can we use simulation models?

Ex ante → Ex post

Primarily used for ex-ante analysis. One can forecast policy outcomes before implementation, simulating different policy scenarios.

Ex post analysis is less common but can apply for data interpretation (i.e., like sensitivity analysis) and for recalibration or validation vs actual outcomes or to explore why certain outcomes occurred.

e.g., to explore the difference on impacts which would have occurred in the case of different policy mix(es) such as different policy scopes, different targeting of beneficiaries, etc.

Examples:

- EU agriculture faces a need to increase production by 30% by 2050 - simulation models can help us achieve this sustainably.
- An RDP with a focus on productive investments generated X number of new jobs; A higher/lower number of new jobs would have been generated if the RDP had focused on greener investments.

2. Scope of simulation models used for agricultural policy analysis & evaluation – Types of models

Economic models

- Partial Equilibrium Models: focus on specific sectors of the economy (e.g., agriculture) and analyze how policy changes affect prices, quantities, and welfare in that sector.
- General Equilibrium Models (CGE): consider interactions across all sectors of an economy. Useful for understanding the broader economic impacts of agricultural policies, including indirect effects through markets for labor, capital, and other goods.

Bio-economic models

- Combine biological and economic aspects to simulate the performance of agricultural systems under different policy scenarios.
- Particularly useful for analyzing sustainability and the impact of policies on natural resources like soil, water, and biodiversity

Agent based models

- Simulate the actions and interactions of autonomous agents (i.e., farmers, consumers, or policymakers) to assess their effects on the system as a whole.
- Can capture the heterogeneity of agricultural agents and their decision-making processes, providing insights into how policies might be adopted or resisted

2. Scope of simulation models used for agricultural policy analysis & evaluation – Types of models

System Dynamics Models

- Useful for understanding the behavior of complex systems over time.
- Can model feedback loops, delays, and non-linear relationships that are common in agricultural systems, helping to forecast the long-term implications of policy changes.

Optimization Models

- Can be used to find optimal policy solutions under given constraints.
- Might involve linear programming for maximizing profit or minimizing costs under various policy scenarios or environmental constraints.

Environmental Impact Models

- Life Cycle Assessment (LCA) Models: evaluate the environmental impacts associated with all stages of an agricultural product's life. Can help in policy-making by assessing sustainability.
- Hydrological and Soil Models: Such as SWAT (Soil & Water Assessment Tool); crucial for policies related to water management, soil health, and erosion control in agriculture.

2. Scope of simulation models used for agricultural policy analysis & evaluation

- **Scales** of simulation models: farm level; regional; national; global
- **Key features**:
  - Ability to integrate multiple variables (e.g., weather, farmers' behavior, markets)
  - Capacity to perform predictive and scenario-based analysis
- **Agricultural policy areas** covered:
  - Land use and resource management (e.g., impacts of irrigation policies)
  - Climate change adaptation and mitigation (e.g., carbon pricing, resilience to draught, etc.)
  - Subsidies (e.g., farm income support; support for investments)
  - Trade (e.g., impacts of tariffs, etc.)
  - Food security and supply chains (e.g., price volatility, production shocks).

3. Relevance of simulation models used for agricultural policy analysis & evaluation

- Why they are useful:
  - **Bridge between data and decision-making**: Translate complex systems into actionable insights. Facilitate evidence-based decisions.
  - **Address uncertainty**: Model and test risks such as climate variability or market fluctuations.
  - **Stakeholder inclusivity**: Provide a common framework for farmers, governments, and researchers.
- Alignment with current needs:
  - Rising demand for sustainable agriculture amid population growth and climate change.
  - Policy complexity: Need for tools to evaluate trade-offs (e.g., productivity vs. environmental impact, etc.).
  - Example (more in the next presentation): i) Use of CAPRI model in EU subsidy reform led to improved targeting of CAP funds; ii) IMPACT model predicts how trade tariffs affect global food prices, etc.

4. Models - Summary Examples

- **IFM-CAP:** Developed by JRC and designed for micro-level economic and environmental assessment. It is a farm-centric, static simulation tool optimized for detailed CAP analysis, especially micro-level economic and environmental impact assessment. While primarily used for ex-ante, it can also be adapted for ex-post analysis by calibrating the model with actual policy outcomes to understand past impacts on individual farms.
- **CAPRI:** Employed for both ex ante and ex post assessments of CAP impacts. For ex-post evaluations, it has been used to analyze historical data to assess actual outcomes of policy changes.
- **AGLINK-COSIMO:** A recursive-dynamic, multi-commodity, partial equilibrium model tailored for medium-term agricultural market analysis, relevant for global coverage and policy simulation. This model, used for agricultural market projections, can also be applied to understand historical policy impacts by comparing model projections with actual market outcomes following policy changes.

4. Models - Summary Examples

- **SEAMLESS-IF:** SEAMLESS-IF is a modular, multi-scale, and policy-focused framework that integrates bio-physical and economic models to evaluate agricultural sustainability and policy impacts, offering a robust and complex tool for linking science to decision-making in the EU context. The model allow for ex-post analysis by comparing simulated outcomes with observed data after policy implementation. SEAMLESS-IF has 4 components, namely:
  - APES (Agricultural Production and Externalities Simulator): A bio-physical model simulating crop and livestock production at the field level, capturing yields and environmental externalities (e.g., nutrient leaching)
  - FSSIM (Farm System Simulator): A bio-economic farm model optimizing farm decisions (e.g., crop choice, input use) under policy and market conditions, applied at farm-type level.
  - EXPAMOD: An econometric model for upscaling farm-level results to regional aggregates.
  - CAPRI Market Module: Adapted from the CAPRI model, it handles global trade and market equilibrium, linking farm supply to regional and international markets.

4. Models - Summary Examples

- **RURAL-ECMOD:** Recursive-Dynamic CGE models utilized for ex-ante CAP impact assessement in several EU regions and MS.
- **IMPACT:** Model developed by IFPRI to assess trade policy impacts.
- **iMAP Platform:** The iMAP (Integrated Modelling Platform for Agro-economic Commodity and Policy Analysis) is a comprehensive modelling framework developed by the JRC, in collaboration with DG AGRI. It was established in 2005 and serves as a policy support tool for evaluating the economic impacts of agricultural, rural development, and related policies across the EU and beyond.

5. Models in detail

- CAPRI (Common Agricultural Policy Regionalised Impact) Model:
    - Global agro-economic tool designed for ex-ante impact assessment of agricultural, trade, and environmental policies, with a primary focus on the EU. A partial equilibrium model that integrates economic and environmental analyses to support decision-making, particularly for the CAP.
    - CAPRI's structure consists of two interlinked core modules: a supply module and a market module, which together provide detailed projections and scenario analyses for medium- and long-term perspectives, extending as far as 2085.
    - The supply module is regionally focused, covering approximately 280 aggregate programming models at the NUTS 2 level across the EU27, Norway, Turkey, and the Western Balkans. These models represent agricultural activities by maximizing regional income under constraints such as land availability, policy variables, and nutrient requirements. Each region includes around 50 crop and animal activities, with high- and low-yield variants allowing for endogenous yield adjustments. This granularity enables CAPRI to capture the diversity of EU agriculture, including farm-type specifics when extended to around 2,450 farm-regional models. The module incorporates detailed CAP instruments, ensuring policy relevance.

5. Applications in detail

- Main characteristics of CAPRI (Common Agricultural Policy Regionalised Impact) Model:
  - The market module provides a global perspective, modelling bilateral trade for about 50 agricultural commodities across 77 countries grouped into 40 trade blocks. It simulates market-clearing prices, which are iteratively aligned with the supply module's fixed-price assumptions, ensuring consistency between regional production and global market dynamics. This spatial multi-commodity approach allows CAPRI to assess trade impacts and welfare effects, including agricultural profits, tariff revenues, and consumer welfare, at both Member State and global levels.
  - A standout feature is CAPRI's environmental analysis capability, facilitated by a spatial downscaling component that maps results to a 1x1 km grid across the EU27. This enables precise assessment of environmental indicators like greenhouse gas emissions, ammonia, nutrient balances (NPK), and biodiversity, linking agricultural practices to ecological outcomes. Data consistency is maintained through a robust database sourced from EUROSTAT, FAOSTAT, and other reliable statistics, processed in GAMS.
  - CAPRI's template-based design ensures structural uniformity across regions and products, enhancing comparability and maintenance efficiency while integrating with broader modelling networks like SEAMLESS. Its open-source nature and active Pan-European developer network further bolster its adaptability and scientific credibility, making it a key tool for EU policymakers in DG AGRI, DG ENV, and DG CLIMA. Results are presented through interactive maps and tables, offering actionable insights into economic and environmental trade-offs.

5. Models in detail

- Main characteristics of RURAL-ECMOD Model:
  - The RURAL ECMOD is a recursive dynamic Computable General Equilibrium (CGE) model developed to assess the economic impacts of agricultural and rural development policies, particularly the CAP, on regional economies. Designed for ex-ante spatial policy analysis, it focuses on rural-urban interactions and was applied to six case study regions in the EU, simulating policy scenarios over the period from 2006 to 2020. The model's primary aim was to evaluate the effects of CAP reforms, such as shifts between Pillar 1 (direct payments) and Pillar 2 (rural development) funding or redistributions within Pillar 2, on rural and urban economic structures.
  - A key feature of RURAL ECMOD is its foundation on a Social Accounting Matrix (SAM), constructed by mechanically downscaling higher-level input-output data and balancing it with superior regional data. This SAM provides a detailed snapshot of economic flows, disaggregated by rural and urban areas, agricultural sectors by farm size, and household types. The model's recursive dynamic structure solves year-by-year, capturing short-term adjustments and long-term trends, making it suitable for medium-term policy analysis up to 2020. It incorporates key elements like rural-urban disaggregation and farm-size differentiation, enabling simulations of policy impacts across diverse economic agents and spatial contexts.

5. Models in detail

- Main characteristics of RURAL-ECMOD Model:
  - RURAL ECMOD simulates economy-wide effects, though its results show limited overall impact, with more pronounced and significant outcomes in rural economies. It models policy measures based on Rural Development Programme (RDP) spending, mapping investments into specific SAM sectors, such as agriculture, infrastructure, or rural services. The model accounts for interdependencies between rural and urban areas, including commodity flows and factor incomes, using a bi-regional SAM framework. This allows it to capture spillover effects, like how urban demand influences rural production or how rural policy shifts affect urban welfare.
  - The model's strengths lie in its detailed sectoral and spatial granularity, offering insights into how CAP scenarios influence agricultural output, employment, and income distribution. For instance, it assesses whether increasing Pillar 2 funding boosts rural diversification or if redistributing funds enhances small farm viability. However, its focus on six specific regions limits broader generalization, and its recursive nature may overlook long-term structural shifts beyond 2020. Developed under the EU's Joint Research Centre, RURAL ECMOD remains a useful tool for policymakers seeking to balance rural development with urban spillovers, providing a framework to test policy trade-offs in a controlled, data-driven environment.

5. Models in detail

- Main characteristics of iMAP Framework:
  - The iMAP (Integrated Modelling Platform for Agro-economic Commodity and Policy Analysis) framework is a comprehensive, policy-oriented agro-economic modelling system developed by the European Commission’s Joint Research Centre (JRC) since 2005. Designed to support evidence-based policymaking, particularly for the Directorate General Agriculture and Rural Development (DG AGRI), iMAP integrates a suite of partial equilibrium (PE) and computable general equilibrium (CGE) models to analyse agricultural, rural development, and related policies, such as trade, energy, environment, and climate change. Hosted at the JRC, it collaborates closely with academic and international research institutions, evolving into a robust tool for medium- to long-term projections and scenario analyses up to 2032 and beyond.
  - The framework comprises several well-established models, including PE models like CAPRI, AGMEMOD, and AGLINK-COSIMO, and CGE models such as MAGNET, GLOBE, and RegEU27. These models operate at varying scales—global, EU-wide, Member State, regional, and farm levels—allowing iMAP to address diverse policy questions with complementary perspectives. For instance, CAPRI provides regional detail, AGMEMOD focuses on Member State-level projections, and AGLINK-COSIMO offers global market insights, while farm-level models like IFM-CAP assess micro-level impacts. This multi-model approach enables cross-validation of results, enhancing reliability and providing feedback for model refinement.

5. Models in detail

- Main characteristics of iMAP Framework:
  - iMAP's primary strength lies in its ability to deliver timely and scientifically sound policy support. It produces annual medium-term outlooks for EU agricultural markets, serving as a baseline for counterfactual policy assessments. The framework excels in analysing the CAP, trade agreements, and environmental impacts, incorporating detailed sectoral and regional data. Since its inception, iMAP has expanded beyond traditional agro-economic focus to integrate environmental considerations, such as climate change and biodiversity, often linking with biophysical models and satellite imagery for enhanced accuracy.
  - Data management is a cornerstone of iMAP, supported by tools like DataM, which ensures harmonized, updated, and comparable agro-economic and trade datasets. The platform's flexibility allows standalone or combined model use, addressing topics from bioeconomy transitions to CAP Strategic Plans for 2023-2027. While it prioritizes medium- to long-term dynamics, iMAP acknowledges predictive uncertainties, framing scenarios as insights into policy-driven changes rather than precise forecasts. Its collaborative development, rigorous scientific standards, and adaptability make iMAP a vital tool for shaping EU agri-food policies.