4.5 REPORT ON INTEGRATION OF COMPLEX IDMS IN ABMS AND INTERFACES WITH THE MIND STEP MODEL TOOLBOX

Background and key outcomes/messages towards policy makers

Evaluating current Common Agricultural Policy (CAP) often requires a detailed representation of farmers' production, technology, and investment choices. To assess the environmental outcomes of policy changes, models also need to reflect detailed bio-physical processes and capture a broad range of environmental indicators. At the same time, aggregated policy outcomes crucially depend on feedback mechanisms on (local) input and output factor markets and general interaction between farms. So far, no existing agricultural policy model can deliver all these aspects simultaneously. Individual farm-level models can capture the detailed farm-level decision, bio-physical process, and environmental aspects, but they are by design not able to consider interaction between farms or market mechanisms. Agent-based Models (ABM) in turn typically do not match the production detail of single farm-level models but are well suited to cover interaction and market feedback. As a solution, this task aims to link individual farm-level model and ABM to harness the advantages of both.

This report presents an approach to link two well-established policy models, specifically the individual farm-level model FarmDyn and the ABM AgriPoliS. We present a novel surrogate modelling approach in which a deep neural network approximates the farm-level model FarmDyn and integrate the neural network into the ABM AgriPoliS. Thus, the key outcome of this task is an integrated modelling system that harnesses the strengths of both detailed farm-level analysis and broader agricultural sector dynamics. The integration facilitates the assessment of policy impacts on farm economic performance, production decisions, and environmental outcomes, capturing interactions among farmers, which offers policymakers a powerful tool for informed decision-making aimed at sustainable agricultural development.

The core message is the applicability of deep learning-based surrogates in approximating detailed farm-level models and the critical importance of adopting integrated modeling system to understand the multifaceted effects of agricultural policies. Such modelling systems not only provide a granular view of farm-level decisions and their environmental impacts but also offer insights into market dynamics and farmer interactions under different policy scenarios.

Methodological developments

The project's methodological innovation lies in the successful linkage of two advanced policy models through the use of surrogate modeling based on deep neural networks. This development is significant for several reasons. Firstly, linking the two models requires a conceptual alignment of the two models and a clear definition and technical implementation of the interface between them. Defining the interface contributes to a modular software development approach, which is central to the MIND STEP project. Secondly, linking the two

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models poses additional computational challenges in terms of the model run time and differences in software environments. To overcome these challenges, we present a novel surrogate modelling approach in which a deep neural network approximates the farm-level model. Instead of coupling FarmDyn directly with AgriPoliS, we then use the surrogate model of FarmDyn for the model linkage. The surrogate modelling approach reduces computational demands, simplifies exchanges across software environments, and naturally fosters model modularization.

Policy implications of obtained empirical results

We implemented the coupled model of FarmDyn and AgriPoliS using surrogate models for a specific case study region. The implementation illustrates that we can successfully run the coupled model for an entire region over a 25-year simulation period. The simulation shows realistically stable results with a plausible level of interaction on the land market and dynamics for farm structural change. Based on the detailed level of environmental indicators from FarmDyn, the coupled model can present detailed environmental aspects and their dynamic development. This implementation provides the basis for further policy simulations, allowing for a more comprehensive understanding of the detailed farm-level decision-making, complex farmers' interactions, and environmental impacts in the system. The coupled model can be used in further studies to explore various scenarios, assess potential interventions, and make informed decisions that contribute to sustainable agricultural practices and land-use policies.

Data needs

Data needed for this working package not only includes farm-level data, such as farm-level production data, machinery investment, farm endowment, environmental indicators, and economic performance, but also regional-level data, such as numbers and types of farms, market dynamics, agricultural policy settings, and environmental regulations. The need for such data highlights the importance of robust agricultural data collection and management systems. Policymakers and researchers must prioritize investments in data infrastructure to support the ongoing development and refinement of policy models. Access to comprehensive and up-to-date data is essential for calibrating models accurately, validating their predictions, and ensuring that policy simulations remain relevant to current and future challenges in agriculture. This comprehensive data collection allows for a nuanced analysis of policy impacts across different scales and contexts, enabling the development of targeted, effective agricultural policies that can address the specific needs and challenges of diverse farming communities and regions.

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