D3.1: INTER-MODEL BASELINE HARMONIZATION AND COMPARISON

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Executive summary

Changes with respect to the DoA

No changes

Dissemination and uptake

This Deliverable presents the analysis of the reference scenarios generated by the SUPREMA model suite. The models have been harmonized in a manner, such that they produce comparable simulation results. This Deliverable will be made available to all participants and put on the SUPREMA website. The dataset can be accessed at: http://data.europa.eu/89h/d6ef74c6-ba91-4e37-827e-d0854fbe85dd

Short Summary of results

This deliverable focuses on comparing the results of the reference scenarios simulated by the SUPREMA model suite and on providing possible reasons for their divergence. It follows an earlier request by JRC to the SUPREMA partners to participate in the baseline comparison effort and the subsequent Deliverable *Milestone #7*, which documents the models' baseline assumptions. Differences in these assumptions have led the model teams to use a harmonized set of external variables for producing comparable modelling outcomes. The current effort is the first coordinated attempt to harmonize and compare the baselines of the models, which are reviewed in this report. Therefore, this deliverable also discusses further options for aligning the models and their subsequent successful linking.

Evidence of accomplishment

Deliverable D3.1

GLOSSARY AND ACRONYMS

AGMEMOD	Agricultural Member State Modelling for the EU and Eastern European Countries
CAPRI	Common Agricultural Policy Regionalised Impact Modelling System
IFM-CAP	Individual Farm Model for Common Agricultural Policy Analysis
GLOBIOM	Global Biosphere Management Model
MAGNET	Modular Applied General Equilibrium Tool
MTO2019	EU medium term Outlook 2019
UAA	Utilised agricultural area

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1. Introduction

This report compares two sets of baselines of the five SUPREMA models: AGMEMOD (Agricultural Member State Modelling for the EU and Eastern European Countries), CAPRI (Common Agricultural Policy Regionalised Impact Modelling System), IFM-CAP (Individual Farm Model for Common Agricultural Policy Analysis), GLOBIOM (Global Biosphere Management Model) and MAGNET (Modular Applied General Equilibrium Tool). The models AGMEMOD, CAPRI and IFM-CAP produce medium-term (2030) reference scenarios for the EU agricultural sector, and the models GLOBIOM, MAGNET and CAPRI produce long-term reference scenarios (2050).

The two groups of models are harmonized for the two sets of external variables, CAPRI being adjusted for 2030 and for 2050 baselines separately, thus, resulting in two model versions. The harmonization approach is based on aligning key external assumptions such as population growth rates, GDP, land use, CAP policies, external baseline, etc. The model versions used for this task are the latest available (see Chapter 2 for the details).

The current work brings conclusions on comparability of the simulation results of the model groups under the current harmonization approaches, and whether further alignment is possible and sensible from the theoretical and practical points of view. In light of the increasing demand for the economy-wide and inter-disciplinary policy analysis including CAP, this report contributes to the development of instruments for performing such research.

1.1 Structure of the document

This report is structured in six Chapters as follows. Chapter 2 describes the specifications of the models employed. Chapter 3 presents the approaches of harmonizing the baselines. Comparison and analyses of the differences among the 2030 baselines and among the 2050 baselines are presented in, respectively, Chapters 4 and 5. Finally, Chapter 6 summarises the results and provides with recommendations for the next steps in alignment of the SUPREMA models family.

2. Specifications of the models employed

Baselines 2030 are generated for the agricultural sector of the EU countries[1]. The scenarios follow the "business as usual" assumptions. This implies CAP as of 2019 and values of the external macro-economic factors following the trends observed so far. The models used for this exercise are AGMEMOD, CAPRI and IFM-CAP.

The main differences between the three models lie in their spatial coverage, temporal scale and simulation approaches. IFM-CAP is an EU static farm-level non-linear programming model. It simulates values for a number of farming activities at the spatial level of a single farm, although crop areas, animal numbers and production quantities can be aggregated at the country and EU levels. CAPRI and AGMEMOD are, on the contrary, market models. They focus on simulating market balances and prices at the aggregated EU and country levels. AGMEMOD covers the EU and Eastern European countries as well as some African and Balkan countries. Its highest regional disaggregation level is NUTS0. CAPRI is a global model and its disaggregation levels for the EU are NUTS0, NUTS2, farm-type, and for some environmental indicators, 1x1km grid. AGMEMOD is a dynamic model: it provides results for each simulation year and includes year-lags in its equations. CAPRI is a calibrated static model.

GLOBIOM, MAGNET and CAPRI models are used to generate the baselines for the EU agriculture in 2050. They provide with the results on the economic indicators such as prices, production, use and trade, as well as on the GHG emissions and land use. The models of this group differ among each other as well. GLOBIOM is a dynamic partial equilibrium model, CAPRI is, as it has already been mentioned above, a static partial equilibrium model, and MAGNET is a computable general equilibrium model which can be used in static and recursive dynamic ways. MAGNET models production with CES function, GLOBIOM applies Leontieff technology, and CAPRI uses non-linear programming models, which combine Leontief-technology for variable costs with a non-linear cost function. The Deliverable 1.5 *Documentation of the SUPREMA model tools* (Blanco et al. 2019) describes in detail the five models listed. The current chapter focuses on their key features that may lead to divergence among the modelling outcomes.

2.1 AGMEMOD

AGMEMOD is an econometric, dynamic, partial-equilibrium, multi-country, multi-market model that covers the main EU agri-food markets at national level. It is built as a set of commodity-specific model templates in country-specific models. This allows for combination of national markets into the EU block. The model includes: six types of cereals, three types of oilseeds and their processed products – oil and meal, sugar beet and sugar, protein crops and potatoes, live animals (cattle, pigs, sheep and goats) and meats (beef, pig meat, poultry, sheep and goat meat), raw milk and its processed products – drinking milk, cream, fresh dairy products, butter, skimmed milk powder, whole milk powder and cheese. Vegetables and fruit commodities are currently being built in.

The variables simulated for the crop sectors include market prices, area harvested, yield, total production (as a product of yield and area), total domestic use as a sum of food, feed, processing uses and losses, total import, export and change in stocks. Apart from the markets for meat and dairy products, AGMEMOD considers markets for live animals and simulates such variables as livestock herds (i.e., number of dairy cows, sows, ewes, slaughter pigs, etc.), animals crop and slaughter weight.

[1] EU after 2019.

The agricultural sectors interact in the model on the demand and supply sides as substitutes in consumption and production. This interaction is captured by the model structure that allows for solving the AGMEMOD system for each of the projection years following the partial equilibrium approach of market clearing prices.

The endogenous variables of the model are computed with equalities and behavioural equations. For example, rapeseed oil production in AGMEMOD is computed as equality. It is a product of rapeseed use for processing and the crush coefficient. The use of rapeseed for processing is, in turn, a behavioural equation. Its parameters are econometrically estimated from the time series data. Some of the parameters of the behavioural equations in AGMEMOD rely on expert knowledge and literature.

AGMEMOD uses EUROSTAT, national statistics and expert data sources. These comprise AGMEMOD database which prior to the use for estimation of the model's equations is subject to the "balancing" process. This process implies generation of the missing observations in the series and examination for adhering to the balance principles (e.g., crop yields equal total production divided by area harvested, the sum of production, domestic use, stocks, import and export equals zero).

Thanks to the use of econometrically estimated equations, AGMEMOD does not require the classic parameter calibration process and the use of the external baseline to produce its projections. In the recent years, however, the model has been used for producing the JRC baseline at the EU countries level. Therefore, AGMEMOD projections at the EU aggregate level[2] have been scaled to the official baseline of the European Commission, i.e., EU medium term Outlook (MTO2019) generated by the Aglink-COSIMO model. The scaling procedure aims at bringing the values of the aggregated variables as close as possible between the two models. It follows a standardized step-wise process, which is based on adjustment of the AGMEMOD parameters (the sources for this section are Chantreuil et al. 2012 and Salamon et al. 2017).

The AGMEMOD model version used for producing this report is of April 2020. It includes the new iso-glucose sector, updated model database and a baseline that has been scaled to the MTO2019 and revised by the market experts at the Brussels workshop in February 2020.

2.2 CAPRI

CAPRI is a multi-commodity static spatial global partial equilibrium model for ex-ante impact assessment of agricultural, environmental and trade policies with a focus on the EU. The model provides with estimates of a wide range of agricultural activities and commodities. It simulates values for the major EU agri-food markets, markets of citrus fruits, permanent crops, vegetables, apples and tobacco, for such activities as palm oil, tea and coffee trade, for a range of GHG emissions, for variables related to CAP policy such as direct payments, as well as for areas of intensive and extensive grassland, fallow land and set aside, numbers of high and low intensity livestock and young animals. All of the CAPRI commodity markets and activities, following the general economic theory of demand, supply and trade, interact at the supply and demand sides, as well as trade. A great number of activities and commodities covered in CAPRI leads to a great number of inter-dependencies in the model, and thus, high level of model complexity.

[2] The scaling procedure uses two country aggregates: EU before and after 2004.

Due to its static partial equilibrium nature, CAPRI is solved for the market clearing prices at the targeted simulation year. This solution depends, among else, on the two types of values: i) values of parameters of the behavioural equations representing various agricultural activities and markets that are calibrated to the base year values of the CAPRI database, and ii) the so-called "support" points which, depending on the activity/commodity, represent expert knowledge or values of the external baseline. Calibration of parameters of the behavioural functions follows a CAPRI-specific approach, which implies the interaction of two modules: supply and market. The supply module consists of non-linear programming models representing farmers' decisions. The market module is a deterministic partial equilibrium model. The supply module operates at NUTS2 level, and the market module at country and regional aggregates levels. The interaction of the supply and market modules results in optimized values of farming activities and market values at the clearing prices. The "support" points act as references in the calibration and baseline generation processes, directing the simulation outcome towards these values.

The CAPRI database is generated from two major sources: EUROSTAT and FAOSTAT. Due to the level of details required by CAPRI, the original EUROSTAT and FAOSTAT values are subject to the balancing process and are used for calculation of additional required coefficients. This results in some differences between the original statistical values and the values of the CAPRI database. CAP and environmental policies are included in CAPRI model as exogenous variables.

CAPRI is an Armington bilateral trade model. It simulates global trade flows among countries and regional blocks. As a result, the EU domestic market prices are functions of the EU farm gate and import prices (the source for this section is Britz and Witzke 2014).

CAPRI model version used for generation of the current 2030 and 2050 baselines is of April 2020. Among else, it includes:

- only for 2030 baseline: calibration to the MTO2019,
- only for 2050 baseline: using of the 2050 GLOBIOM baseline for the land use projections,
- endogenous manure trade module,
- update of regional and national database until 2016/2017 and some other series,
- update of exogenous input file for biomass production and
- update of the farm practices and environmental constraints.

2.3 IFM-CAP

IFM-CAP is a comparative static positive mathematical programming model applied to each individual farm from the Farm Accountancy Data Network (FADN). The model allows for assessing a wide range of farm-specific policies while capturing the heterogeneity of EU commercial farms. Its main simulation outputs are land allocation, herd size, livestock density, share of arable land in utilised agricultural area (UAA), share of grassland in UAA, land use change, agricultural production, intermediate input use, CAP first and second pillar subsidies, intermediate input costs, variable costs, total costs, gross farm income, and net farm income, as well as biodiversity index and soil erosion.

IFM-CAP uses data from FADN, Farm Structure Survey (FSS), CAPRI database and Eurostat. The data are adjusted to the model format, the outliers and the missing values are addressed. Because some of the indicators such as, for example, unit input costs of crops, are not directly available in FADN, they are estimated using external data sources.

IFM-CAP is based on the assumption that farmers maximise their expected utility at given yields, product prices and CAP subsidies, subject to resource endowments (arable land, grassland and feed) and policy constraints. The farmers' expected utility is defined as expected income and the associated income variance with a constant absolute risk aversion specification. The expected income, in turn, includes direct payments, the accounting costs (costs of seeds, fertilisers, crop protection etc.) and total revenue, which is calculated using expected prices and yields. Model calibration follows positive mathematical programming approach, and estimates model parameters from an observed base-year situation. IFM-CAP is calibrated for the base year 2012 using cross-sectional analysis (i.e. multiple observations) and Highest Posterior Density approach with prior information on regional supply elasticities and dual values of resources (e.g. land rental prices) (the sources for this section are Blanco et al. 2019 and Louhichi et al. 2015).

Although IFM-CAP has been developed to analyse policy scenarios in a 'what if' manner, rather than to provide projections, it, nevertheless, can produce a baseline. In the model version, used for the current report, the growth rates of prices and yields of CAPRI 2030 baseline have been used. In particular, the growth rates of commodity and country specific farm gate prices and yields in 2030 relatively to the base year values of CAPRI entered IFM-CAP to imitate the changes by 2030. Since 2012 (Base year for IFM-CAP) was a particular year with price spikes in many agricultural commodities, the growth rates assumed for IFM-CAP were calculated using a three-year average (2011-2013) as a reference point.

2.4 MAGNET[3]

The Modular Applied GeNeral Equilibrium Tool (MAGNET) model is a multi-regional, multi-sectoral, applied general equilibrium model of the world economy based on neo-classical microeconomic theory (Nowicki et al. 2009, Woltjer and Kuiper, 2014). It is an extended version of the standard GTAP model (Hertel 1997). MAGNET focusses, among others, on impact assessment of agricultural policies, climate change impact and related policies, trade and land use change developments.

The core of MAGNET is an input–output model, which links industries in value added chains from primary goods, over continuously higher stages of intermediate processing, to the final assembly of goods and services for consumption. On the production side, MAGNET uses a multilevel sector specific nested CES (constant elasticity of substitution) production function, allowing for substitution between primary production factors (land, labour, capital and natural resources) and intermediate production factors, and for substitution between different intermediate input components (e.g. energy sources, and animal feed components). Primary production factors are region specific. Their prices are determined endogenously to meet the "aggregated supply equals aggregated demand" equilibrium condition. Similarly, prices of goods in each region adjust to assure that both national and international demand and supply are equal.

On the consumption side, one household per region is distinguished. It distributes its income across savings and (government and private) consumption expenditures according to fixed budget shares. Private consumption expenditures are allocated across commodities according to a non-homothetic dynamic CDE (constant difference of elasticities) expenditure function which allows for changes in income elasticities when PPP (purchase power parity)-corrected real GDP (Gross domestic product) per capita changes. Government expenditures are allocated across commodities according to fixed

[3] The sources for this section are Blanco et al. 2019 and Woltjer and Kuiper 2014.

shares. The commodities consumed by firms, government and households are CES composites of domestic and imported commodities. The MAGNET model includes bilateral trade between all regions of the model and accounts for trade barriers between regions via tariffs. The imported commodities are differentiated by region of origin using Armington elasticities.

MAGNET includes several extensions towards better representation of the agricultural sector. It includes, among others, substitutability of land between sectors, imperfect mobility of labour between agricultural and non-agricultural sectors, endogenous land supply, biofuel sectors, modulation of the CAP from first to second pillar measures and agricultural production quotas.

Agricultural commodities are present in MAGNET mostly as aggregates with a few exceptions. For example, cereals sector is modelled as other coarse grains and wheat, and oilseeds are aggregated into one generic commodity. There are aggregates for fruits, vegetables and nuts, for other crops, for non-ruminant meats and for dairy products, whereas rice, raw milk, poultry eggs, poultry and pork meats are modelled as separate commodities. Agricultural activities simulated include producer, market and export prices, total production, areas per activity, crops and animal yields, domestic uses, import, export, fertilizer use, GHG emissions a number of other indicators.

MAGNET can be used for comparative-static simulations as well as for long-term projections (till 2050 and, sometimes, 2100). The long-run scenarios are built in recursive-dynamic manner by updating the MAGNET database in several consecutive, mostly 10-year long, time steps. This approach uses a set of exogenous assumptions on developments in population, GDP, land productivity and capital over time.

2.5 GLOBIOM

GLOBIOM is a global recursive dynamic (10-year-step intervals up to 2050) partial equilibrium model for the forest and agricultural sectors. It was created to explore trade-offs and synergies around land use and ecosystem services. By including not only the bioenergy sector but also forestry, cropland, grassland and livestock management, the model allows for a full account of the most important agriculture and forestry GHG sources.

The market equilibrium for agricultural and forest products is computed by allocating land use among production activities to maximize the sum of producer and consumer surplus, subject to resource, technological, demand, and policy constraints. GLOBIOM includes six land cover types: cropland, grassland, other natural vegetation land, managed forests, unmanaged forests and plantations. Economic activities are associated with the first four types. Total forest area is calibrated according to FAO Global Forest Resources Assessments (FRA). Depending on the relative profitability of production activities, the model switches from one land cover type to another, implying a conversion cost, which increases with the area of land converted. This cost is taken into account in the producer optimization behaviour, which builds up into the supply side of the model.

Demand and international trade occur globally for 57 regional aggregates. Besides primary products for the different sectors, the model has several final and by-products, for which the processing activities are defined. Trade is modelled following the spatial equilibrium approach: the trade flows are balanced out between different specific geographical regions based on cost competitiveness.

GLOBIOM accounts for ten sources of GHG emissions, inventories of which are based on IPCC accounting guidelines. The sources of carbon stocks depending on the land cover include G4M, the 2010 Forest Assessment Report (FAO, 2010) and Ruesch et al. (2008). In the model, the mitigation mechanisms in the agricultural sector include technological options, e.g., improved fertilizer management (based on the mitigation option database from EPA – Beach et al. 2015), structural changes, e.g., crop management systems, and consumers' response to price changes.

A number of biofuels feedstock (e.g., crops, oilseeds, perennials, short rotation plantations, woody biomass), and various energy conversion processes (e.g., combustion, fermentation) are modelled in GLOBIOM as well. Competition for biomass resources between the various uses (i.e., food, feed, timber and energy) is simulated based on the relative profitability of these uses, which, in turn, depend on the crop management systems. Within each management system, input structure follows a Leontief production function. However, crop yields can change in reaction to external socio-economic drivers. Long-term technological change and crop rotation (using model CropRota described in Schönhart et al. 2011) are included in the yield functions as well.

The global livestock sector in GLOBIOM distinguishes dairy and other bovines, dairy and other sheep and goats, laying hens and broilers, and pigs. The production activities are defined in several alternative production systems, e.g., grass based (arid, humid, temperate/highlands), mixed crop-livestock (arid, humid, temperate/ highlands), and other for livestock. Feed rations are defined with a digestion model RUMINANT (see Havlík et al. 2014). Switches between production systems allow for feedstuff substitution and for intensification or extensification of livestock production (the source for this section is Blanco et al. 2019).

3. Models harmonization

For generating the comparable baseline scenarios of the EU agriculture in 2030, AGMEMOD, CAPRI and IFM-CAP models are harmonized by aligning the sources of their major external factors. In particular, AGMEMOD and CAPRI models are calibrated to MTO2019. MTO2019 is as well the source for the projections of national GDP, GDP deflator, currency exchange rates, population and crude oil prices that are used by AGMEMOD and CAPRI as exogenous variables. IFM-CAP is not a market model; it is a farm level (supply) model. Therefore, it does not simulate market balances and prices. The latter are exogenous to the model. To generate the 2030 baseline, IFM-CAP uses growth rates of yields and producer prices of the 2030 baseline projected by CAPRI. These growth rates are applied to the respective base year values in the IFM-CAP database (see section 2.3 for the details). All three models consider 2012 as their base year; CAP policy assumptions represent the current CAP.

Generation of the 2050 baselines by GLOBOIM, MAGNET and CAPRI follows the approach of harmonizing the sources of the external factors as well. The models consider population and GDP projections for the European region from Capros et al. 2016, and for the Rest of the World region – from the Shared Socioeconomic Pathways Database, Version 2.0. Globally uniform carbon price is applied in all three models, as well as energy prices, energy plant and forest areas. In addition, CAPRI uses the 2050 GLOBIOM baseline for the land use projections.

4. Comparison of the 2030 baselines

For comparing the simulation results of the 2030 baselines, the following commodities are selected: soft wheat, corn, rapeseed, rapeseed oil, beef, pork and raw milk from cow. These commodities are among the most straightforward in their definition. Definition of rye and oats, for example, may vary among the data sources and thus, among the models. Rye may be defined as rye or as an aggregate of rye and meslin, and oats may be defined as oats or as an aggregate of oats and spring cereals. Additional reason for selecting soft wheat and corn are that they occupy considerable shares of the UAA in many EU countries. The shares of rapeseed and rapeseed oil in the production quantities of, respectively, oilseeds and oilseed oils are large in many EU countries as well. Beef, pork and raw cow milk are important livestock products for the EU agricultural sector.

The commodities are reviewed from the market perspective, implying the focus on comparison of producer prices, production, total use and net-trade. The EU region as well as the EU countries are considered. The basis for comparison of the baseline results of AGMEMOD and IFM-CAP is the baseline results of CAPRI. The reason for choosing CAPRI over the other two models is that IFM-CAP uses growth rates of prices and yields projected by CAPRI to generate its baseline. Thus, comparing the two models provides with additional insights on the outcome of alignment of these two models.

It would as well be useful to review the divergences of the models from MTO2019, and compare the projected growth rates instead of the 2030 values. The former would allow examination of the differences among the calibration procedures of the models, whereas the latter would partially eliminate the issue of the database differences. However, comparison to MTO2019 involves analysing of Aglink-COSIMO, the model which produces the outlook and which is not included in the SUPREMA model suite. Therefore, this analysis is not performed in the current study, but is considered for the future work. Comparing the projected growth rates, in addition to comparing of the actual projected values, would assist in identifying input of the simulation approaches and model parameters into the differences among the models' outcomes. Although such comparison is partially provided in the Annex, it merits a more detailed analysis in the future.

Another important aspect which has not been examined in the current study is the effect of the expert knowledge on the projections. For instance, baseline results of AGMEMOD model are examined by the market experts and, where applicable, are adjusted according to their comments (see section 2.1). Thus, AGMEMOD 2030 baseline is not only the outcome of the modelling, but of the experts' expectations as well. Analysing the differences of the baselines of CAPRI and IFM-CAP with the AGMEMOD baseline with and without the implemented expert information could provide with additional knowledge on the impact of expert opinion on the modelling outcome. Furthermore, CAPRI model makes use of expert knowledge on an array of its parameters. It would as well be interesting to see whether alignment of expert information among the models would bring their projection results closer.

4.1 Crops

Soft wheat

The projected values for total production of soft wheat at the EU level are quite close among the models. IFM-CAP reports 3.5% less, and AGMEMOD 3.6% more of soft wheat production in the EU in 2030 as compared to the projection by CAPRI. The differences in production result from the differences in the areas harvested and yields. IFM-CAP reports 17.2% less of area of soft wheat, whereas AGMEMOD projects +0.7% difference with CAPRI. The differences in the yields are: IFM-CAP shows 16.5% difference with CAPRI, and AGMEMOD 5.1%.

We first review the yields. The median value of the differences between IFM-CAP and CAPRI at the country level is -5.9% (Spain), abs maximum is (-)20.5% (Latvia) and minimum (+)0.3% (Netherlands). The statistics of the differences of AGMEMOD yield projections at the country level are: median is 1.6% (Hungary and Latvia), abs maximum is (+)25.3% (Romania) and abs minimum is (+)0.2% (Italy).

The situation with soft wheat areas approximates the one with the yields. The median for the country level differences between IFM-CAP and CAPRI is -11.8% (Denmark), abs maximum (+)83.0% (Ireland) and abs minimum (+)0.5% (Belgium). The median for the country level differences between AGMEMOD and CAPRI is 5.2% (Poland and Lithuania), abs maximum (+)63.5% (Finland) and abs minimum (+)0.7% (Romania). Portugal has been excluded from this review, because of the relatively small values projected by all three models and, thus, very large % differences (Table 4.1).

Table 1: % differences in soft wheat projections by AGMEMOD and IFM-CAP with respect to the projections by CAPRI.

SOFT WHEAT	Yield		Area	
	IFM-CAP	AGMEMOD	IFM-CAP	AGMEMOD
EU	16.5	5.1	-17.2	0.7
EU countries				
Median	-5.9	1.6	-11.8	5.2
ABS min	0.3	0.2	0.5	0.7
ABS max	20.5	25.3	83.1	63.5

Note: Portugal is excluded from the review, because of the relatively small values projected by all three models and, thus, very large % differences.

The 2030 values of producer prices of soft wheat in AGMEMOD and IFM-CAP vary from -25% to +29% (with the exception of Cyprus, Hungary, Malta and Sweden) as compared to CAPRI. Although IFM-CAP does not project producer prices (growth rates of CAPRI model are applied to the respective base year values in the IFM-CAP database, see section 2.3), the latter are included in the comparison. The figure below demonstrates the distribution of the differences.

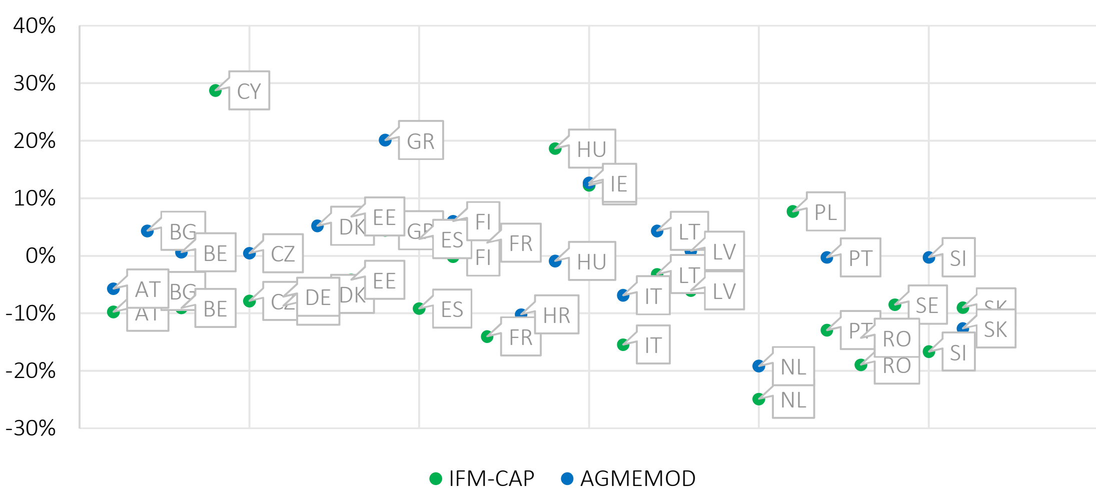

Figure 1: % differences in the 2030 values of producer prices of soft wheat in AGMEMOD and IFM-CAP as compared to the projections by CAPRI.

Because IFM-CAP does not simulate market balances, further comparison is conducted only between CAPRI and AGMEMOD. The difference between the projections of total domestic use between AGMEMOD and CAPRI at the EU level is quite small, only -0.6%. The net-trade, however, differs considerably. AGMEMOD projects a 72% better net-trade balance for soft wheat as compared to CAPRI. In particular, whereas AGMEMOD projects around 32.2 million tonnes of net-trade, CAPRI simulates 18.7 million tonnes. Total domestic use, import and export quantities at the country level are demonstrated in Figures 2 and 3. The differences in per capita consumption and in the growth rates of producer prices and production of soft wheat are presented in the figures of the Annex.

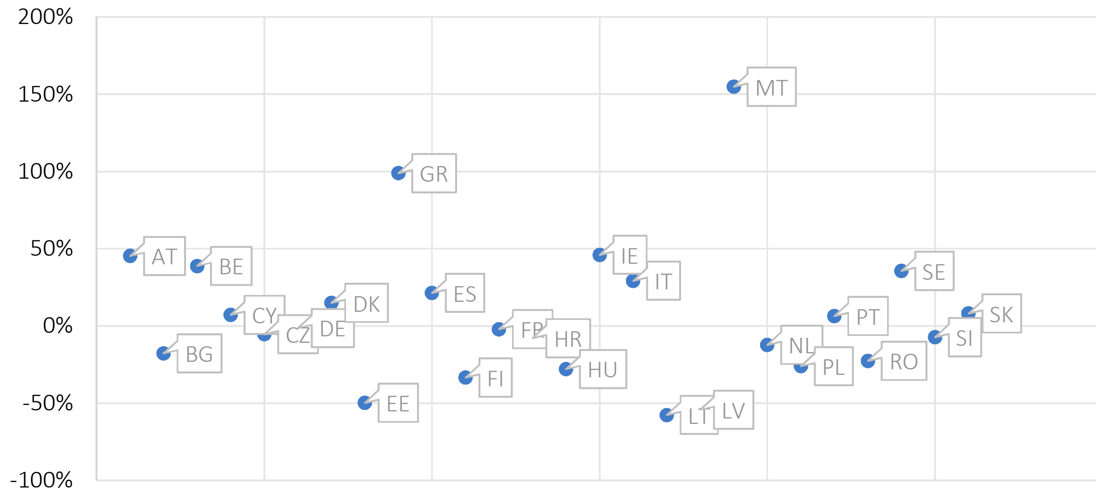

Figure 2: % differences in the projections of total domestic use of soft wheat at the country level by AGMEMOD as compared to the projections by CAPRI.

Figure 3: % differences in the projections of exports and imports of soft wheat at the country level by AGMEMOD as compared to the projections by CAPRI.

Corn

Total EU production of corn in IFM-CAP and AGMEMOD differ from CAPRI by, respectively, 10.8% and 11.8%. For IFM-CAP, the difference in yield is 9.9% and in area harvested is 0.8%, and for AGMEMOD, the differences are 1.3% and 10.3%, respectively.

The statistics for the differences among the models in yield and area at the EU country level is the following. The median value of the yields difference between IFM-CAP and CAPRI is 9.3% (Belgium), abs maximum is (-)41.9% (Hungary) and abs minimum (-)0.7% (Sweden). The differences in the yield projections by AGMEMOD with the yield projections by CAPRI are: median is 1.5% (Austria and Bulgaria), abs maximum is (-)37.8% (Lithuania) and abs minimum is (+)1.1% (France). As regards area harvested, the numbers are the following. For IFM-CAP: median is 15.826% (Bulgaria and Austria), abs maximum is (+)629.4% (Denmark) and abs minimum is (+)3.4%(France). For AGMEMOD: median is 15.830% (Hungary and France), abs maximum is (+)56.6% (Denmark) and abs minimum is (-)0.4% (Germany). The distributions of the yield and area differences at the country level among the models are visualized in the figures below.

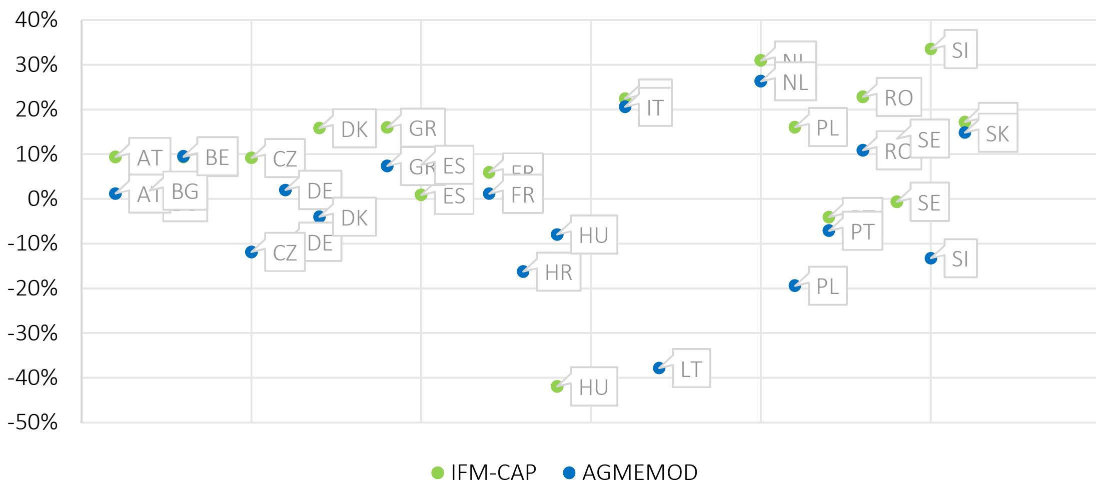

Figure 4: % differences in the projections of corn yields at the country level by AGMEMOD and IFM-CAP as compared to the projections by CAPRI.

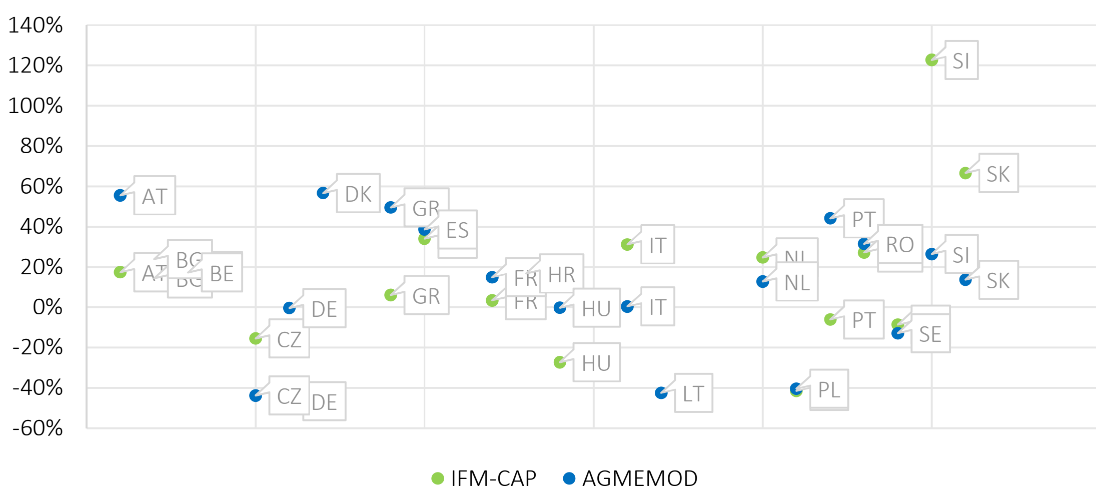

Figure 5: % differences in the projections of corn areas at the country level by AGMEMOD and IFM-CAP as compared to the projections by CAPRI.

The differences between AGMEMOD and CAPRI in the projections of domestic use, import, export and net-trade are larger than in the case with soft wheat. In particular, AGMEMOD projects 21.6% more of the EU corn use; the net-trade volume simulated by AGMEMOD is 21.9% worse than simulated by CAPRI. The median value of the total use differences at the country level is 12.4% (Hungary and

Austria), abs maximum is (+)107.2% (Hungary) and abs minimum is (+)4.1% (Bulgaria). The per capita consumption projections are rather diverse as well (see Annex). The median values for quantities of corn exported and imported at the country level are 14.0% (Italy and Hungary) and 9.3% (Spain), respectively; abs maximum values are (+)234.4% (Malta) for export, and (+)350.8% (Poland) for import; and abs minimum values are (-)3.5% (France) for export, and (-)2.7% (Netherlands) for import.

The differences in the 2030 values of producer prices[4] at the country level range from 80% to -100% with most of the countries remaining in the range from +20% to -20% (see figure below).

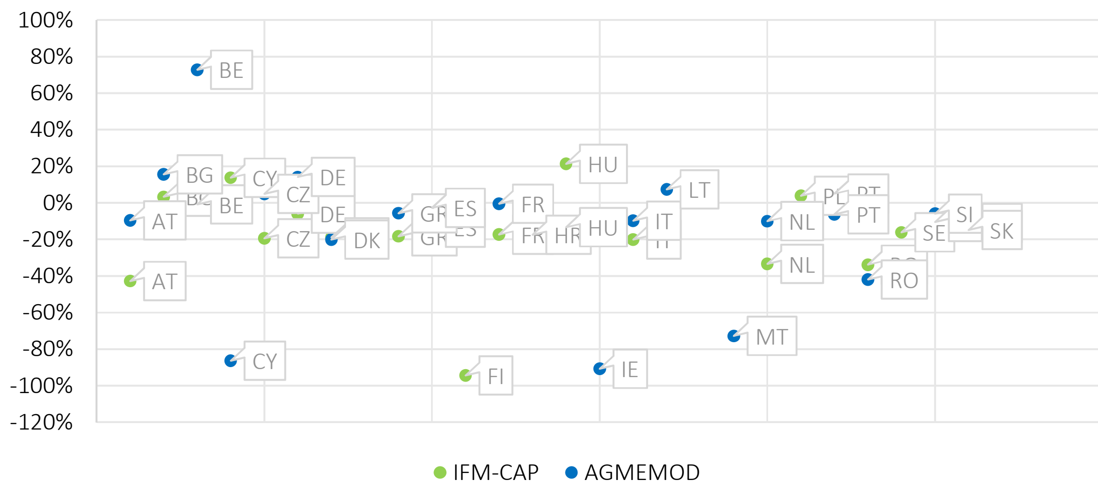

Figure 6: % differences in the 2030 values of producer prices of corn at the country level in AGMEMOD and IFM-CAP as compared to the projections by CAPRI.

Rapeseed and rapeseed oil

The projections of rapeseed production in 2030 at the EU level differ between IFM-CAP and CAPRI models by -5.7% and between AGMEMOD and CAPRI by 10.8%. The differences in yields are 38.4% for IFM-CAP and 14.0% for AGMEMOD, and the differences in areas harvested are -31.9% and -1.8%, respectively. The differences in projections at the country level are presented in Figures 7 and 8 below.

[4] IFM-CAP does not project prices. The latter are exogenous to the model. The model calculates the 2030 values of the prices based on the base year values in its own database and the growth rates projected by CAPRI.

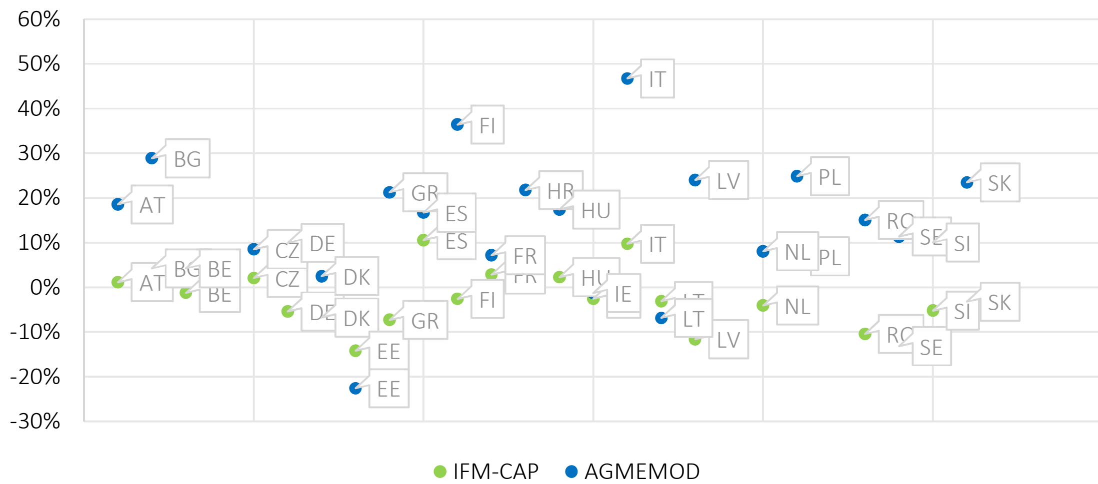

Figure 7: % differences in the projections of rapeseed yields at the country level by IFM-CAP and AGMEMOD as compared to the projections by CAPRI.

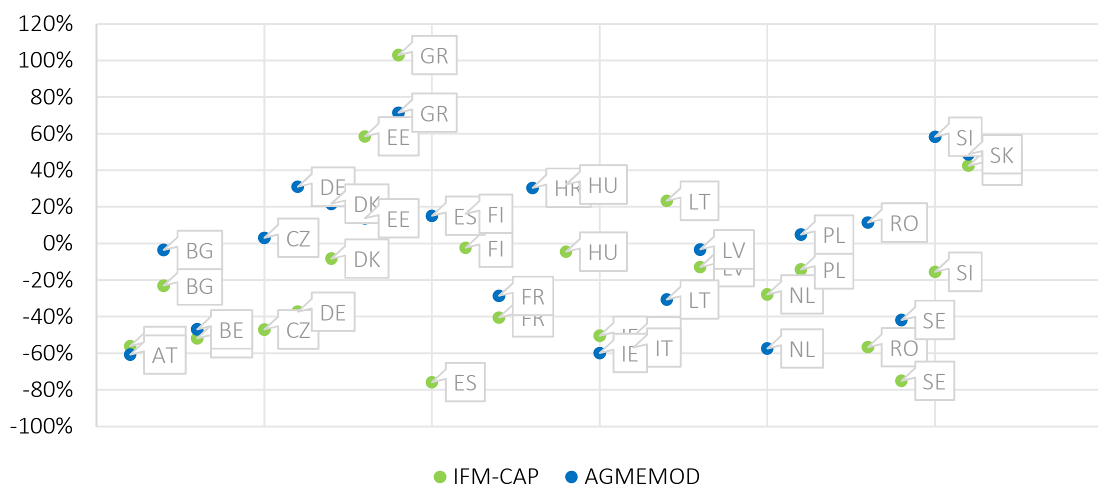

Figure 8: % differences in the projections of rapeseed areas at the country level by IFM-CAP and AGMEMOD as compared to the projections by CAPRI.

With the exception of Belgium and Italy, the differences in prices of IFM-CAP and AGMEMOD as compared to CAPRI lie in the range from -40% to 26 (see Figure 9).

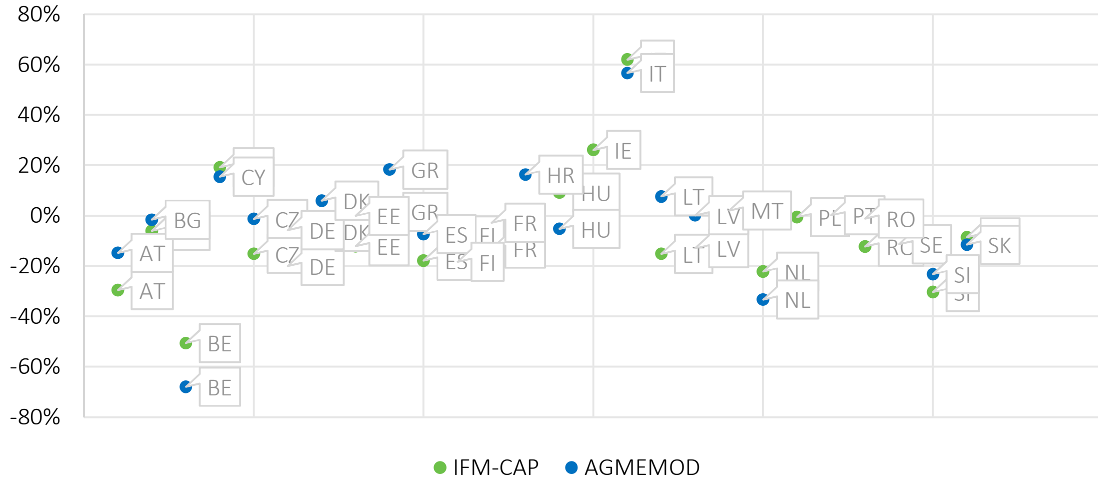

Figure 9: % differences in the 2030 values of producer prices of rapeseed at the country level in AGMEMOD and IFM-CAP as compared to the projections by CAPRI.

Because rapeseed oil is a processed product, and IFM-CAP is a farm-level model, the latter does not simulate production of this commodity. Therefore, the projections for rapeseed oil sector, as well as trade and domestic use of rapeseed are compared only between AGMEMOD and CAPRI. Thus, AGMEMOD projects 3.8% less of rapeseed oil production in the EU than CAPRI. For Denmark, Finland, Hungary, Italy, Latvia, Lithuania, Romania and Slovakia the projections differ by more than 50%.

Rapeseed and rapeseed oil uses and trade differ between AGMEMOD and CAPRI considerably. AGMEMOD projects 7.5% less of rapeseed use and 28.1% less of rapeseed oil use in the EU in 2030 (see per capita rapeseed oil use in the Annex). It as well simulates an improved by 57.8% net-trade[5] balance of rapeseed, and an improved by 200.1% net-trade balance of rapeseed oil as compared to CAPRI.

The differences in prices for rapeseed oil projected by AGMEMOD with the projected by CAPRI range from -34% to 40% (see Figure 10). The differences in per capita consumption of rapeseed oil and in the growth rates of producer prices and production of rapeseed are presented in the figures of the Annex.

[5] Improved net-trade balance implies increase in export and/or decrease in import of the commodity.

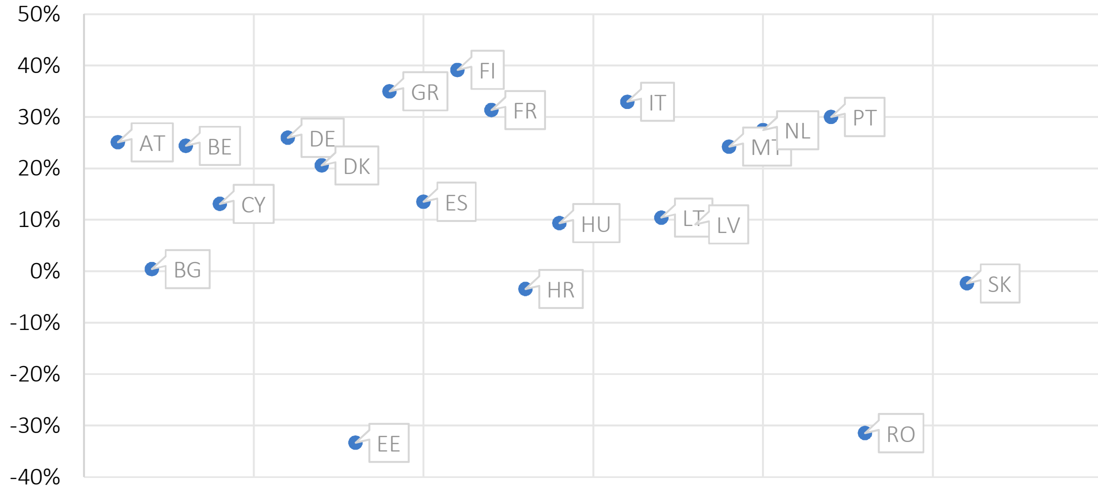

Figure 10: % differences in the projections of producer prices of rapeseed oil at the country level by AGMEMOD as compared to the projections by CAPRI.

4.2 Livestock products

Beef

Projection of beef production in the EU by IFM-CAP differs from CAPRI by +14.5%. At the country level, the differences range from -29.7% (Portugal) to +133.1% (Romania), median value being 16.7% (Germany). Beef production in the EU projected by AGMEMOD differs from CAPRI by 14.0%. At the country level the differences range from -56.4% (Bulgaria) to +98.5% (Italy) with a median value of 4.3% (Germany and Hungary). Producer prices of IFM-CAP[6] and projected by AGMEMOD at the country level differ from CAPRI in a range of absolute values from 3.9% to 75.8% and from 0.5% to 78.0%, respectively.

Total domestic use of beef projected by AGMEMOD for 2030 differ from CAPRI by -9.5%. AGMEMOD projects an improved net-trade quantity of beef as compared to CAPRI: 193.0%. The projections at the country level display quite wide variation for the use, import and export values. Figures 11-14 demonstrate these differences. The differences in per capita consumption and in the growth rates of producer prices and production of beef are presented in the figures of the Annex.

[6] IFM-CAP does not project prices. The latter are exogenous to the model. The model calculates the 2030 values of the prices based on the base year values in its own database and the growth rates projected by CAPRI.

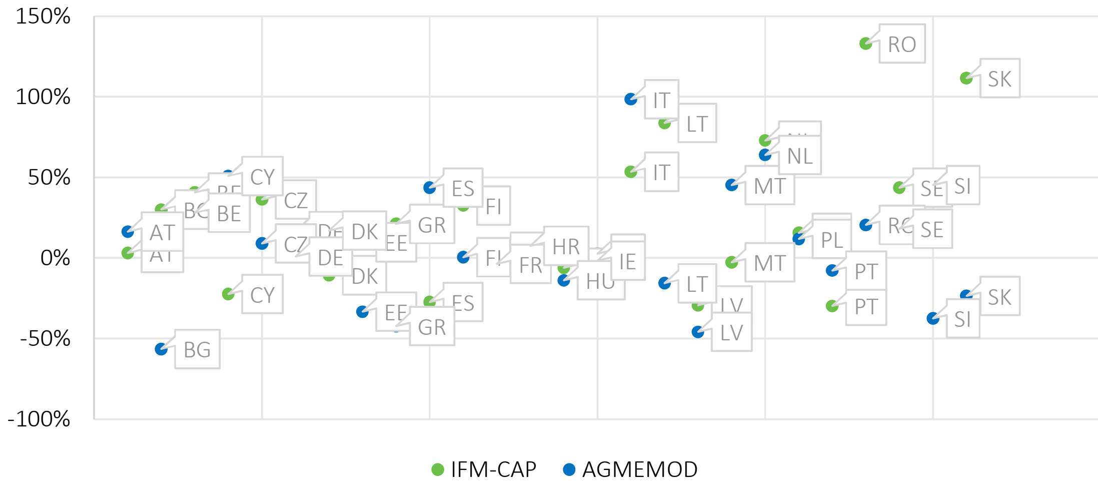

Figure 11: % differences in the projections of beef production at the country level by IFM-CAP and AGMEMOD when compared to the projections by CAPRI.

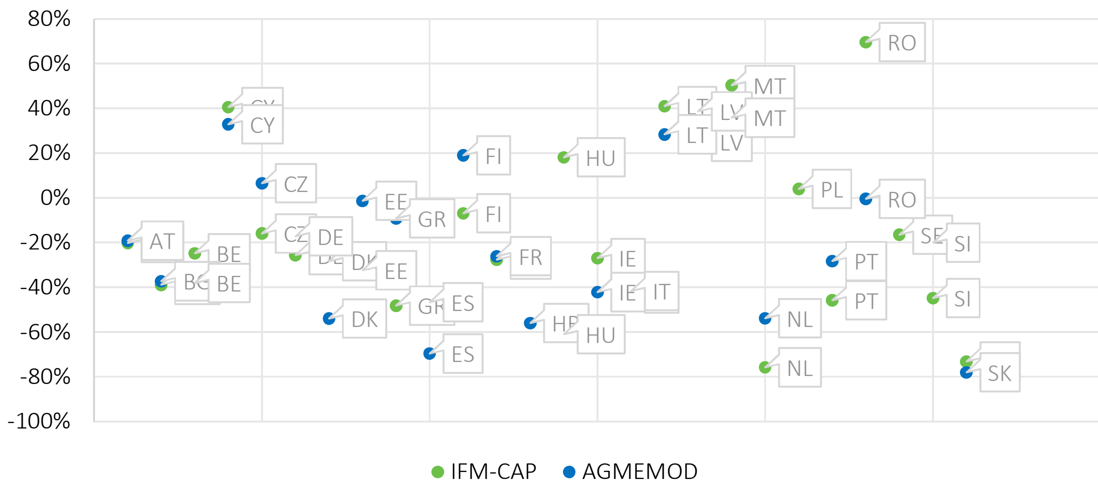

Figure 12: % differences in the 2030 values of producer prices of beef at the country level in IFM-CAP and AGMEMOD when compared to the projections by CAPRI.

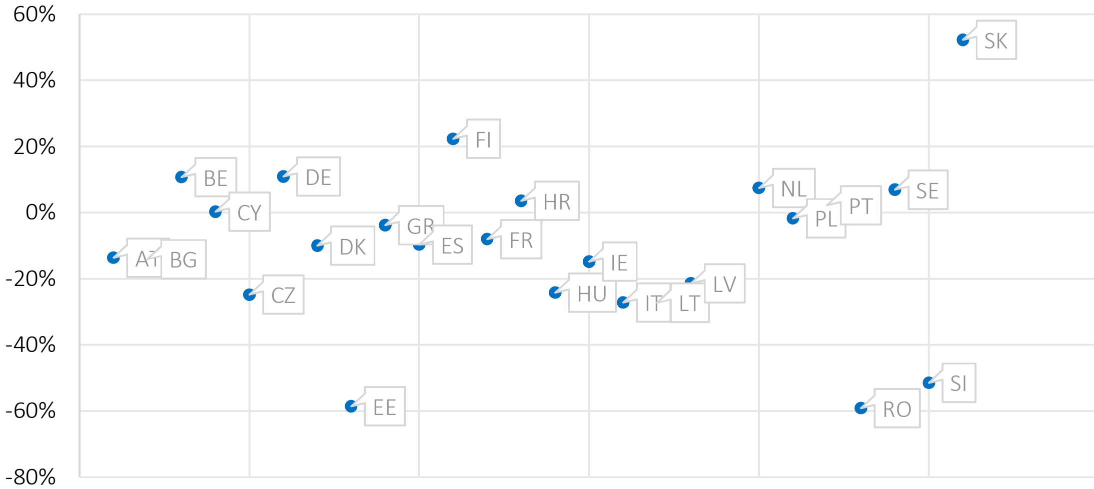

Figure 13: % differences in the projections of beef consumption at the country level by AGMEMOD when compared to the projections by CAPRI.

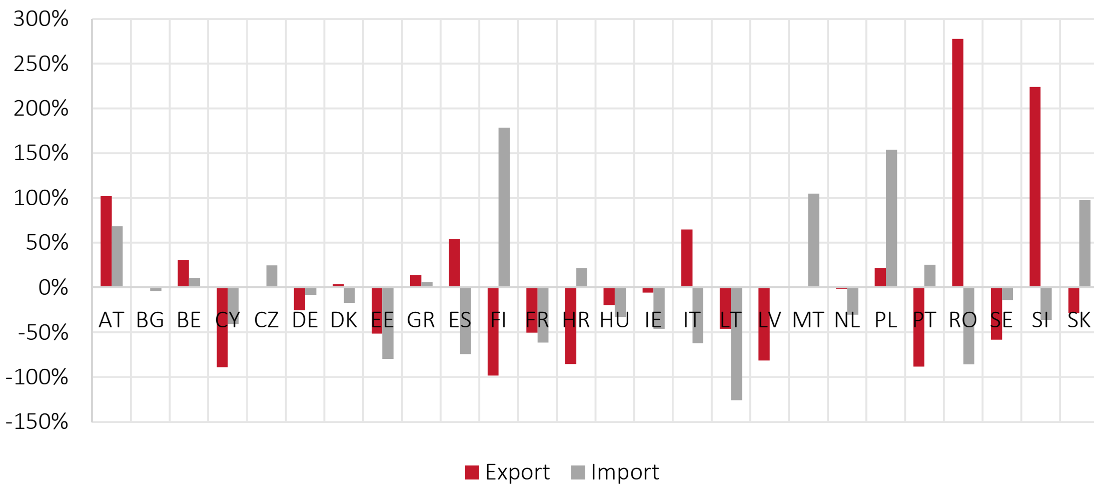

Figure 14: % differences in the projections of import and export of beef at the country level by AGMEMOD when compared to the projections by CAPRI.

Pork

Projections for the EU pork production by AGMEMOD and IFM-CAP differ from the CAPRI projections significantly. IFM-CAP projects 22.8% less of pork meat production and AGMEMOD 1.3% less. Absolute differences in 2030 prices of pork at the level of EU countries level range from (+)0.9% (Romania) to (+)83.1% (Bulgaria) for IFM-CAP[7], and from (+)0.8% (Lithuania) to (-)37.6% (Hungary) for AGMEMOD. Pork consumption in the EU is projected by AGMEMOD to be less by 7.9% than by CAPRI. The consumption at the country level is relatively close between the two models. In particular, the median difference is -5.4% (Hungary and Croatia) and absolute maximum and minimum differences are, respectively, (+)30.0% (Bulgaria) and (+)0.1% (Austria). The EU net-trade balance projected by

[7] IFM-CAP does not project prices. The latter are exogenous to the model. The model calculates the 2030 values of the prices based on the base year values in its own database and the growth rates projected by CAPRI.

AGMEMOD is better than the one projected by CAPRI by 35.1%. The differences in imports and exports at the country level, however, are quite considerable. The differences in the projections of pork production, prices, consumption (see Annex for the differences in per capita pork consumption) and trade at the country level are demonstrated in the figures below.

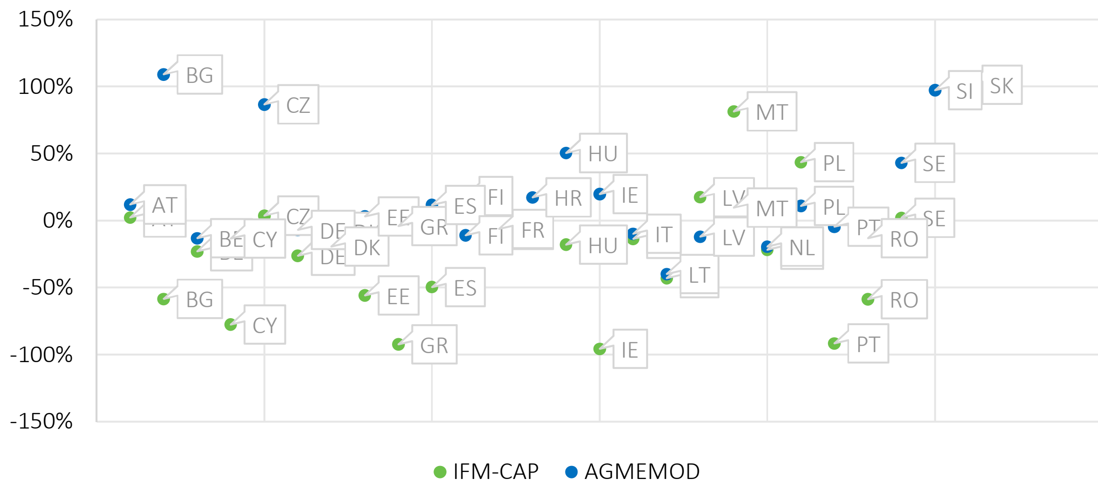

Figure 15: % differences in the projections of pork production at the country level by IFM-CAP and AGMEMOD as compared to the projections by CAPRI.

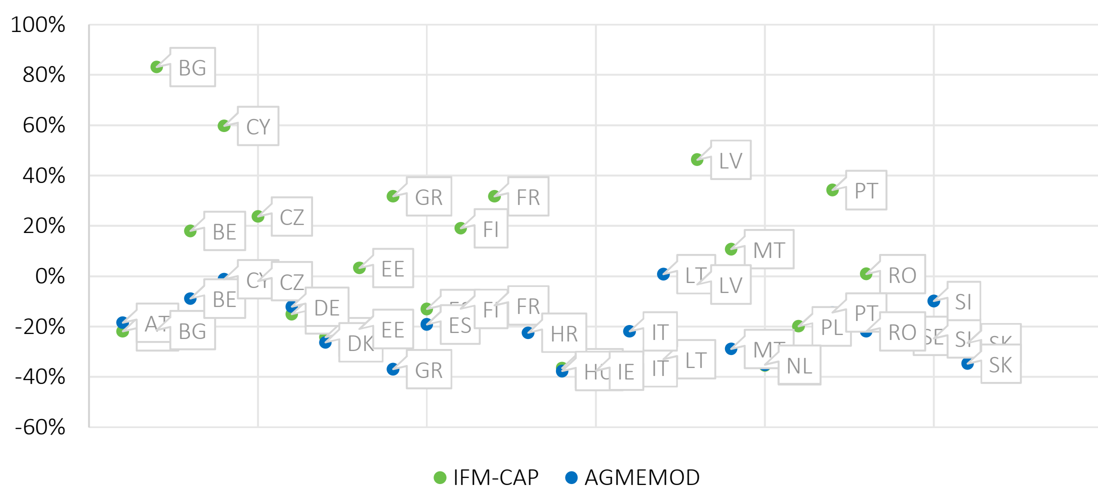

Figure 16: % differences in the 2030 values of producer prices of pork at the country level in IFM-CAP and AGMEMOD as compared to the projections by CAPRI.

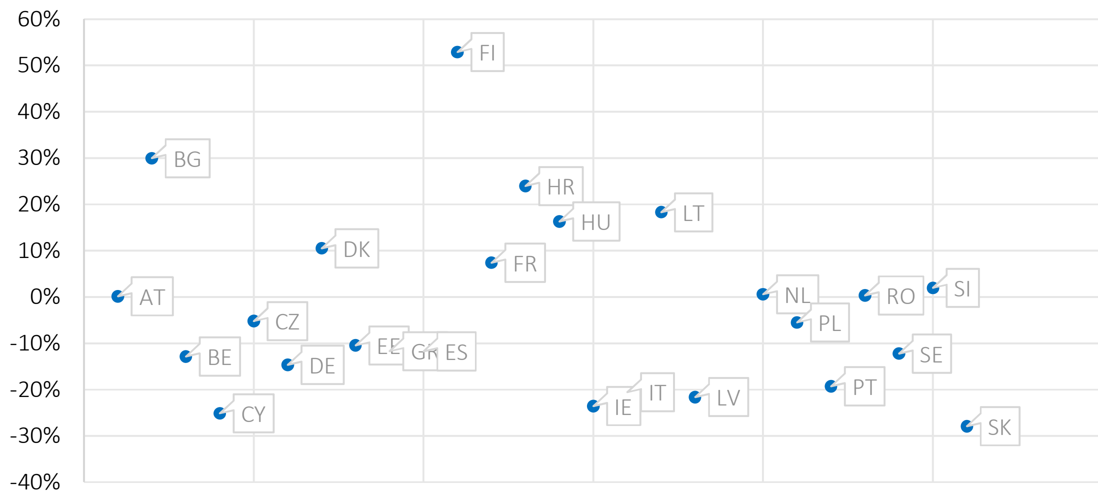

Figure 17: % differences in the projections of pork consumption at the country level by AGMEMOD as compared to the projections by CAPRI.

Figure 18: % differences in the projections of import and export of pork at the country level by AGMEMOD as compared to the projections by CAPRI.

Raw cow milk

Raw cow milk production in the EU in 2030 is projected by IFM-CAP to be higher than in CAPRI by 12.1%, and by AGMEMOD higher by 4.5%. Domestic use of raw milk is projected by AGMEMOD to be lower than in CAPRI by 1.5%. The differences in the producer prices at the country level between IFM-CAP[8] and CAPRI are within a range from -20.2% to +9.8%, and between AGMEMOD and CAPRI from -23.7% to 16.0% with the exception of Cyprus, Malta, Poland and Sweden. The figures below display the differences at the country level.

[8] IFM-CAP does not project prices. The latter are exogenous to the model. The model calculates the 2030 values of the prices based on the base year values in its own database and the growth rates projected by CAPRI.

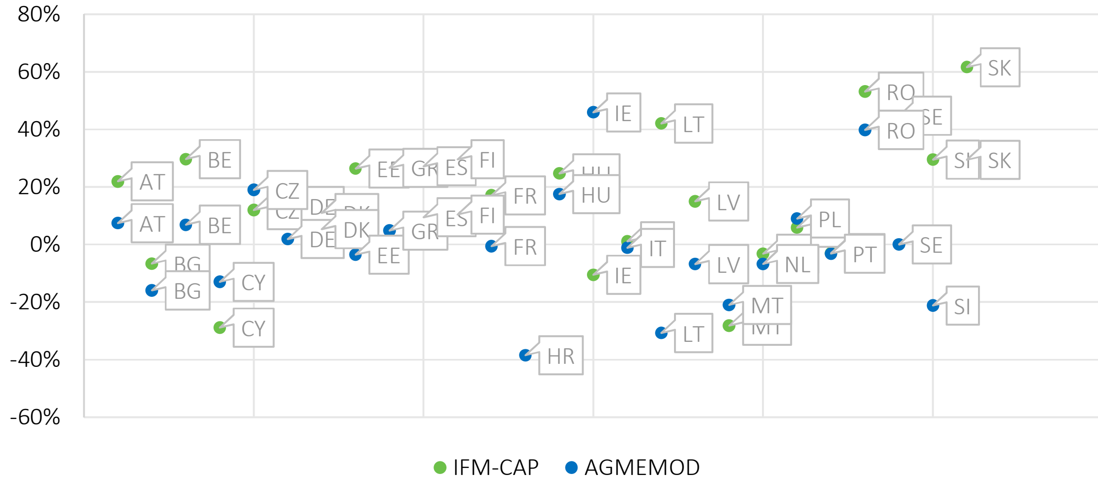

Figure 19: % differences in projected quantities of raw cow milk production by IFM-CAP and AGMEMOD at the country level as compared to the projections by CAPRI.

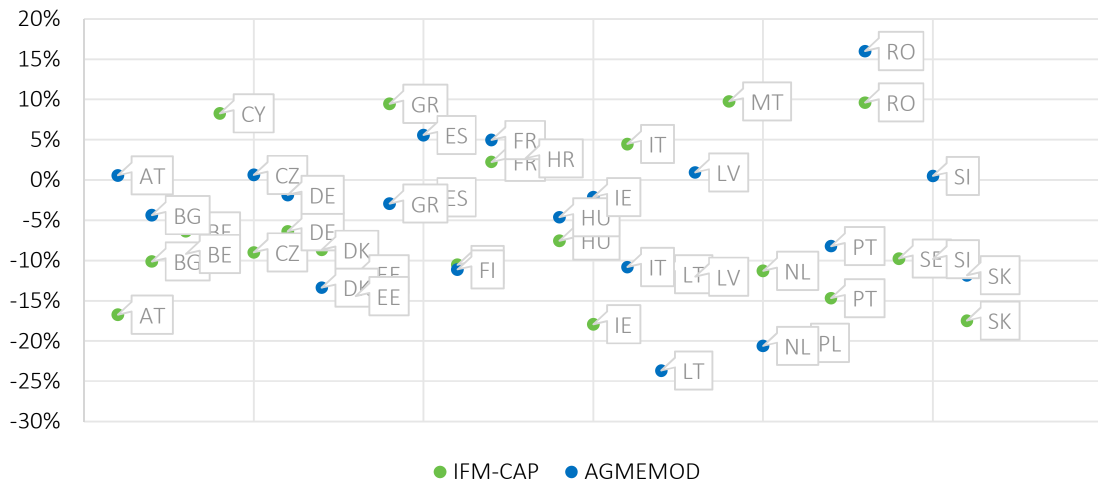

Figure 20: % differences in the 2030 values of producer prices of raw cow milk in IFM-CAP and AGMEMOD at the country level as compared to the projections by CAPRI.

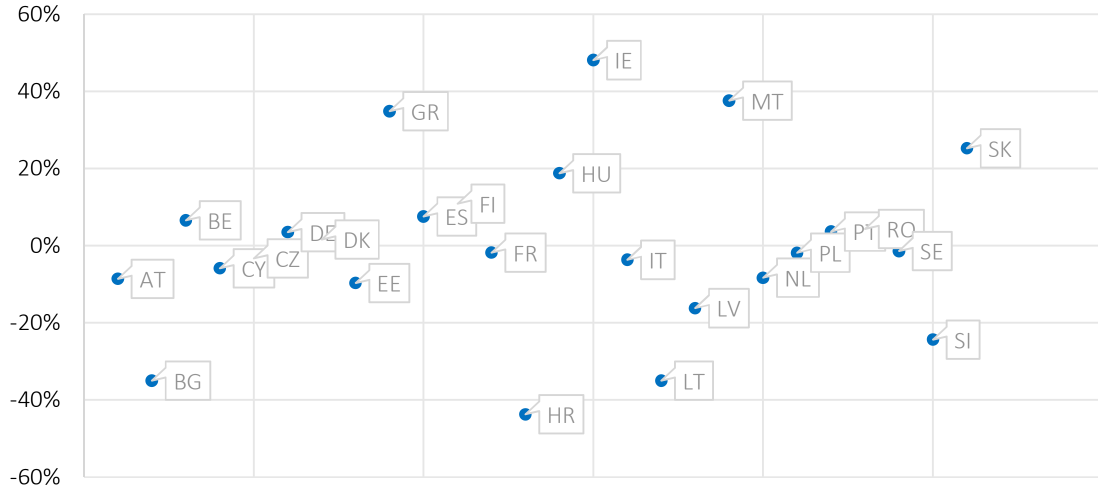

Figure 21: % differences in the projected quantities of raw cow milk use by AGMEMOD at the country level as compared to the projections by CAPRI.

4.3 Analysis of the differences

In the 2030 baselines of CAPRI, AGMEMOD and IFM-CAP, the assumptions of future values of GDP, population, exchange rate, inflation and crude oil prices, as well as the external baselines and representation of CAP have been harmonized. Nevertheless, the models have produced quite different modelling outcomes, especially at the EU country level. This can be explained by four major groups of causes: (i) data, (ii) model structure and methodology, (iii) details in implementation of the CAP assumptions and (iv) approach to scaling/calibration to the external baseline.

Different data sources and different set of indicators for computing values of the common variables will inevitably result in non-similar outcomes. This refers to calculating such factors as processing coefficients, yields, animal slaughter weights, per capita consumption, as well as to the estimation of models' parameters during calibration procedures (IFM-CAP and CAPRI) or econometric estimation (AGMEMOD).

Model structure covers a wide range of model characteristics, such as regional aggregation level at which the simulation takes place, commodity coverage, level of detail of agricultural production and agricultural/market activities considered in the model (e.g., livestock feeding, crops fertilization, on-farm consumption) and representation of trade (e.g., bilateral trade, net-trade models). Methodology implies estimation/simulation methods used in the models (e.g., statistical methods, mathematical optimization, system of equations) and functional forms representing behaviour of the economic agents in production, consumption, trade and other activities. Although in theory, different model structures and methodologies, when applied to a common research question, should produce, if not similar, then very close results, in reality this is often not the case. Not only because economic models are, in essence, a simplification of reality and thus, their nature implies an error term in the projections, but also because the required data and knowledge on parameters characterizing the industries are usually limited. The latter especially refers to the elasticities of various production processes, consumption and use, as well as parameters for import and export functions. Therefore, every model employs the information available and accessible to its modelling teams, in the form of data, estimations or assumptions. The models with more detailed representation of agricultural sector and the models with greater aggregation level will require different set of data and assumptions that, given the imperfect availability of information, will lead to different simulation results.

The way CAP is implemented in the models matters as well. For example, CAP decoupled payments are built in CAPRI, IFM-CAP and AGMEMOD in different ways. CAPRI maximizes income at regional level, and the decoupled payment only affects the decision of land expansion or contraction for agriculture. IFM-CAP considers land per farm fixed, and therefore, decoupled payments do not affect the land allocation. AGMEMOD uses a coupling factor to reflect that the decoupled payments still have an impact on production levels, and therefore provides a price premium for those crops, which are included in the area for calculating historical endowments. As regards CAP coupled payments, the three models, while using the same data, apply different disaggregation levels. Furthermore, whereas CAPRI and IFM-CAP implement the 2014-2020 greening limitations regarding permanent pastures, Ecological Focus Areas (EFA) and crop diversification, AGMEMOD considers only the last two.

IFM-CAP, CAPRI and AGMEMOD use the 2030 projections of MTO2019 for calibrating/scaling their projections in very different ways. CAPRI weights the values of MTO2019 by the values of its base year to smoothen the possible differences with the Aglink-COSIMO database. Thus, weighted MTO2019 values are used in the calibration. AGMEMOD applies scaling procedure, which adjusts the parameters of the behavioural equations at the country level to fit the values of MTO2019 at the level of EU aggregates. The adjustment of the parameters is as well bounded by the trends observed in the AGMEMOD database. IFM-CAP applies projected by CAPRI yield and price growth rates. Such different among the models approaches result in the differences of the baselines, especially at the country level, even when a common external baseline is used.

5. Comparison of the 2050 baselines

Generation of long term baselines is often serves the purpose of analysing the effects, which reveal themselves in a more distant future, such as for example, climate change. GLOBIOM, MAGNET and CAPRI are the models that are very well suitable for such research, because they include a wide range of climate-change and land-use related indicators and are capable of producing long-term projections. The joint application of these three models for the analysis of climate-related policies may bring added value in terms of broader coverage of the economy and of the agricultural production.

Employing a group of models for analysing a common research question implies a certain degree of their linkage. The latter should be preceded by studying similarities and differences of the models involved. This would allow for development of better fitted linkage approaches. Among the first steps of such examination is a comparative analysis of scenarios generated under similar assumptions. Thus, in the following section we compare the baseline scenarios of GLOBIOM, MAGNET and CAPRI, external factors of which have been aligned as described in Chapter 3. We as well make an attempt to understand the causes of their possible differences.

The current investigation focuses on GHG emissions and agricultural land use due to the relevance of these variables for the climate-related research. Projections of crops production and market balances are reviewed as well. The commodities considered include rice, wheat, oilseeds, non-ruminant and ruminant meat products, as well as aggregates, such as agriculture, crops and livestock. The regional aggregation considered is EU before 2019.

5.1 Areas and market balances

As it is demonstrated in Figure 22, the differences among the areas of crops and UAA projected by CAPRI, MAGNET and GLOBIOM vary. Whereas the acreage of UAA projected by MAGNET is 2% less than by CAPRI, acreage of wheat is 50% greater. Similar situation occurs when comparing GLOBIOM and CAPRI projections for oilseeds and wheat. Larger differences may stem from the differences in the database of the models. Therefore, we continue analysing the results by comparing growth rates of the projected to the observed values. The latter are the 2010 (2011 for MAGNET) values of the models' databases. In the remaining of this chapter, we will refer to them as the base year values.

MAGNET projects the decrease in the UAA by 6.2%, GLOBIOM by 6.3% and CAPRI by 5.2%, when compared to the respective base year values of the models. The growth rates for the crops aggregate, wheat, oilseeds and rice are close among the pairs of the models. For example, whereas MAGNET projects decrease in the total crops area by 1.3%, CAPRI and GLOBIOM by, respectively, 10.4% and 7.8%. Similarly, the growth rates of wheat area in MAGNET is 6.8%, and -21.9% and -22.8% in CAPRI and GLOBIOM, respectively. Growth rates of the oilseeds areas are closer between MAGNET and CAPRI, and growth rates of rice areas are very different among all three models.

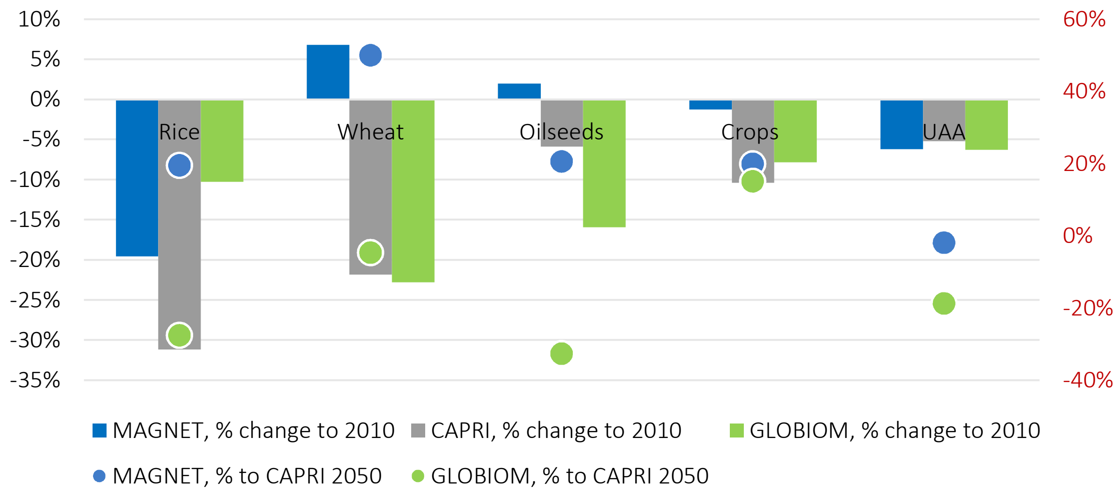

Figure 22: % differences in the crop areas and growth rates projected by MAGNET, GLOBIOM and CAPRI. Note: 1) the comparison base year for MAGNET is 2011; 2) *% change to CAPRI 2050* uses the right axis.

The remaining of this section reviews the differences in the change rates of market balances for rice, wheat, oilseeds, ruminant and non-ruminant meat products projected by CAPRI, MAGNET and GLOBIOM. CAPRI and GLOBIOM report market balance variables in physical quantities (1000 tons), whereas MAGNET calculates these variables in monetary values, i.e. 2011 constant USD. To make MAGNET data comparable with CAPRI and GLOBIOM, the additional effort was taken to represent the required MAGNET variables in physical quantities.

The quantities available in MAGNET database are production quantities (and related nutrients) concerning agricultural commodities in the base year. The related data are sourced from FAO. To calculate production quantities in the simulation periods, we updated base year quantities by volume changes calculated by MAGNET. Since MAGNET distinguishes between primary and process agricultural products, we need not only calculate trade flows in physical quantities for primary agricultural products but also to re-calculate trade flows of processed agricultural products in primary products equivalent in physical quantities. The additional code is used in the post-simulation process to make these calculations. It calculates trade quantities from production quantities and volumes of trade, production and different uses. For instance, the export quantity is obtained by multiplying production quantity with exports volume share in total production volume and to determine quantity of primary products in exported processed products related input-output coefficients are used. This method implicitly assumes a uniform market price of each primary agricultural commodity for producer and all users, which is not necessary truth in real world, and that products are homogenous by regions contrary to regional heterogeneity assumed by MAGNET. These strong assumptions made to calculate the required quantities can lead to differences of calculated trade flows compared with statistics as well us with aggregated volume changes calculated by MAGNET. Therefore obtained MAGNET quantities needs to be analysed with caution.

In the rice sector, the production growth rate projected by GLOBIOM is -3.8%, by CAPRI -13.4% and by MAGNET -15.9%. Total use on the domestic market is projected to grow by 14.6% according to CAPRI model, by 13.9% according to GLIOBIOM model and to drop by 11.6% according to MAGNET. GLOBIOM and CAPRI simulate worsening of the net-trade balance by -28.4% and -55.1%, respectively; MAGNET projects its improvement by 9.2%. The differences are due to the changes in imports and exports of rice. GLOBIOM and CAPRI project increase in both, exports and imports of rice. The projected quantities of imports, however, are greater than the projected quantities of exports. This leads to the decreased net-trade balances. MAGNET, on the contrary, simulates decrease in the quantities of rice imported and exported. In this case, decreased export quantity is lesser than the decreased import quantity. This leads to improvement of the net-trade balance of rice in 2050 as compared to 2010.

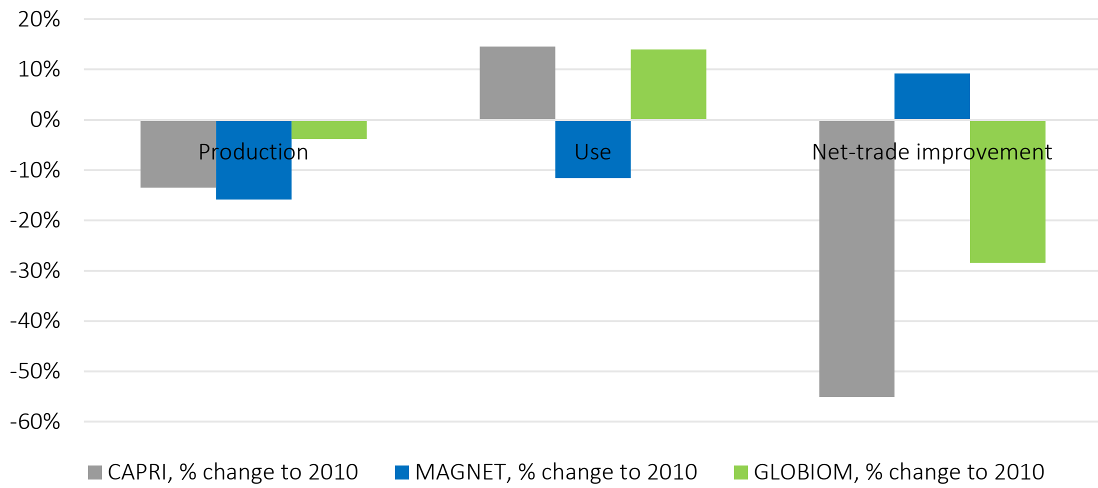

Figure 23: Changes in the market balances of rice projected by CAPRI, MAGNET and GLOBIOM.
Note: 1) the comparison base year for MAGNET is 2011; 2) Use indicates Total use on the domestic market; 3) Net-trade improvement indicates improvement (positive % change) or worsening (negative % change) of the net-trade balance (see also comments to the graph in the text).

The projections of growth rates of wheat production by GLOBIOM, CAPRI and MAGNET are, respectively, -2.1%, 1.8% and 29.9%. The changes in the domestic use are rather close between the models: 8.3% in CAPRI, 4.5% in MAGNET and 5% in GLOBIOM. The net-trade changes are, however, quite different. Whereas CAPRI and GLOBIOM simulate worsening of the net-trade balances by, respectively, 37.5% and 69.5%, MAGNET projects its improvement by 225.8% (Figure 24). The projections of the former two models are explained by increase in imports (28.1% in CAPRI and 29.6% in GLOBIOM) and decrease in exports (-30.5% in CAPRI and -7.2% in GLOBIOM) of wheat in 2050 as compared to 2010. Although MAGNET projects increase in import of wheat as well, this change is rather small – 2.7%. Combined with 60.2% increase in export, the net-trade balance of wheat simulated by the model improves considerably.

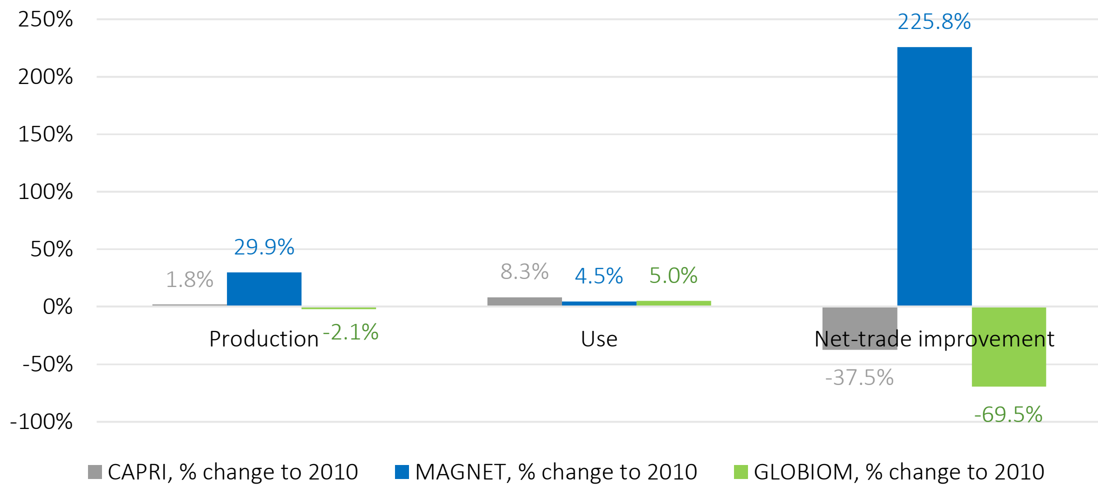

Figure 24: Changes in the market balances of wheat projected by CAPRI, MAGNET and GLOBIOM.
Note: 1) the comparison base year for MAGNET is 2011; 2) Use indicates Total use on the domestic market; 3) Net-trade improvement indicates improvement (positive % change) or worsening (negative % change) of the net-trade balance (see also comments to the graph in the text).

CAPRI and MAGNET simulate increase in oilseeds production by 30.2% and 35.6%, respectively. GLOBIOM projects the 12.1% growth rate. The projected changes in the domestic use of oilseeds vary: 10.9% in GLOBIOM, 29.1% in CAPRI and 44.9% in MAGNET. Although the differences in the projected net-trade quantities are not small, they follow similar pattern: MAGNET projects worsening of the net-trade balance by 51.5%, CAPRI by 27.2% and GLOBIOM by 9.4%. Although all three models simulate increases in exports, as well as in imports, quantities imported are projected to be considerably higher than quantities exported that results in degrading of the net-trade balances.

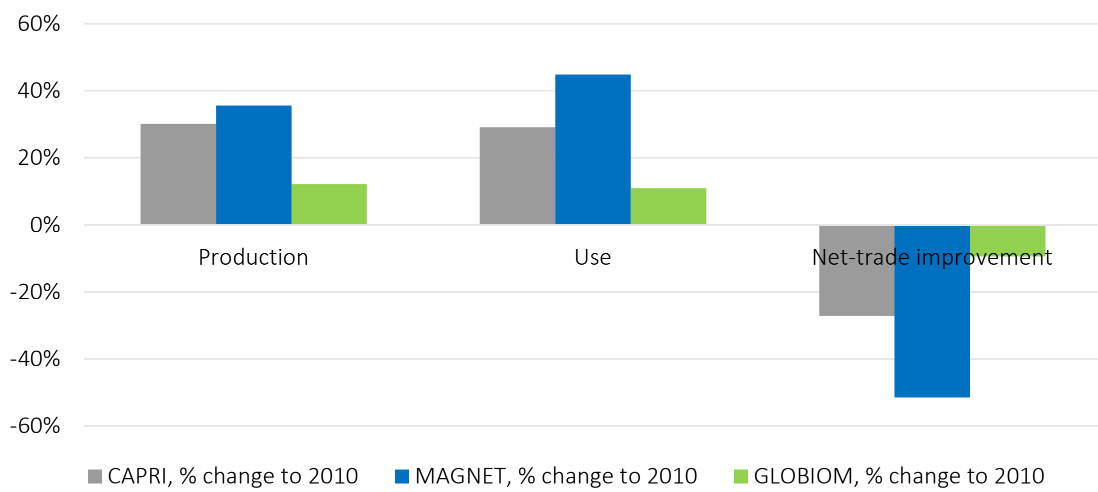

Figure 25: Changes in the market balances of oilseeds projected by CAPRI, MAGNET and GLOBIOM.
Note: 1) the comparison base year for MAGNET is 2011; 2) Use indicates Total use on the domestic market; 3) Net-trade improvement indicates improvement (positive % change) or worsening (negative % change) of the net-trade balance (see also comments to the graph in the text).

Growth rates of total use of meat projected by the models are rather close. They vary from -8.5% to 8.1% for ruminant meat, and from 7.8% to 14.4% for non-ruminant meat. The growth rates of production by GLOBIOM and CAPRI are rather close, whereas they differ from the projections by MAGNET. In particular, ruminant meat production is projected to decrease by 7.6% by GLOBIOM, and by 6% by CAPRI. MAGNET projects increase in ruminant meat production by 30%. Non-ruminant meat production is expected to increase by 19.8% according to CAPRI and by 12.9% according to GLOBIOM. The projection of growth rate for non-ruminant meat production by MAGNET is 5.3%.

Changes in the net-trade balances projected are rather different among all three models. MAGNET and CAPRI project improvement of the net-trade balance of ruminant meat by, respectively, 795% and 257%, and GLOBIOM by 40.6%. The explanations are the following. In CAPRI, export increases and import decreases, and in MAGNET, export increases by a considerably greater quantity than import. GLOBIOM projects a slight decrease in both, export and import, where the decrease in import is only marginally greater than the decrease in export. Net-trade balance of non-ruminant meats is simulated to be improved only by CAPRI (55%). GLOBIOM and MAGNET project its worsening by, respectively, 21% and 195%. Whereas CAPRI projects increase in export and decrease in import of non-ruminant meats, GLOBIOM and MAGNET simulate greater increase in imports than in exports of this type of meat by 2050 (Figures 26 and 27).

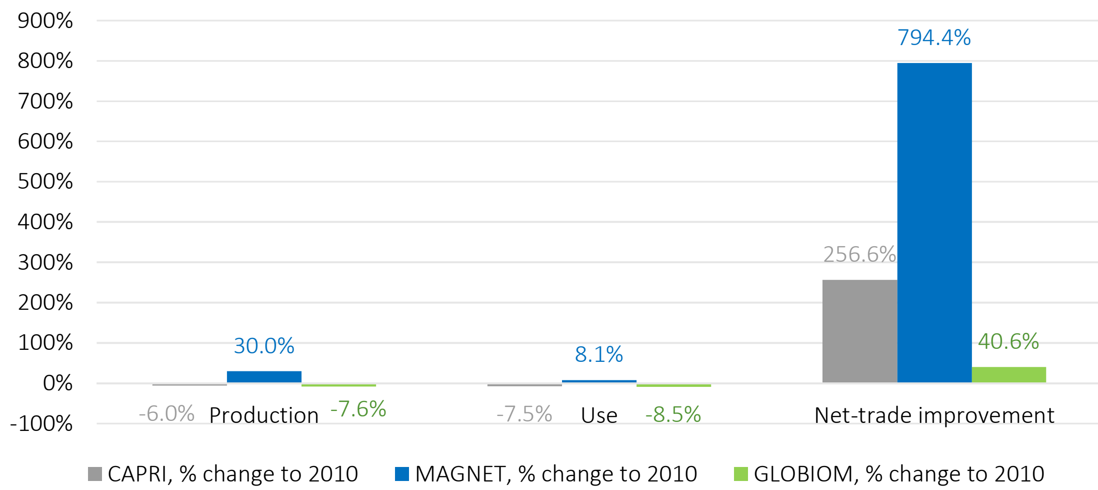

Figure 26: Changes in the market balances of ruminant meats projected by CAPRI, MAGNET and GLOBIOM.
Note: 1) the comparison base year for MAGNET is 2011; 2) Use indicates Total use on the domestic market; 3) Net-trade improvement indicates improvement (positive % change) or worsening (negative % change) of the net-trade balance (see also comments to the graph in the text).

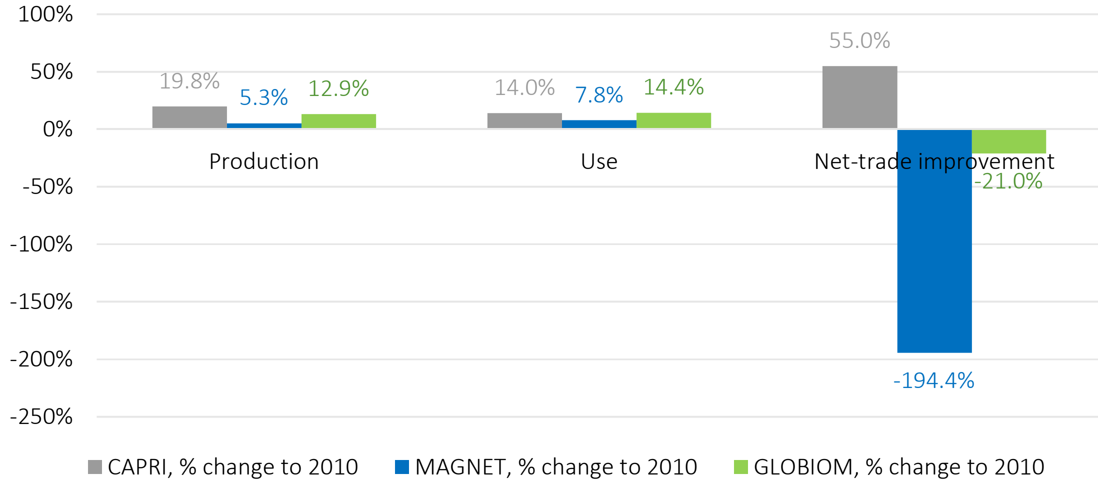

Figure 27: Changes in the market balances of non-ruminant meats projected by CAPRI and GLOBIOM.
Note: 1) the comparison base year for MAGNET is 2011; 2) Use indicates Total use on the domestic market; 3) Net-trade improvement indicates improvement (positive % change) or worsening (negative % change) of the net-trade balance (see also comments to the graph in the text).

5.2 GHG emissions

CAPRI, MAGNET and GLOBIOM simulate a number of GHG emission indicators from various sources. In the current report, we review the differences in the total GHG emissions, N2O and CH4, from agricultural activities in general, crops and livestock production.

Projected changes in the total GHG emissions from agriculture with respect to the values of 2010 differ among the models. CAPRI projects the reduction by 1%, whereas GLOBIOM and MAGNET increase by, respectively, 11.7% and 9.1% (Figure 28).

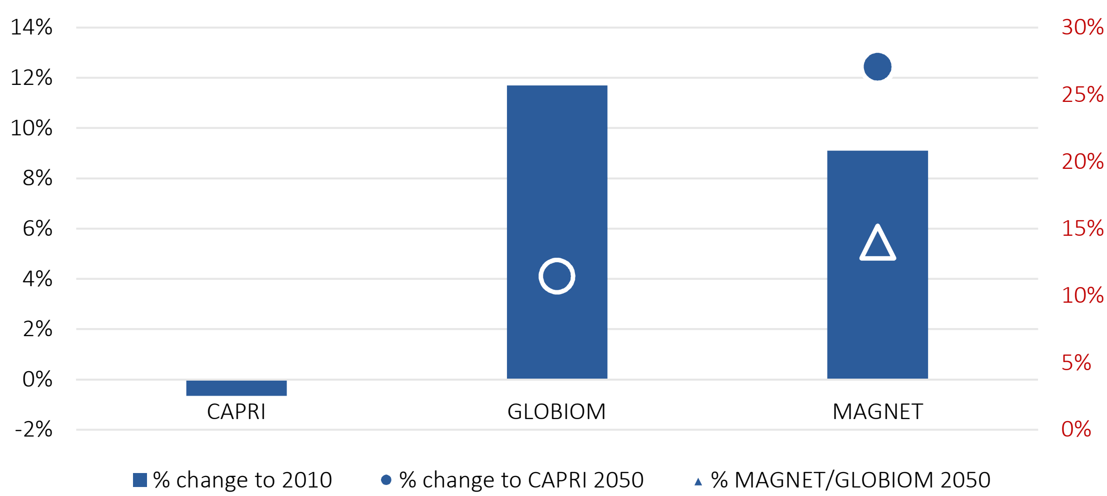

Figure 28: % differences of the total GHG emissions from agriculture projected by CAPRI, MAGNET and GLOBIOM (Mt CO2eq/yr).
Note: 1) the comparison base year for MAGNET is 2011; 2) *% change to CAPRI 2050* and *% MAGNET/GLOBIOM 2050* use the right axis.

Projected changes in the emissions from crops production as compared to 2010, follow similar patterns among the models, although with some exceptions. Thus, CAPRI and MAGNET project the reductions in N2O, CH4, as well as total GHG emissions, whereas GLOBIOM projects the reduction only in CH4 emissions. The largest reduction in CH4 emissions is simulated by CAPRI, -31.2%. MAGNET projects -26.4%, and GLOBIOM -10.1%. N2O emissions are simulated by CAPRI to be reduced by 2.3%, by MAGNET by 8%, and by GLOBIOM by 5%.

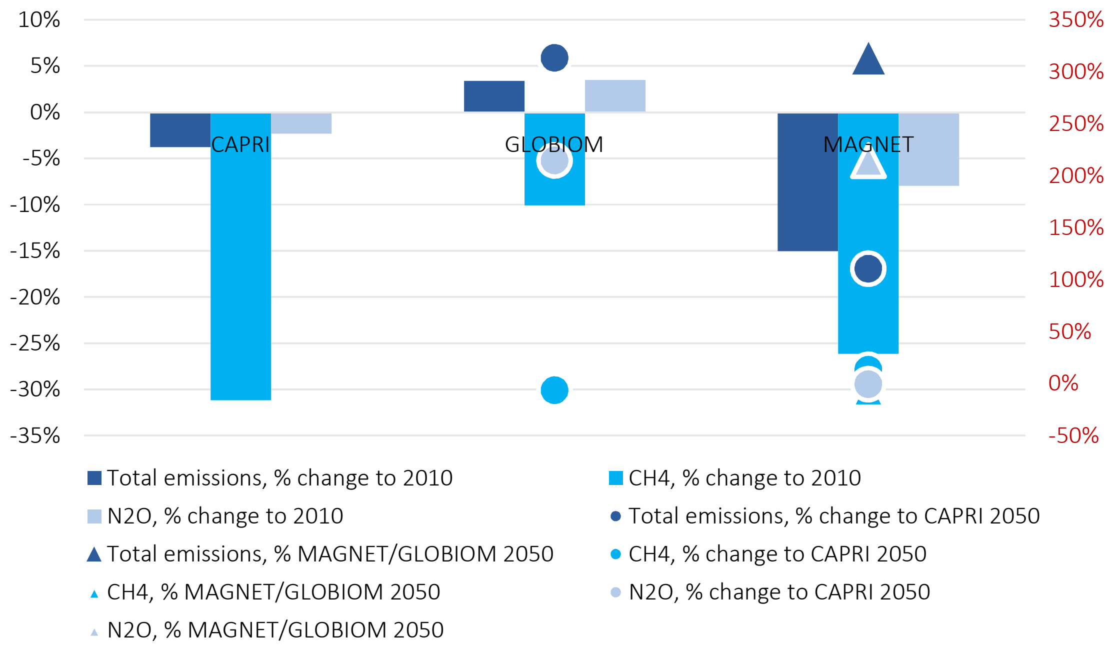

Figure 29: % differences of the total, CH4 and N2O emissions from crops production projected by CAPRI, MAGNET and GLOBIOM (Mt CO2eq/yr).
Note: 1) the comparison base year for MAGNET is 2011; 2) *% change to CAPRI 2050* and *% MAGNET/GLOBIOM 2050* use the right axis.

Changes in the emissions from livestock production as compared to 2010 are close between GLOBIOM and CAPRI. The latter projects almost no change in the total emissions and the former a slight increase. The growth rate of N2O emissions projected by CAPRI is 4.8% and by GLOBIOM 8%; the change in CH4 emissions is -2.9% in CAPRI and +0.6% in GLOBIOM. The differences with MAGNET projections are greater. MAGNET projects increase in the total emissions by 19.9%, in CH4 emissions by 23.5% and in N2O emissions by 18.6% (Figure 30).

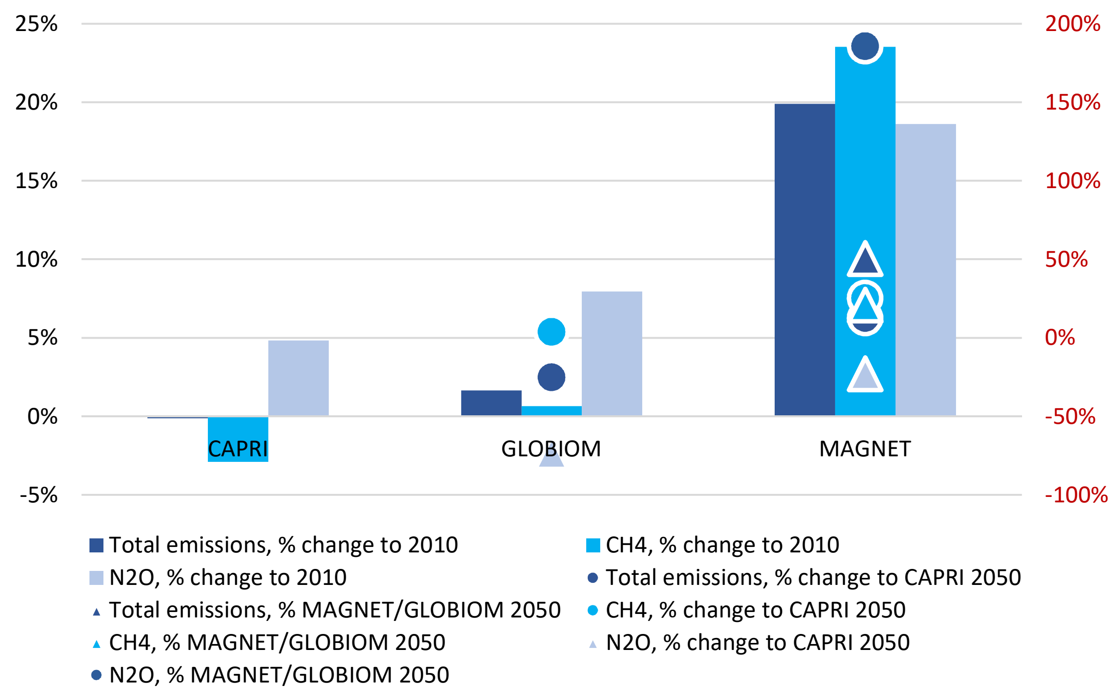

Figure 30: % differences of the total, CH4 and N2O emissions from livestock production projected by CAPRI, MAGNET and GLOBIOM (Mt CO2eq/yr).
Note: 1) the comparison base year for MAGNET is 2011; 2) *% change to CAPRI 2050* and *% MAGNET/GLOBIOM 2050* use the right axis.

5.3 Analysis of the differences

The 2050 baselines of CAPRI, MAGNET and GLOBIOM, despite harmonized projections of population, GDP, energy prices, energy plant and forestry areas, as well as the common value for global carbon price, demonstrate varying results. The main reasons for this phenomenon include the differences in (i) model specifications, (ii) data and (iii) policy representation.

Model specification refers to the economy coverage and the respective economic assumptions, level of details of the agricultural and other sectors, model structure and simulation methods. CAPRI, MAGNET and GLOBIOM are very different models in this respect. Important aspects of these differences include general equilibrium character of the MAGNET model as opposed to the partial equilibrium setting of CAPRI and GLOBIOM. General equilibrium approach assumes clearing markets globally including of the production factors. This may significantly input into the differences with the partial equilibrium models, where a limited number of sectors are considered, and availability and prices of production factors are completely or partially exogenous to the models. The key distinctive features of GLOBIOM, as compared to MAGNET and CAPRI, are detailed representation of the land demand by forestry, cropland, grassland and bioenergy sectors. With three models covering the economy and the agricultural sector at different levels of detail and synergies, considerable variation in the modelling outcome should be expected.

The second type of the reasons for the differences among the models refers to data and data sources. As CAPRI uses Eurostat and FAOSTAT, MAGNET works with GTAP database, and GLOBIOM employs input from various sources and models (see section 2.5 and the references), the differences in the base year values are unavoidable. Moreover, different data requirements result in additional parameters or values that may cause differences among the modelling outcomes.

The third possible cause of diverging modelling results is representation of the climate policy. In the models, it is covered via bioenergy assumptions and mitigation targets (either as hard constraints or as equivalent CO2 prices). GLOBIOM represents mitigation targets for the land use via carbon prices and biomass demand. MAGNET has a module for emission trading, renewable energy targets and biofuels mandates. CAPRI sets the emission targets for the EU based on activities and carbon prices both for the EU and for the rest of the world. The differences in these approaches input into the differences in the projected values of the climate related variables.

6. Conclusions and recommendations

From this review it has become apparent that homogenisation of the external drivers does not necessarily result in similar modelling outcomes among the models considered. A number of model specific characteristics cause the differences. In the case of 2050 baselines which were generated by CAPRI, MAGNET and GLOBIOM, as well as in the case of 2030 baselines which were generated by CAPRI, AGMEMOD and IFM-CAP, these causes can be aggregated into three groups: (i) data requirements and data sources, (ii) model specification, parametrization and methodology, and (iii) policy representation. The approach of calibration/scaling to the external baseline, where applicable, matters as well.

Comparison and analysis of the differences among the baselines and the models, described in this report, reveals three important aspects, which should be considered when linking the models:

- Differences among the simulation results of the models, unless stemming from different commodity/activity definitions or exogenous variables, add value to these results rather than devaluate them. As the models work with different levels of details of the agricultural and other sectors, consider different synergies between them, as well as are based on varying data and evidence (e.g., processing coefficients, industry characteristics), their modelling results demonstrate a possible span of the effects of the simulated policy or shock. This allows for examination of the researched phenomenon from more perspectives and, thus, in a more complete and comprehensive way.

- With respect to the point mentioned above, model linking should elaborate on the strengths of each of the models involved. The models should complement the relevant modelling blocks of each other, rather than substitute them. Each model is built in a unique way and upon a set of evidence and theory based assumptions that altogether constitute an organism-like system. A particular advantage of such systems is that they simulate the impacts on the large number of indicators rather than on few specific variables. Therefore, when linking the models, it is important to avoid turning complex systems into simplistic simulation tools with predictable outcomes.

- Finally, and yet important are the correct concordance tables between activities and commodities of the models. It is a common knowledge that commodity as well as activity definitions may differ among the models. Common examples are commodity aggregates such as *Other cereals*, definitions of specific commodities such as milk and definition of prices. *Other cereals* usually include all of the cereal crops not particularly specified in the model, thus, might be different among the models. Milk may be defined as raw milk including or excluding on-farm use or milk delivered to dairies. Prices may be defined as farm gate prices, wholesale prices, include or exclude transportation and processing costs. Therefore, careful mappings is essential for assuring proper functioning of the linked models.

As it appears from the current report, linking and harmonizing large-scale economic models, such as the reviewed in the current report, may be rather challenging. The number of model specific details that will need to be examined for relevance and compatibility, as well as the number of informed decisions, which will need to be taken in this respect and which will, nevertheless, be called into question by the reviewers and modellers themselves, may be overwhelming. However, in the near future, interdependencies in the world economy are likely to become tighter, the world population will most likely keep growing and natural resources will keep being depleted. Moreover, changing consumer demands and changing climate are likely to put more pressure on the agricultural sector in terms of producing food more efficiently, following stricter standards (e.g., food quality standards, animal welfare and environmental standards etc.) and delivering social and environmental services. Thus, the research questions are likely to become more interdisciplinary and demand greater precision of the results. Linked large-scale models with highly detailed components may appear a very useful tool for this kind of research. Therefore, if *God is in the detail*, these complex systems may provide with a uniquely broad and, at the same time, detailed overview of impacts of agricultural and other policies, and of economic, environmental and social shocks.

References

Blanco, M., P. Martinez, P. Witzke, M. van Leeuwen, R. Jongeneel, P. Salamon, S. Frank, P. Havlík, J. Barreiro-Hurlé, M. L. Rau, H. van Meijl, A. Tabeau, J. P. Lesschen (2019). Deliverable 1.5: Documentation of the SUPREMA model tools. Project Support for Policy Relevant Modelling of Agriculture (SUPREMA). Online: https://www.suprema-project.eu.

Beach, R. H., J. Creason, S. Bushey Ohrel, S. Ragnauth, S. Ogle, C. Li, P. Ingraham, W. Salas (2015). Global mitigation potential and costs of reducing agricultural non-CO_2 greenhouse gas emissions through 2030. Journal of Integrative Environmental Sciences: 12 (sup1), 87-105.

Britz, W., P. Witzke (2014). CAPRI model documentation 2014. Online: https://www.capri-model.org.

Capros, P., A. De Vita, N. Tasios, P. Siskos, M. Kannavou, A. Petropoulos, S. Evangelopoulou, M. Zampara, D. Papadopoulos, L. Paroussos, K. Fragiadakis, S.Tsani, P. Karkatsoulis, P. Fragkos, N. Kouvaritakis, L. Höglund-Isaksson, W. Winiwarter, P. Purohit, A. Gomez-Sanabria, S. Frank, N. Forsell, M. Gusti, P. Havlík, M. Obersteiner, H. P. Witzke, Monika Kesting (2016). EU Reference Scenario 2016 Energy, transport and GHG emissions Trends to 2050. European Commission. Online: https://ec.europa.eu/clima/sites/clima/files/strategies/analysis/models/docs/ref20160729_report_en.pdf.

Chantreuil, F., K. F. Hanrahan, M. van Leeuwen (2012). The Future of EU Agricultural Markets by AGMEMOD. Springer Science+Business Media B.V. Springer Netherlands.

FAO (2010). Global Forest Resources, Assessment 2010, Main report. Rome, Food and Agriculture Organization of the United Nations. Forestry Paper 163: 340.

Havlík, P., H. Valin, M. Herrero, M. Obersteiner, E. Schmid, M. C. Rufino, A. Mosnier, P. K. Thornton, H. Böttcher, R. T. Conant, S. Frank, S. Fritz, S. Fuss, F. Kraxner, A. Notenbaert (2014). Climate change mitigation through livestock system transitions. Proceedings of the National Academy of Sciences 111(10): 3709-3714.

Hertel, T. (1997). Global Trade Analysis: Modeling and Applications. New York: Cambridge University Press.

Louhichi, K., P. Ciaian, M. Espinosa, L. Colen, A. Perni, S. Gomez y Paloma (2015). An EU-Wide Individual Farm Model for Common Agricultural Policy Analysis (IFM-CAP). First application to Crop Diversification Policy. European Commission. Joint Research Centre. Online: https://publications.jrc.ec.europa.eu/repository/bitstream/JRC92574/jrcreport_jrc92574.pdf.

Nowicki, P., V. Goba, A. Knierim, H. van Meijl, M. Banse, B. Delbaere, J. Helming, P. Hunke, K., Jansson, T. Jansson, L. Jones-Walters, V. Mikos, C. Sattler, N. Schlaefke, I. Terluin and D. Verhoog (2009) Scenar 2020-II – Update of Analysis of Prospects in the Scenar 2020 Study, Contract No. 30–CE-0200286/00-21. European Commission, Directorate-General Agriculture and Rural Development, Brussels. http://ec.europa.eu/agriculture/analysis/external/scenar2020ii/report_en.pdf.

PICCMAT (2008): Deliverable D7: European quantification results. Wageningen, Alterra: 42.

Ruesch, A., H. K. Gibbs (2008). New IPCC Tier-1 Global Biomass Carbon Map For the Year 2000, Available online from the Carbon Dioxide Information Analysis Center http://cdiac.ornl.gov, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Salamon, P., M. Banse, J. Barreiro-Hurlé, O. Chaloupka, T. Donnellan, E. Erjavec, T. Fellmann, K. Hanrahan, M. Hass, R. Jongeneel, V. Laquai, M. van Leeuwen, A. Molnár, M. Pechrová, G. Salputra, W. Baltussen, J. Efken, S. Hélaine, J. Jungehülsing, O. von Ledebur, I. Rac, F. Santini (2017). Unveiling diversity in agricultural markets projections: from EU to Member States. A medium-term outlook with the AGMEMOD model. JRC Technical Report, 29025 EUR, Publications Office of the European Union, Luxembourg, ISBN 978-92-79-77335-8, doi:10.2760/363389.

Schönhart, M., E. Schmid, U. A. Schneider (2011). CropRota - A crop rotation model to support integrated land use assessments. European Journal of Agronomy 34(4): 263-277.

Woltjer, G., M. Kuiper, A. Kavallari, H. van Meijl, J. Powell, M. Rutten, L. Shutes, A. Tabeau (2014). The MAGNET model - Module description. Agricultural Economics Research Institute (LEI), LEI Report 14-057. The Hague, Netherlands.

Annex

Figures A1-A14 present visualization of the growth rates of the 2030 baseline projections by CAPRI and AGMEMOD at the EU and selected country levels with respect to the corresponding base year values. Because IFM-CAP computes base year values only at the farm level, the required for the current analysis calculations could not be performed. Figures A15-A19 present % differences between the projections of per capita consumption in 2030 by AGMEMOD as compared to CAPRI.

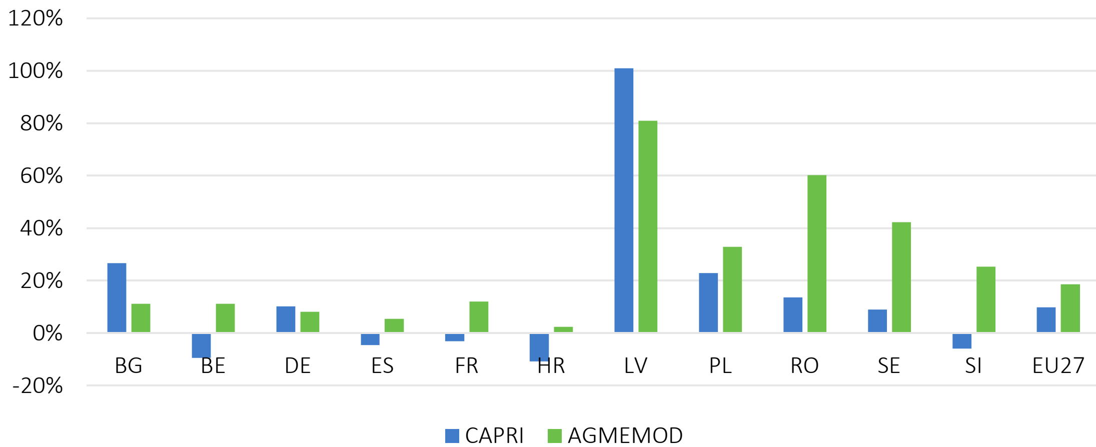

Figure A1: Growth rates of soft wheat production projected by CAPRI and AGMEMOD with respect to the base year values.

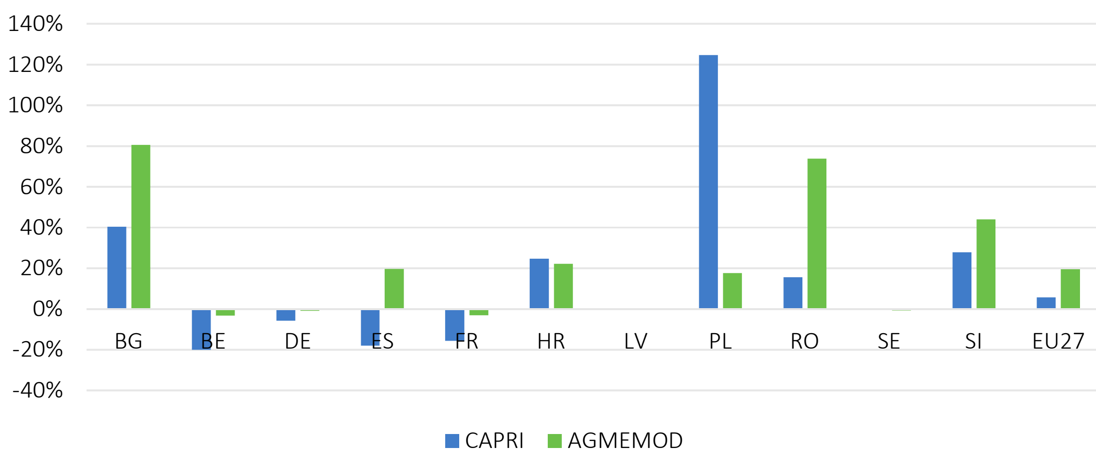

Figure A31: Growth rates of corn production projected by CAPRI and AGMEMOD with respect to the base year values.

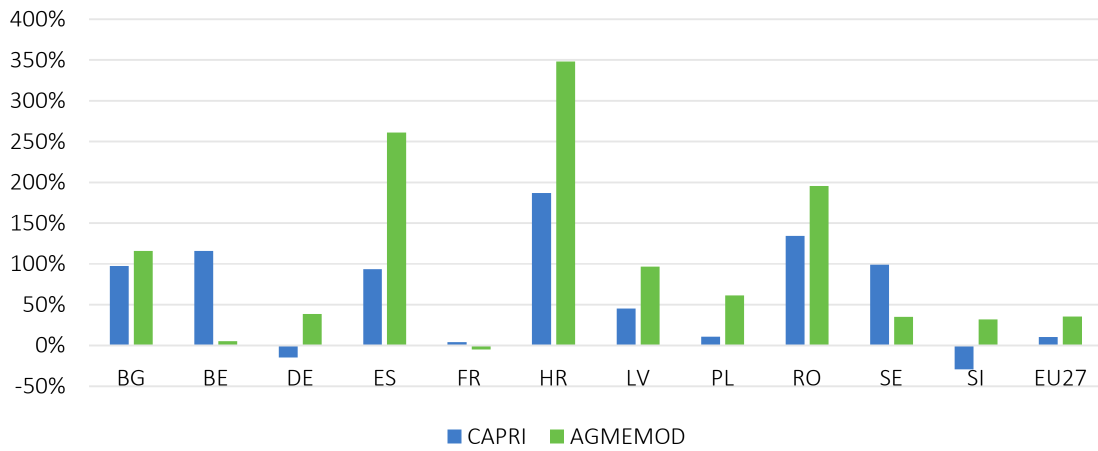

Figure A3: Growth rates of rapeseed production projected by CAPRI and AGMEMOD with respect to the base year values.

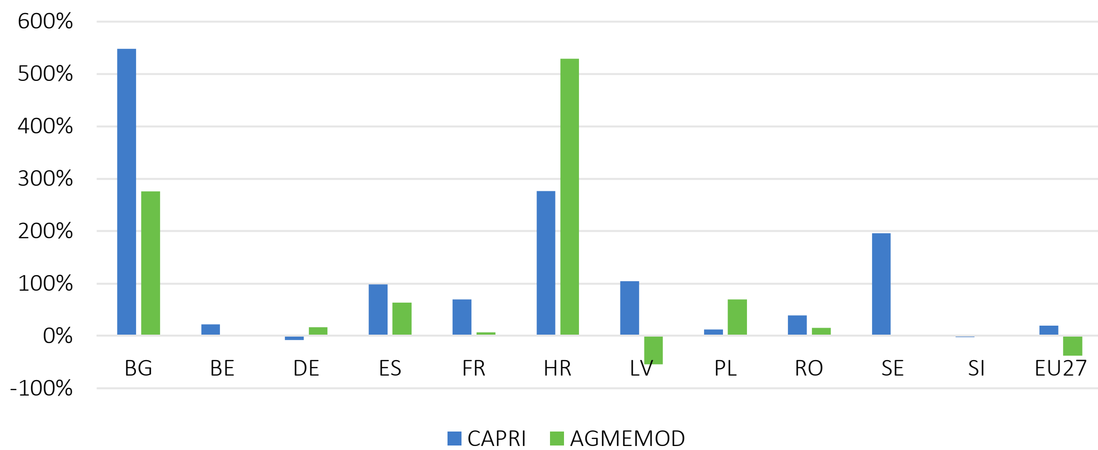

Figure A32: Growth rates of rapeseed oil production projected by CAPRI and AGMEMOD with respect to the base year values.

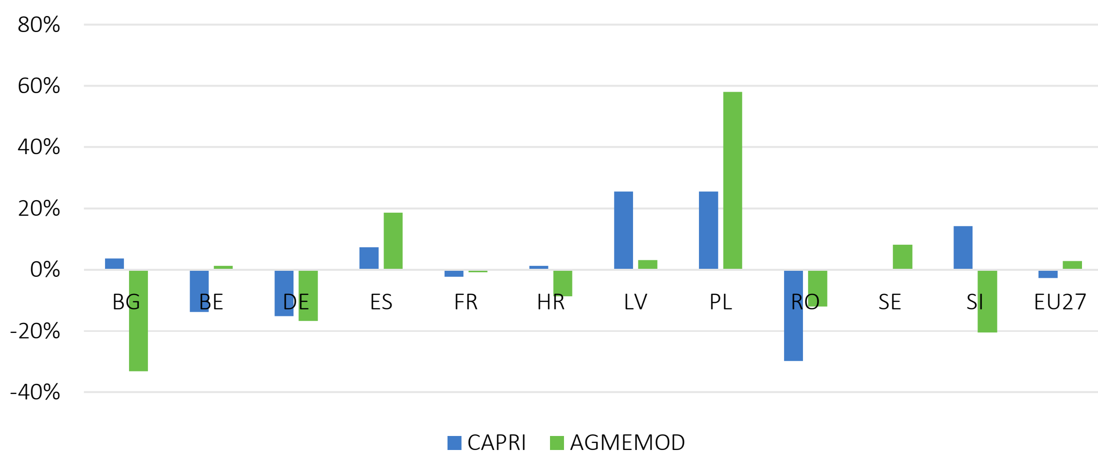

Figure A5: Growth rates of beef production projected by CAPRI and AGMEMOD with respect to the base year values.

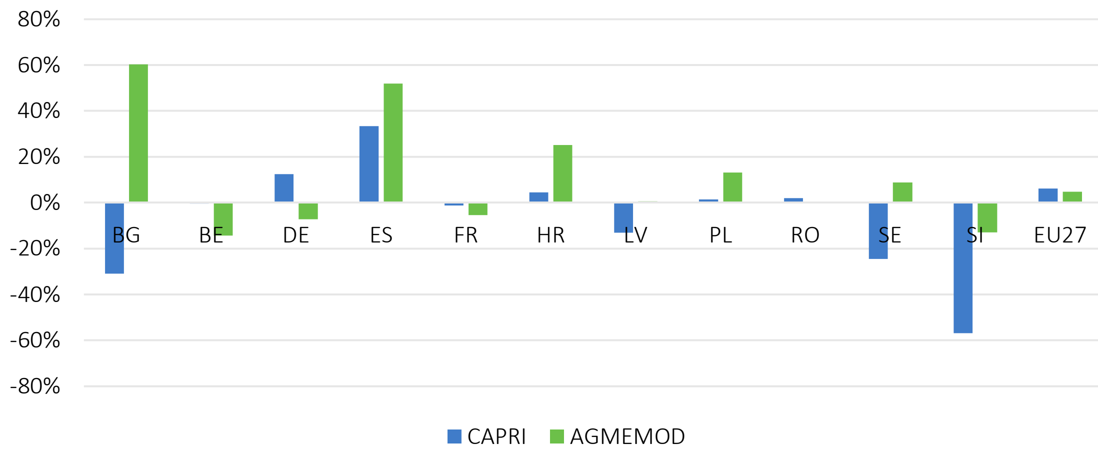

Figure A33: Growth rates of pork production projected by CAPRI and AGMEMOD with respect to the base year values.

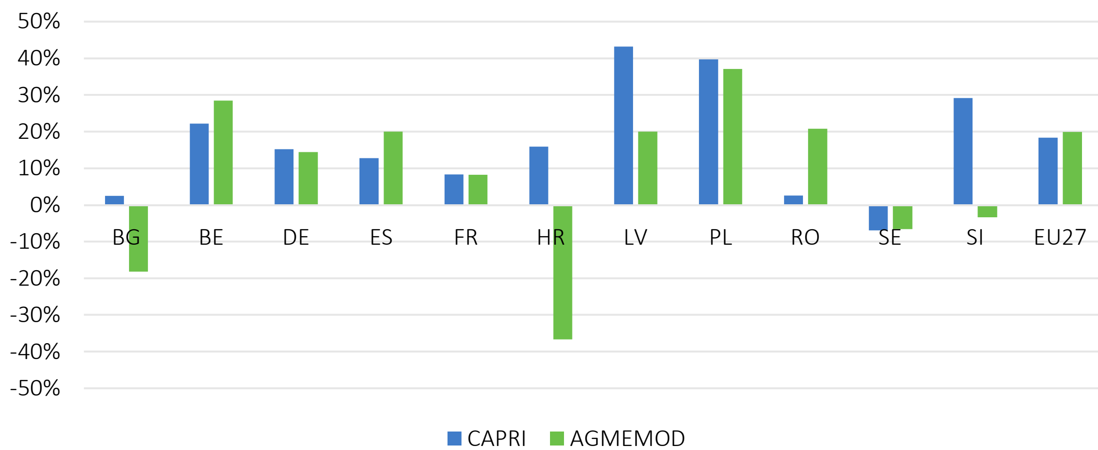

Figure A7: Growth rates of raw cow milk production projected by CAPRI and AGMEMOD with respect to the base year values.

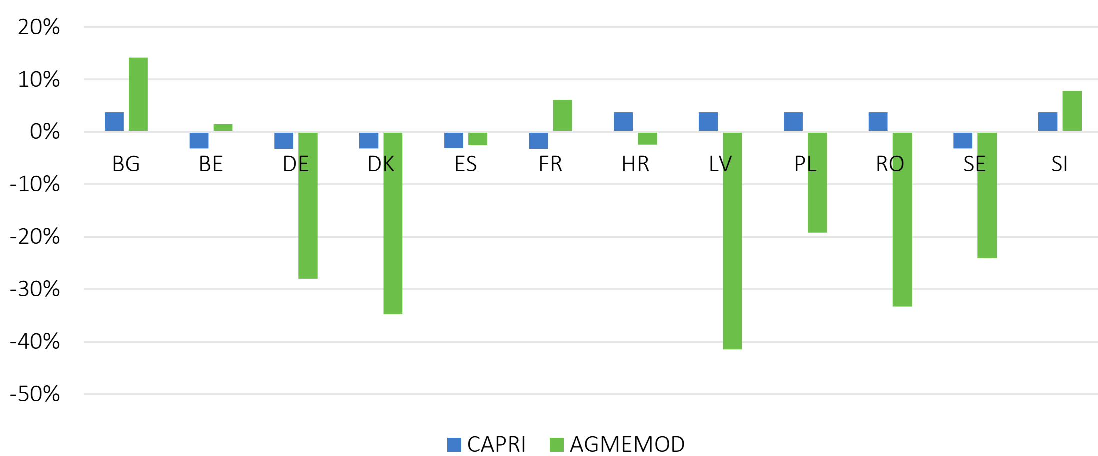

Figure A8: Growth rates of producer prices of soft wheat projected by CAPRI and AGMEMOD with respect to the base year values.

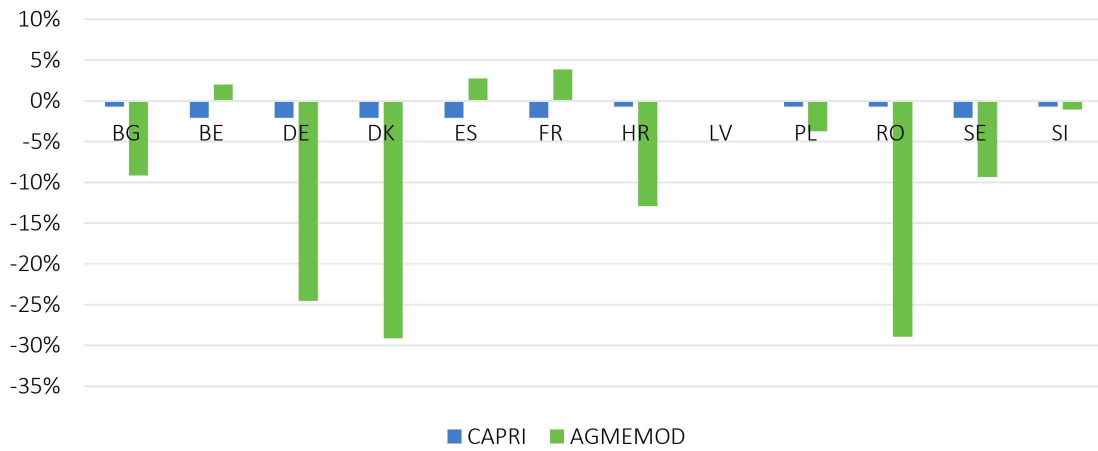

Figure A34: Growth rates of producer prices of corn projected by CAPRI and AGMEMOD with respect to the base year values.

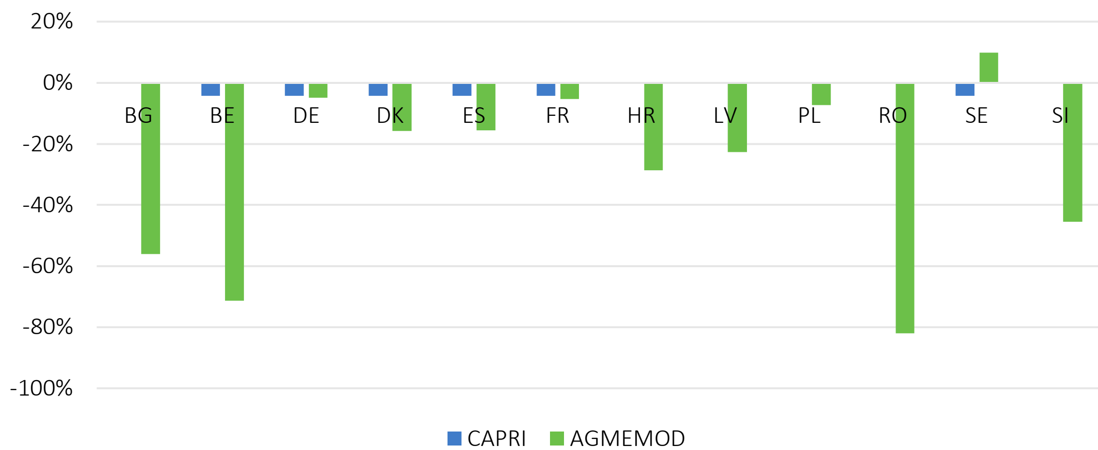

Figure A10: Growth rates of producer prices of rapeseed projected by CAPRI and AGMEMOD with respect to the base year values.

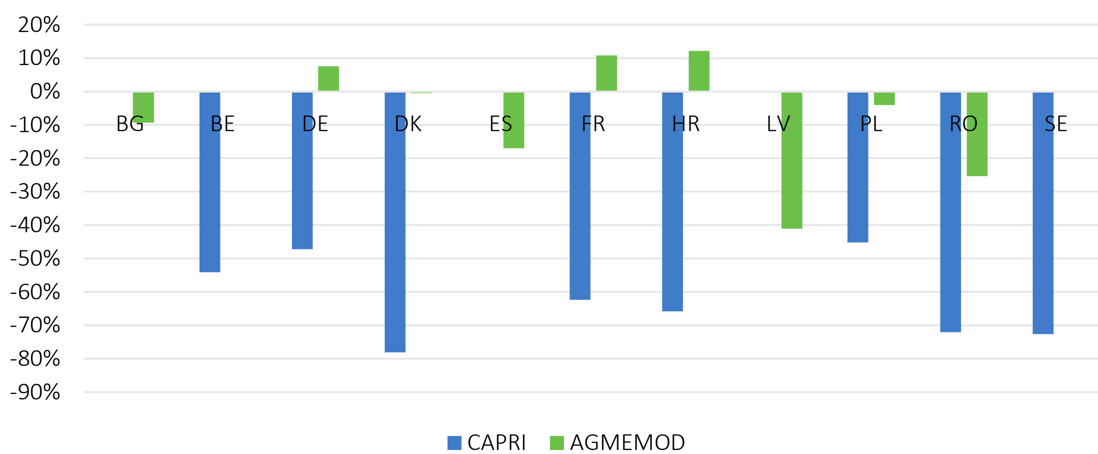

Figure A35: Growth rates of producer prices of rapeseed oil projected by CAPRI and AGMEMOD with respect to the base year values.

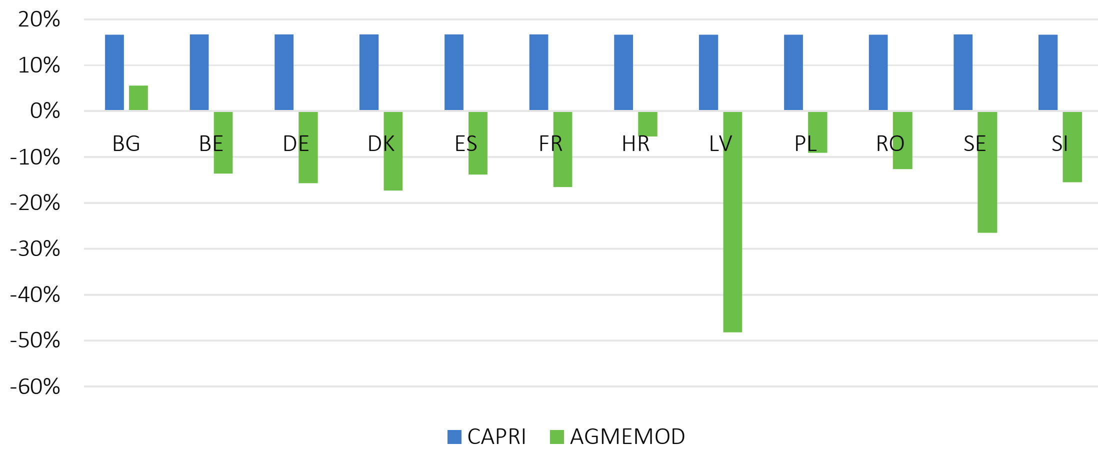

Figure A12: Growth rates of producer prices of beef projected by CAPRI and AGMEMOD with respect to the base year values.

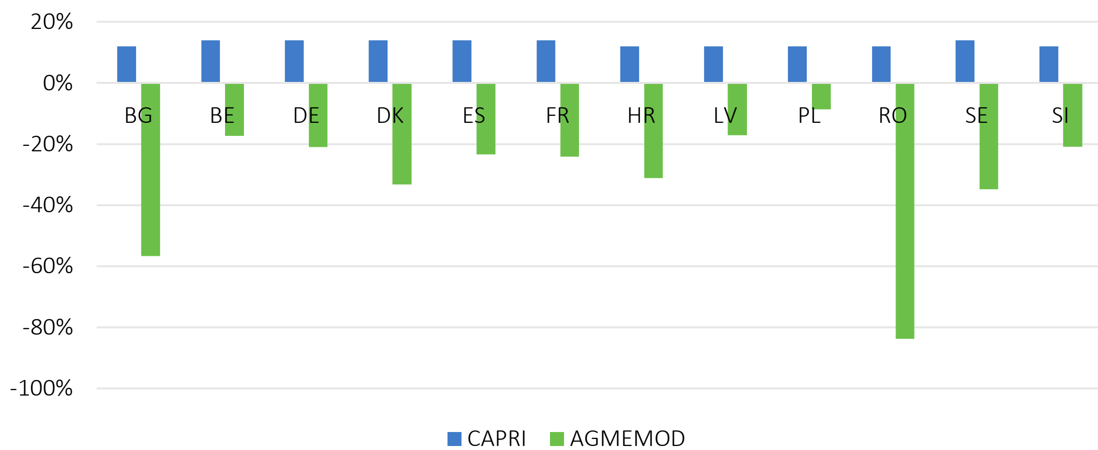

Figure A36: Growth rates of producer prices of pork projected by CAPRI and AGMEMOD with respect to the base year values.

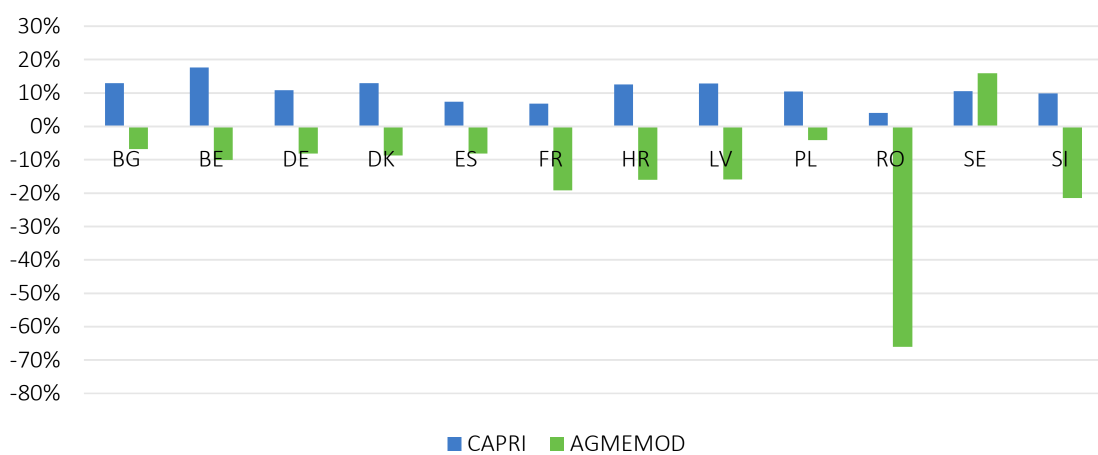

Figure A14: Growth rates of producer prices of raw cow milk projected by CAPRI and AGMEMOD with respect to the base year values.

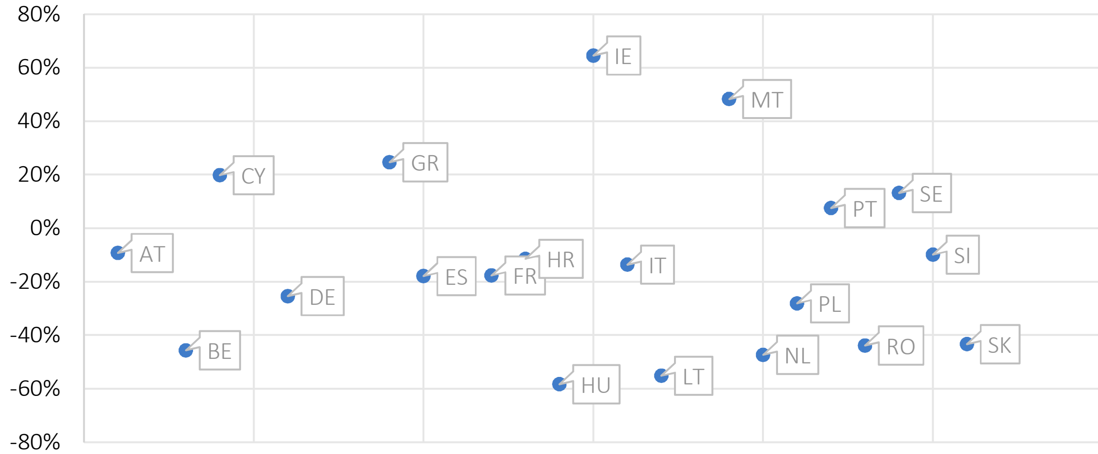

Figure A15: % differences between the projections of per capita soft wheat consumption in 2030 by AGMEMOD as compared to the projections by CAPRI.

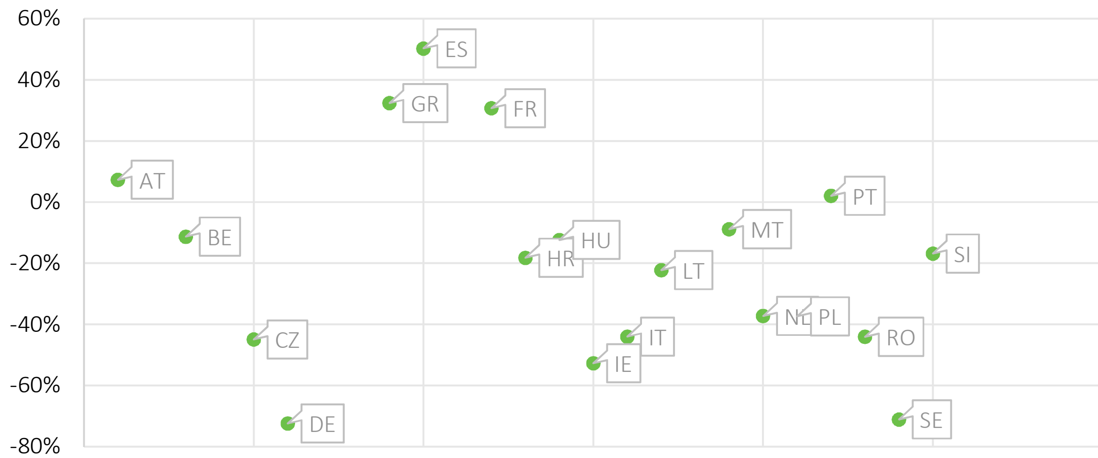

Figure A16: % differences between the projections of per capita corn consumption in 2030 by AGMEMOD as compared to the projections by CAPRI.

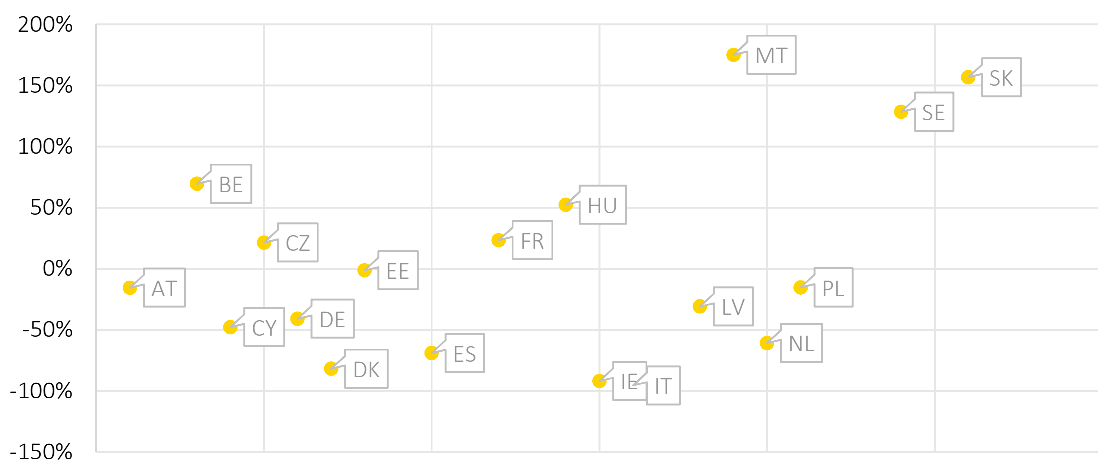

Figure A17: % differences between the projections of per capita rapeseed oil consumption in 2030 by AGMEMOD as compared to the projections by CAPRI.

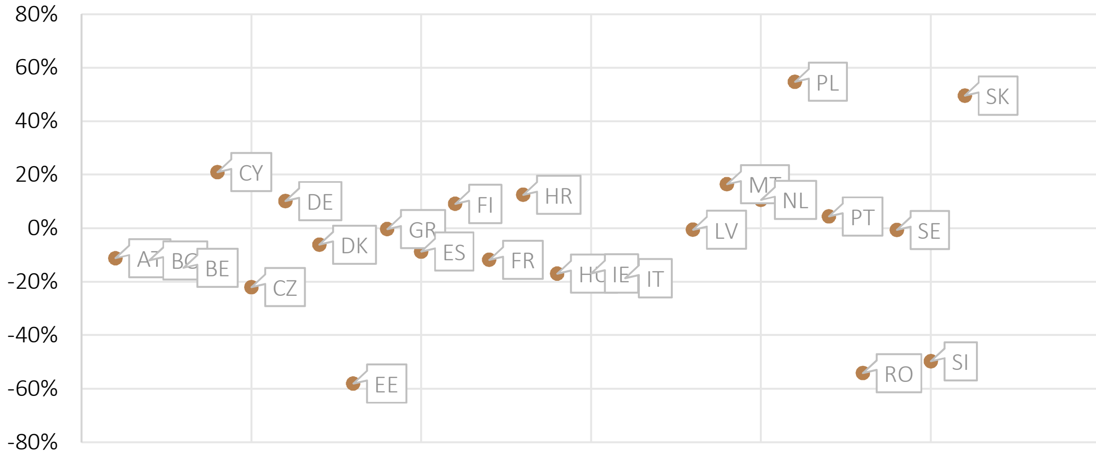

Figure A18: % differences between the projections of per capita beef consumption in 2030 by AGMEMOD as compared to the projections by CAPRI.

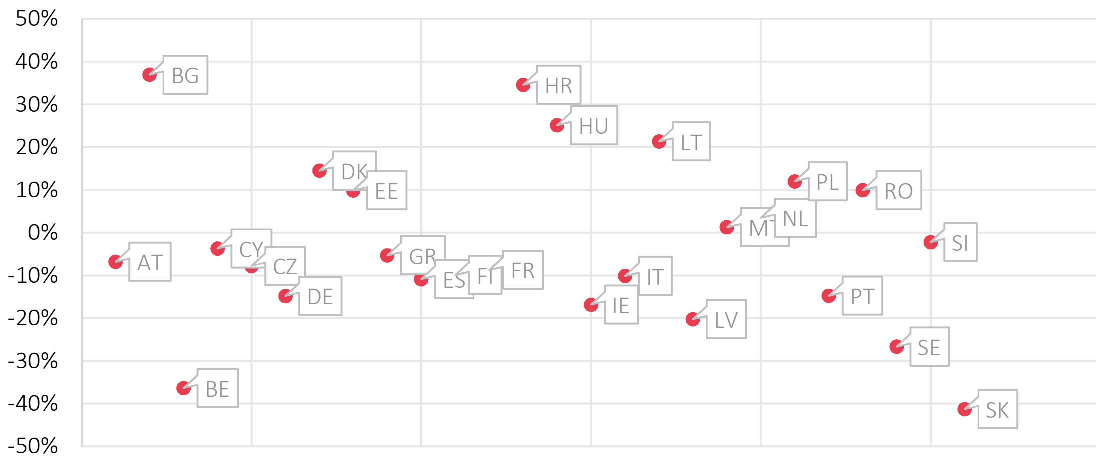

Figure A19: % differences between the projections of per capita pork consumption in 2030 by AGMEMOD as compared to the projections by CAPRI.