Linking three market models to project Russian and Ukrainian wheat markets till 2030

Verena Wolf*, Andre Deppermann**, Andrzej Tabeau***, Martin Banse*, Siemen van Berkum***, Marlen Haß*, Petr Havlik**, George Philippidis***, Petra Salamon*, Monika Verma***

**Thünen Institute of Market Analysis, Braunschweig, Germany*

*** IIASA International Institute for Applied Systems Analysis (IIASA)*

****LEI Wageningen UR*

Correspondence: verena.wolf@thuenen.de

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Abstract

Several economic models project global agricultural market developments. In each of these models, certain relevant aspects influencing agricultural markets are underrepresented. In order to overcome this, three economic models are linked to each other, namely GLOBIOM, AGMEMOD and MAGNET. The method to link these models consists of several parts: mapping, harmonization, data transfer, scenario development and successive model runs. The developed Model Junction Linkage Tool (MOJITO) facilitates and automates these parts. In addition to a common baseline scenario, two scenarios reflecting two important factors in the future development of wheat markets in Ukraine and Russia are analyzed. While the baseline results differ widely between the models the scenarios develop in a similar fashion.

Keywords: economic modeling, wheat market, Russia, Ukraine, yield gap, trade policies

1 Introduction

The development of agricultural markets is uncertain. Several institutions project global or regional developments of these markets using their established models e.g. USDA (2016), OECD/FAO (2016) and DG Agri and JRC-IPTS (2015). While these models give a good general overview of projected market developments, some relevant aspects influencing agriculture markets are underrepresented. Identified relevant aspects are i) a detailed land use market module allowing for agricultural area expansion or contraction, ii) yield developments taking into account bio-physical properties at a detailed spatial resolution, iii) economic interaction between the agriculture sector and the rest of the economy, iv) bilateral trade and v) a detailed representation of agricultural market policies. Three models are identified which explicitly capture some of these aspects, namely GLOBIOM capturing (i) and (ii), MAGNET capturing (iii) and (iv) and AGMEMOD capturing (v). In order to take advantage of the strength of each model and hence taking into account the relevant aspects in our analysis, a method to link the models is developed in this paper.

The idea of linking models to account for more relevant aspects at once, reuse already developed models and improve overall projections has evolved in the last years. Several studies have linked different kinds of models to improve projection and scenario outcomes in various fields. A detailed literature review is found in Banse et al. (2014).

One important aspect of linking models is the actual technical implementation which should be mostly automated and avoid ad-hoc adjustments. This paper overcomes this challenge by developing the Model Junction Linkage Tool (MOJITO) which automates the successive run of models including the exchange of data between them and the transfer of all data to a joined output data matrix (Wolf and Bouma, 2016). MOJITO is the essential tool to link the three models and apply the system for scenario analysis.

The system of linked models is applied to assess impacts on Russian and Ukrainian agriculture markets, especially the wheat market, by varying important factors driving the market. While the general development of the economy is the main driving factor for the development of agriculture markets, we identified two main specific factors with a strong impact on these markets especially for Russia and Ukraine. The first factor is the increase of crop production through institutional change, infrastructure development, technical change and investments within the country. These drivers lead to yield growth and possibly area expansion taking advantage of the currently unused potentials (Balkovič et al., 2015, Schepaschenko et al., 2015). This factor can be summarized in what is called institutional change and investment in the rest of the paper. The second factor is characterized by changes in trade policies leading to changes in tariffs through trade agreements and trade costs by harmonizing standards or implementing non-tariff trade barriers. These trade policies lead to a redirection of trade and changes in global competitiveness. In order to assess these two aspects, we developed and analyzed, comparing with a baseline, a technology and a trade scenario representing different development paths up to 2030.

The rest of the paper is structured as follows. Section 2 gives an overview of the historical wheat market development in Russia and Ukraine. Section 3 describes the methods of linking the models by first describing the models and then the link in detail. Section 4 describes the scenario narratives and the implementation in the model system. Section 5 discusses the results and section 6 concludes.

2 Historical Wheat Market Development

Russia and Ukraine are important players in global wheat markets. In 2013, the net export of wheat for Ukraine was 7.7 million tons and for Russia 12.9 million tons, which corresponds to 35% and 25% of their production, respectively (AGMEMOD consortium, 2016). In 2013, Ukraine and Russia were within the top ten wheat exporting countries with a share of total wheat exports amounting to 4.5% and 8.6%, respectively (United Nations, 2016).

In the Ukraine, wheat production increased while domestic use slightly decreased leading to an increase in net exports since 1995, see Figure 1. This production increase is due to yield growth and, to a lesser extent, area expansion as shown in Figure 2.

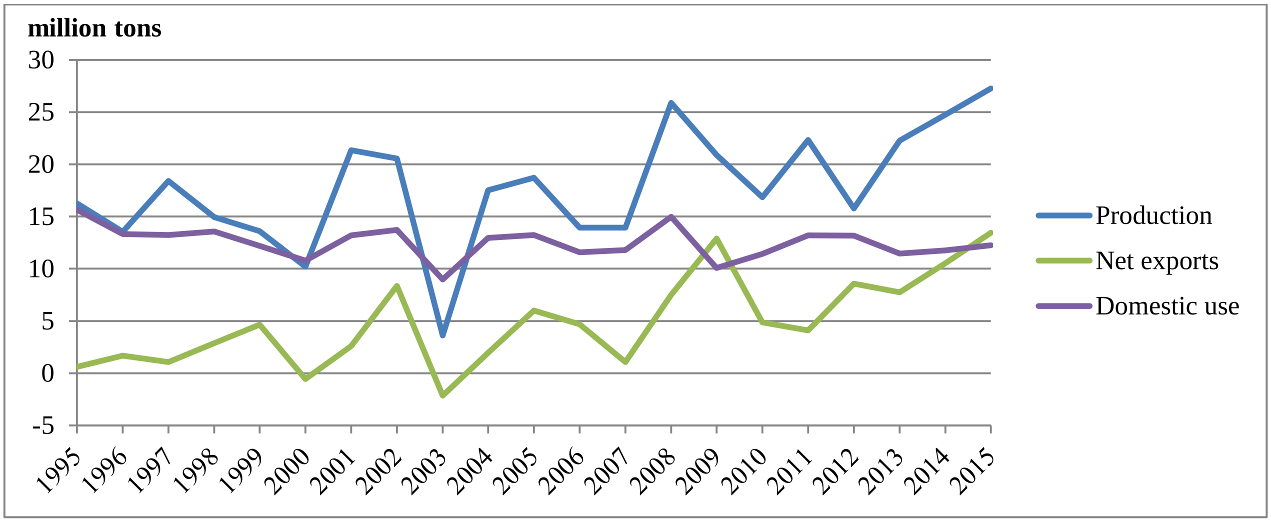

Figure 1 Development of the Ukrainian wheat market, 1995 - 2015, source: AGMEMOD database

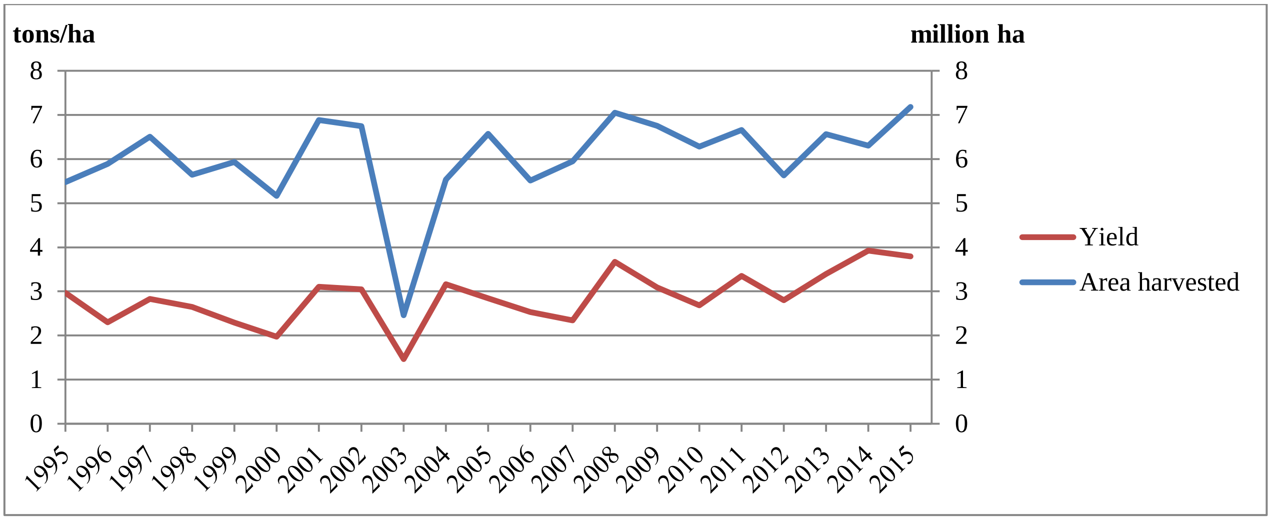

Figure 2 Development of yield and area harvested for wheat in Ukraine, 1995 - 2015, source: AGMEMOD database

Nominal prices for wheat are shown in Figure 3. Due to the current crisis, exchange rates of the Ukrainian hryvnia (UAH) to the US dollar (US$) drastically increased in 2014 and 2015 leading to different developments of the nominal prices for wheat in UAH and US$. This circumstance makes Ukraine even more competitive in the world market and hence favors wheat exports.

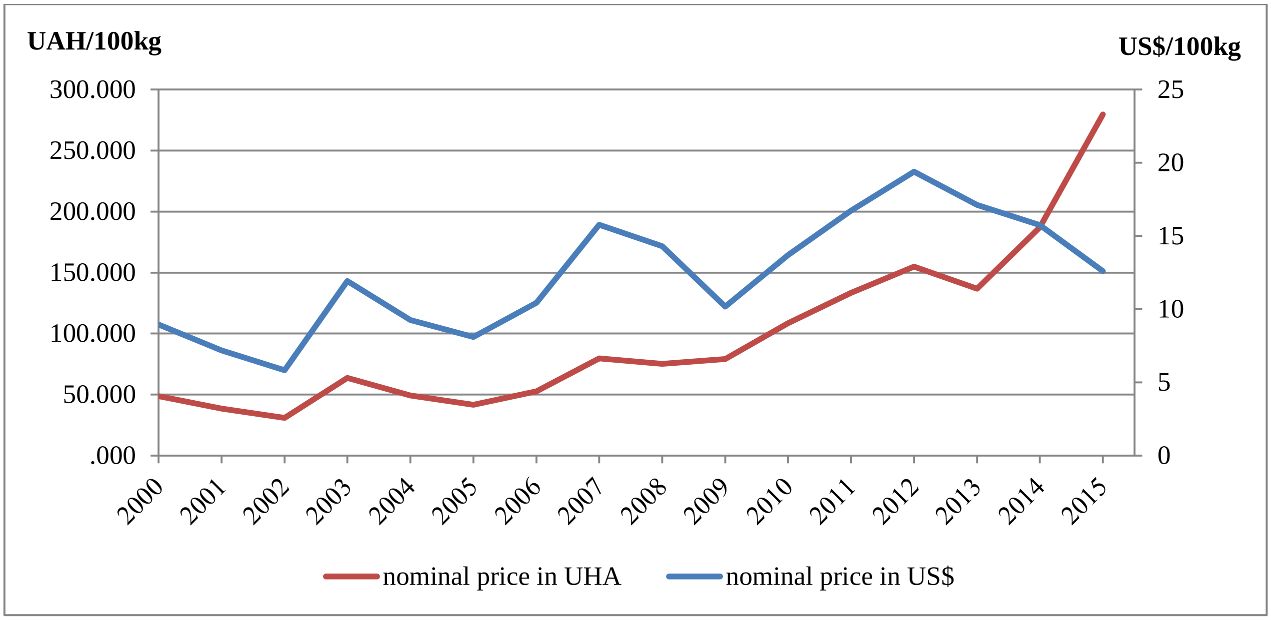

Figure 3 Nominal wheat prices in Ukraine from 2000 - 2015, source: AGMEMOD database

In Russia, a similar picture can be observed, which is displayed in Figure 4 and 5. Increasing production and stable domestic use made Russia a large net exporter of wheat since 2001. The production increase is due to yield growth while the area stayed relatively stable over time.

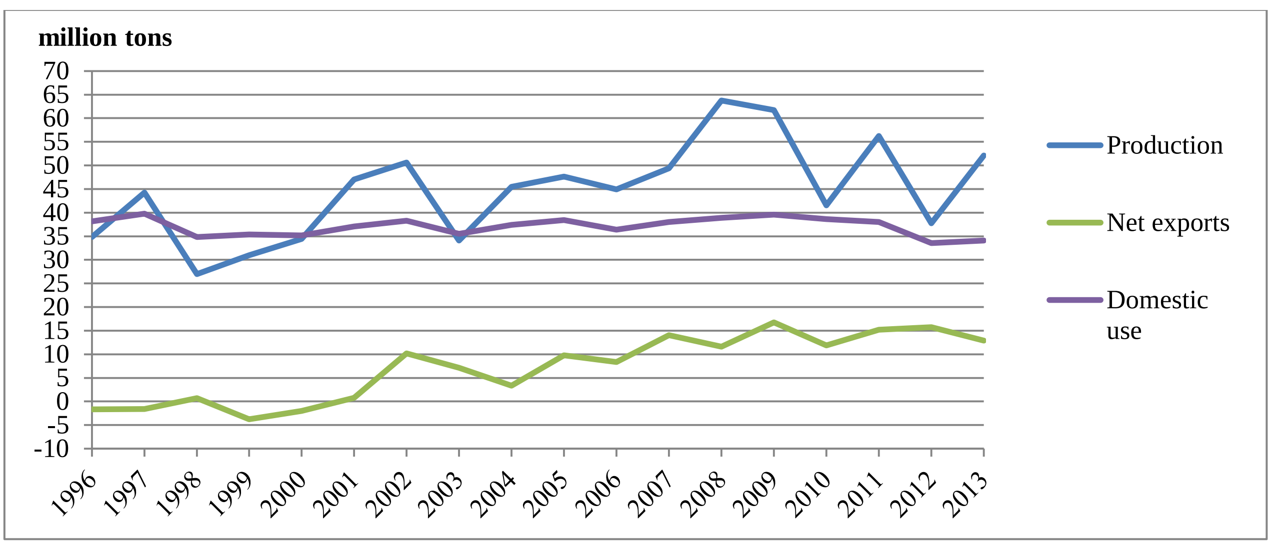

Figure 4 Development of the Russian wheat market, 1996 - 2013, source: AGMEMOD database

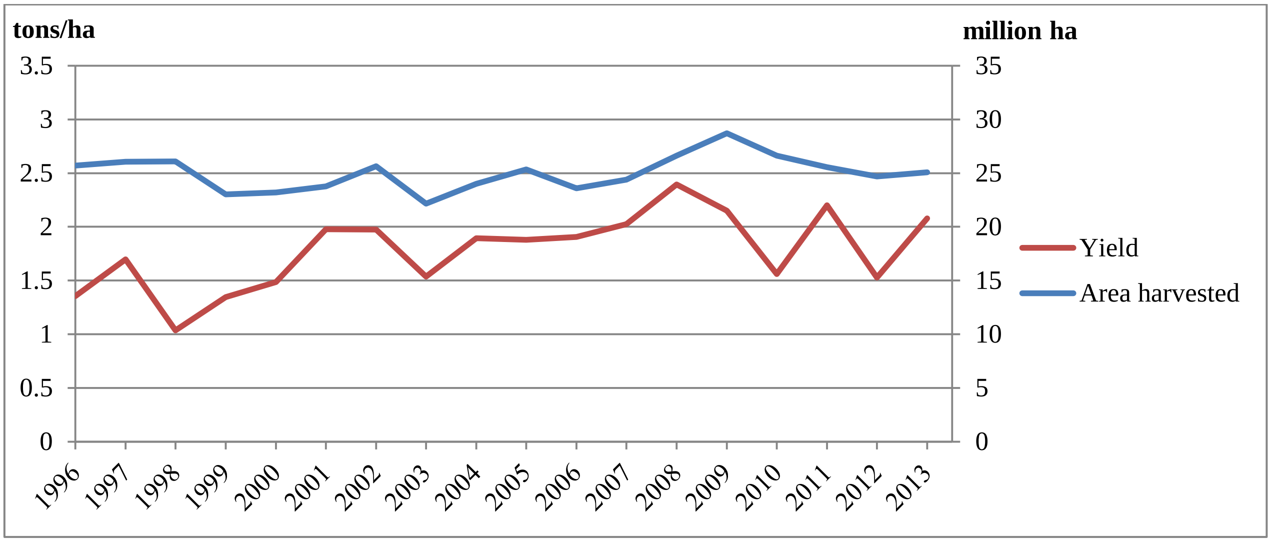

Figure 5 Development of yield and area harvested for wheat in Russia, 1996 - 2013, source: AGMEMOD database

As shown in Figure 6, nominal prices for wheat in Russia evolved similarly in RUB and US$ till 2012. Comparing Figure 3 and 6, Russian nominal prices for wheat in US$ are less than for Ukraine, making Russia even more competitive on the world market than Ukraine.

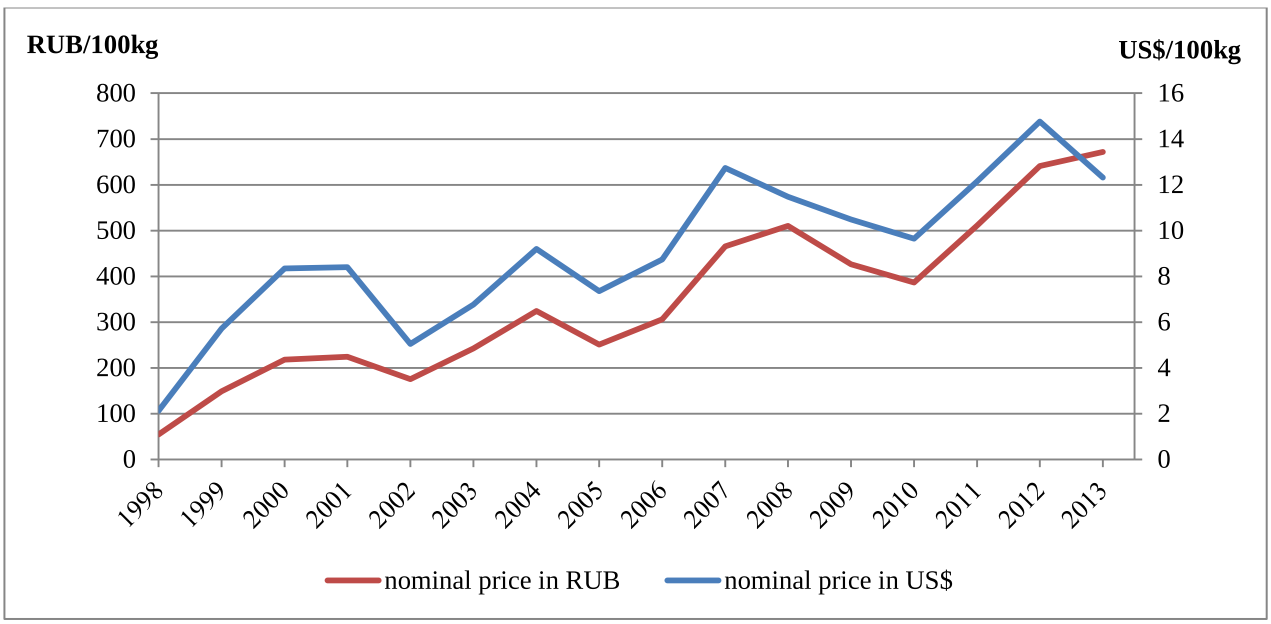

Figure 6 Nominal wheat prices in Russia from 1998 - 2013, source: AGMEMOD database

3 Method

Three economic market models, namely AGMEMOD, GLOBIOM and MAGNET, are linked to analyze the development of the wheat market in Russia and Ukraine. These models all capture agricultural production and markets but from different perspectives. Indeed, each model comprises different aspects with respect to agriculture – e.g. trade, soil properties, and detailed representation of the sector – which are lacking or underrepresented in the other models. AGMEMOD's strength is the richness of presentation of agricultural products and processing activities, while GLOBIOM's strength is the land use allocation taking bio-physical data into account. MANGET's strength is the interaction between the agri-food sectors and the rest of the economy as well as the representation of bilateral trade. In order to combine the strength of each model, we link them through the exchange of data. The outcome gives the best insights of future possible developments even though the results per model differ.

In this section, each model is described briefly followed by the detailed technical description of the implementation of the link.

3.1 The Models

The Global Biosphere Management Model (GLOBIOM) is a global recursive dynamic bottom-up partial equilibrium model integrating the agricultural, bioenergy and forestry sectors (Havlík et al., 2014). It is a linear programming model based on the spatial equilibrium approach developed by Takayama and Judge (1971). Based on a welfare maximizing objective function, agricultural and forest market equilibria are computed subject to resource, technology, demand and policy constraints. The partial equilibrium model GLOBIOM gives insights on the potential of agricultural production through yield increase and land use. On the demand side, a representative consumer is modelled for each region. Food demand projections are based on the interaction of three different drivers: i) population growth, ii) income per capita growth, and iii) response to prices. Price effects (iii) are endogenously computed while drivers (i) and (ii) are exogenously introduced into the model.

On the supply side, the model is built on a spatially explicit, bottom-up setting. The basis is a detailed disaggregation of land into Simulation Units – clusters of 5 arcmin pixels belonging to the same country, altitude, slope and soil class and to the same 0.5° x 0.5° pixel (Skalský et al., 2008). This information is then re-aggregated to 2° x 2° degree cells disaggregated by country boundaries and by three agro-ecological zones. Production technologies are specified through Leontief production functions, which imply fixed input – output ratios.

Regarding crop production, GLOBIOM represents globally 18 major crops (barley, beans, cassava, chickpeas, corn, cotton, groundnut, millet, palm oil, potato, rapeseed, rice, soybean, sorghum, sugarcane, sunflower, sweet potato, wheat) and 4 different management systems (irrigated – high input, rainfed – high input, rainfed – low input and subsistence) simulated by the biophysical process based crop model EPIC (Williams, 1995, Izaurralde et al., 2006). For the current research, yield figures for Russia and the Ukraine are updated and data on high input production systems are implemented, which enable us to mimic the closure of the estimated yield gaps in Russia and the Ukraine.

MAGNET is a general equilibrium model of the world economy used to analyze changes in bilateral trade policies (Woltjer et al., 2013). It represents goods and factor markets, trade and investment across the regions by means of behavioral and accounting equations. In addition to the standard features MAGNET incorporates an endogenous agricultural land supply module (allowing for expansion or contraction of agricultural area), an explicit characterization of the Common Agricultural Policy (CAP) (describing agricultural support payments under both first and second pillars) and production quotas (for imposing limits on milk and sugar production under CAP) and biofuel directives (imposing targets for blending rates of biofuels with fossil fuels).

The model is used to project the world economy forward to the year 2030 in 3 steps: 2007-2015, 2015-2020, and 2020-2030. The first step updates the 2007 database to 2015 situation taking into account historical data concerning macroeconomic, demographical and fossil fuel prices development, as well as trade (including Russian ban), biofuels and agricultural policy changes. To implement the Russian ban, additions are made to the import demand functions, instead of eliminating Russian imports from certain regions by making the Russian import tariffs prohibitively high, it is done by means of adjustments (loss) to aggregate consumer utility in Russia (Boulanger et al., 2016).

AGMEMOD is an econometric, dynamic, multi-product, multi-country, partial equilibrium model used to analyze domestic agricultural market policies and its impacts on national and international markets (Chantreuil et al., 2012). Originally, AGMEMOD was developed to model the CAP at EU member state level and the shift from a national policy to the CAP if a country became a new member of the EU. AGMEMOD combines individual country models which follow a general structure and certain rules in the database and the model specification (Chantreuil et al., 2012).

The database covers historical data of product prices, area harvested, supply and demand balances, policy instruments and macro-economic variables. Different national and international statistics are the sources of the data and vary across countries. The general defined rules of the AGMEMOD database ensure consistency in the database but also make it necessary to adjust some data in order to fulfil these rules.

The model specification follows the general rules defined in Chantreuil et al. (2012). Equations are econometrically estimated based on the database. In case of missing data, the equations can be synthetically parametrized and calibrated. Further, identity equations, i.e. equations calculated as residuals, ensure market clearing at the respective commodity price.

The general framework holds for all country models, while product coverage, equation estimation and policy implementation are country specific. This approach ensures consistency across countries and flexibility to model country specific policies and characteristics. Hence, AGMEMOD is and can be further extended to other countries also outside of the EU. Two of these extensions are Russia (Salputra et al., 2013) and Ukraine (van Leeuwen et al., 2012). In the AGRICISTRADE project (Euroquality SARL, 2016), these two models have been updated with respect to the database and the model specification. A full historical data set is available till 2013 for both countries while further available historical data till 2015 is included for Ukraine. AGMEMOD projects market developments till 2030 on an annual basis.

3.2 Model Linkage

Each model was developed for different purposes and by different teams of researchers. Hence, the models have different databases, theoretical background, structure and specifications. Annex 1 summarizes the main features and specifications of the models in the current project. The models are not directly compatible to each other. This complicates the model linkage but does not make it impossible.

In order to link the three models to each other, the Model Junction Linkage Tool (MOJITO) based on the software GsePro (Dol and Bouma, 2006) was developed. MOJITO facilitates all elements required for a successful model linkage, namely the mapping, harmonization, data exchange, scenario runs and results comparison. The mappings of the regions, sectors and variables are defined in an excel sheet similar to those presented in Annexes 2 to 4. MOJITO uses this sheet to translate data from one model in its mnemonics, i.e. sectors, regions and variable code, to commonly defined mnemonics and to the mnemonics of another model. All data is stored in a central data matrix using the commonly defined mnemonics. The central data matrix is used to compare results between the models and as input to create input files for the models based on data from the other models. The user defines which data is transferred as input to another model and in which form it is transferred i.e. absolute values, differences, percentage changes or indexes. Additionally, scenarios are defined and the models can be run directly through MOJITO in a succession and even iteratively.

Regions, sectors, variables and periods of the models are mapped to each other in order to be able to compare results and exchange data. AGMEMOD covers individual countries which can be aggregated to regions after the model run. In the standard GLOBIOM, countries are aggregated to 34 regions covering the whole world. MAGNET can aggregate the 135 regions in the GTAP database (Narayanan, 2012) flexibly. For this analysis, 27 GTAP regions are aggregated such that they are compatible with the GLOBIOM regions after some further aggregation in both models. This leads to a comparable set of regions across all models. The whole mapping and post model aggregations in each model can be found in Annex 2. While MAGNET covers all sectors of the economy, GLOBIOM and AGMEMOD focus on specific sectors in more detail. Hence, an aggregation of sectors is necessary to be compatible with MAGNET sectors and one-to-one mappings are seldom. GLOBIOM and AGMEMOD sectors are mainly one-to-one mappings; however each model covers sectors the other does not. The set of comparable sectors across all models is small while it is larger between GLOBIOM and AGMEMOD. The mapping including post model aggregations can be found in Annex 3. Each model includes a lot of different variables. For the linkage and result comparison, we selected the variables which are comparable across the models or between two models and relevant for our analysis (see Annex 4). Special attention has to be paid to the units of the variables, which still differ between the models. While MAGNET reports percentage changes of volumes and prices per period, GLOBIOM and AGMEMOD report physical quantities (e.g. tons) and prices in different currencies in real or nominal terms. Our projections go to 2030, although the periods in the models vary. While AGMEMOD projects on an annual basis, GLOBIOM only uses 10-year steps from 2000 to 2030 and MAGNET, starting in 2007, projects in the first step to 2015, then to 2020 and 2030. Hence, there is no common start year for all three models. As a solution, GLOBIOM results are interpolated between 2010 and 2020 to get 2015 figures and 2015 serves as our start year. MAGNET results are interpolated between 2007 and 2015 to get 2010 results which are required as an input to GLOBIOM.

Data is transferred from one model to the other and used as an input as depicted in Figure 7. GLOBIOM yield changes are inputs to MAGNET and AGMEMOD and area changes to AGMEMOD because land use is based on bio-physical properties such as soil, slope, altitude, climate but also several management types which differ in low or high input use and irrigated or rain-fed production at a spatial resolution of 0.5° x 0.5° grid in GLOBIOM (Havlík et al., 2011). Changes in production from AGMEMOD are implemented in MAGNET because AGMEMOD is able to depict agricultural production, demand and resulting prices at the most disaggregated level and includes agricultural market policies, e.g. subsidies on production, production quotas, and decoupled payments. Trade developments from MAGNET are included in GLOBIOM and AGMEMOD because MAGNET is able to explicitly show effects of bilateral trade agreements between two countries or country groups as well as interactions between the wheat and agriculture sector and the rest of the economy e.g. reflected in the competition for factor endowments. In the network of these three models, the properties just described are the strength of the respective model. In order to include these strengths in the other models we link them through the exchange of data which is described in more detail in the following paragraphs.

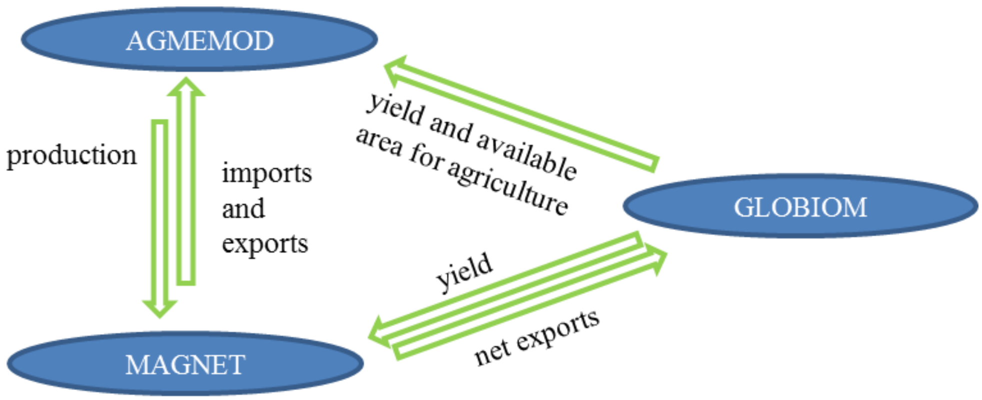

Figure 7 Model link between GLOBIOM, AGMEMOD and MAGNET

In GLOBIOM, external data on net exports are implemented, based on historical exports and imports from the AGMEMOD database and relative changes from the MAGNET model. MAGNET provides relative changes in trade for the simulation periods 2007 to 2015, 2015 to 2020 and 2020 to 2030. Relative changes are available for the periods 2007 to 2010 and 2010 to 2015 after the ex-post interpolation within MOJITO. The direct implementation of relative trade changes can cause difficulties if one model assumes a net-import position and another a net-export positon for a certain crop. Hence, the relative changes in exports and imports from MAGNET for the simulation periods 2007-2010, 2010-2020 and 2020-2030 update the absolute 3-year average trade volumes for 2007 based on the AGMEMOD database (AGMEMOD consortium, 2016). Then, absolute changes in net export volumes are transferred from MOJITO to GLOBIOM for the periods 2010 to 2020 and 2020 to 2030. In GLOBIOM, an additional equation is implemented to force the model to a certain net export position for the focus countries (EU, Russia and Ukraine), with an allowed deviation of ± 10%.

In general, MAGNET uses two types of external data provided through MOJITO: exogenous land productivity (yield) changes from GLOBIOM and production changes of selected agricultural sectors from AGMEMOD. The exogenous land productivity changes replace the exogenous assumption already present in MAGNET. The production changes for wheat from AGMEMOD are used to calibrate the MAGNET scenario for Russia and the Ukraine in all model periods. In such a case, MAGNET production for wheat in these two countries is assumed to be an exogenous variable which changes according to AGMEMOD input and sector specific technological change serves as equilibrating variable. However, depending on the scenarios to be run, MAGNET deviates from this general approach as explained below in the scenario description.

AGMEMOD receives data on yield and land conversion from GLOBIOM as well as export and import changes from MAGNET. Yield projections from GLOBIOM for AGMEMOD are used because yields from GLOBIOM explicitly include the potential yields based on the EPIC model for Ukraine and Russia (Balkovič et al., 2015). Hence, annual percentage changes of yield for crops are calculated based on their 10-year projection period from the GLOBIOM model run and used as input in AGMEMOD. In AGMEMOD, most countries have historical yield data until 2013 or 2016. For the projected years, an econometrically estimated equation determines the yield. This equation is replaced in the first projected year by a 5-year average of yield based on the historical data and is than updated by the calculated annual percentage changes from GLOBIOM until 2030. Annual percentage changes, rather than the absolute projected yield from

GLOBIOM, are used because AGMEMOD's database is more up to date and the actual historical data should always be preferred over projections from the past.

An advantage of GLOBIOM over AGMEMOD is that it determines land conversion from other land categories (forest, grassland, other natural vegetation, and short rotation plantation) into cropland endogenously (Havlík et al., 2014). In the standard AGMEMOD version forest, grassland and other land are exogenous variables which are kept constant over the simulation period, whereas the change in cropland is determined endogenously as the sum of changes of the individual crops (Chantreuil et al., 2012). As a consequence, depending on the various land allocation specifications at country level, the total land balance condition does not necessarily hold in each AGMEMOD country model. In order to overcome this inconsistency and to improve the representation of land allocation and land availability as a limiting factor for crop production in AGMEMOD two major changes are implemented. First, the current structure of land allocation in AGMEMOD has been redefined by a pure top-down approach, where change in forest, grassland and other land affect the land available for crop production. Second, information on absolute annual changes in forest, grassland and other land (other natural vegetation, short rotation plantation) coming from GLOBIOM has been used to model land conversion from other land categories into cropland. Since the land allocation in AGMEMOD has been restructured by a pure top-down approach, changes in cropland are passed on to the level of the individual crops. As a limitation, these changes are currently only implemented for Russia, Ukraine and some member states of the European Union (France, Germany, Poland, Spain, Greece, Italy, Romania and the United Kingdom).

MAGNET in contrast to AGMEMOD is able to model bilateral trade and hence the effects of different trade agreements between countries. In order to take these effects in AGMEMOD into account, MAGNET scenario data on the changes of export and import volumes are transferred as annual percentage changes to AGMEMOD. In the AGMEMOD database, historical imports and exports are available between 2007 and 2015. Afterwards, an econometrically estimated equation or an identity which ensures the closing of the market balance, determines the projected trade figures. These are replaced by the annual percentage changes from MAGNET based on the latest historical value. In order to ensure market balance, domestic use and within domestic feed use is now defined as an identity. MAGNET trade data is reported in US dollars at constant 2007 prices while AGMEMOD data is reported in tons. Also, trade in MAGNET only covers the actual raw product while trade in AGMEMOD includes also trade of processed products of the raw product. These two facts are the reasons to use annual percentage changes from MAGNET into AGMEMOD. One limitation here is that this approach is only done for wheat so far.

4 Scenario Narratives and Implementation

In order to test our method to link the three models, a baseline and two scenarios were developed. The baseline or reference scenario is a business-as-usual scenario and assumes a moderate economic development and technical progress following past trends. Domestic agricultural policies and negotiated trade agreements are to be continued over the projected period. This includes especially the current policies of Russia and Ukraine but also neighboring countries i.e. European Union (EU), Georgia, Moldova, Armenia, Belarus, Azerbaijan, and Kazakhstan (for detailed information about the polices see Volk et al. (2015)).

The following trade policies are specifically implemented: Comprehensive Economic and Trade Agreement (CETA) between the EU and Canada, Deep and Comprehensive Free Trade Areas

(DCFTA) of the EU with Ukraine, Georgia and Moldova and the formation of the Eurasian Economic Union (EEU). Although these agreements are not ratified yet by all the signatories we assume these agreements are in force from January 1 2015 onwards. This implies that the tariffs in bilateral trade are reduced to zero. Moreover, DCFTAs agreed with Ukraine, Georgia and Moldova include provisions of EU support to these countries to help transpose parts of the EU's acquis legislation into national laws and put them into effect. As a result, bilateral trade of the EU with each of these three countries is expected to benefit from progress made in harmonizing regulatory frameworks that facilitate trade. The EEU, comprising of Armenia, Belarus, Kazakhstan, Kyrgyzstan and Russia, was established in 2015 with common external tariffs and is also about regulatory convergence such that non-tariff measures are reduced. Other trade conditions do not change as it is assumed that there will be neither a Doha WTO agreement nor any other bilateral trade agreement than currently in force, except for the fact that the Russian import ban on a set of EU agricultural products is expected to have been lifted in the period 2015 to 2020.

In the baseline scenario, the models are harmonized in their common underlying exogenous drivers. These are population and income alias gross domestic product (GDP). As all models have different data sources and base years and hence different values for population and income, percentage changes of the development of these variables are harmonized. The data source is the AGMEMOD database for all countries in AGMEMOD and the SSP2 path of the SSP database (IIASA, 2015) for all other regions. Table 1 shows the assumed developments for Russia and Ukraine.

Table 1 Income and population changes from 2015 to 2030 in the baseline as index with 2015 = 1

	2015	2020	2030
Income			
Russia	1	1.089	1.240
Ukraine	1	1.089	1.691
Population			
Russia	1	0.995	0.970
Ukraine	1	0.967	0.897

In our technology scenario, institutional changes and increased public investments in the agricultural sectors of Russia and Ukraine result in advantageous developments such as better access to fertilizer, reduced credit constraints in the agricultural sector, increasing quality of agricultural education and better infrastructure. These developments eventually lead to better management practices, increased yields and thus, a reduction of the yield gaps between current and potential yields. Enhanced institutions guarantee the acknowledgement of land property rights and ensure a stable business environment.

The technology scenario differs from the baseline only in the assumption in GLOBIOM. We allow the GLOBIOM model to switch to the high-input ('yield-gap-closing') production systems, as specified by the crop model EPIC. Yield potentials are a theoretical concept and in reality, yields hardly exceed 80% of their estimated potential yields (Lobell et al., 2009). Nevertheless, according to Balkovič et al. (2013), EPIC tends to underestimate the yield potentials of high input systems. Specifically, in the current set-up used for this paper, EPIC estimates the yield potentials for the currently observed crop cultivars and thus, restricts opportunities to further increase yields by switching to another cultivar. We assume that both corrections would cancel each other out and thus, apply 100% of the estimated EPIC yields for our high-input systems. The assumptions of AGMEMOD and MAGNET do not change. However, MAGNET implements the endogenous yields from GLOBIOM instead of the exogenous yields because the exogenous land productivity change from GLOBIOM does not include the effect on yield of the improved institutional changes and investments. AGMEMOD projections only change because of new input data from the other two models.

In the trade scenario, the EEU, the EU and its eastern neighbors intensify their trade relations. This is reflected by a greater than global average reduction of trade costs in the bilateral relationship with EEU as the result of increased harmonization of trade regulations, and by lower import tariffs on agricultural and food products.

The trade scenario differs from the baseline only in the assumptions in MAGNET. In MAGNET, it is assumed that EEU import tariffs on all traded commodities are reduced by 50% for the rest of the non-EU and non-EEU world and by 60% for EU. Under the Baseline we implemented no such inter-regional reductions for the EEU. Trade costs that are associated with non-tariff measures also fall twice as much between DCFTA-EU and within the EEU region in comparison with the Baseline. Also we assume a 10% reduction (in comparison to none at all in Baseline) in trade costs between the EEU and the EU. In this scenario, wheat production in MAGNET is not fed in from AGMEMOD in order to allow the wheat production in the two countries to respond to trade policy changes. AGMEMOD and GLOBIOM projections only change because of new input data from MAGNET.

The baseline and the scenarios are run with each model using information from the previous run of the other models. First, GLOBIOM runs without any data from the other models. Then, AGMEMOD runs with given yield and area changes from GLOBIOM. Afterwards, MAGNET runs using GLOBIOM exogenous yields and AGMEMOD production. In a second run, GLOBIOM takes the trade information from MAGNET into account. The second AGMEMOD run uses yield and area changes from the second GLOBIOM run as well as trade changes from the MAGNET run. The trade scenario deviates slightly from this approach by letting production change endogenously in MAGNET instead of fixing it to AGMEMOD projections which do not include the trade changes yet.

5 Results

The results shown here are based on the first MAGNET run, the second GLOBIOM run and the second AGMEMOD run. While the models cover more than the wheat sector, for this pilot study to consider the veracity of our model linking technique, we focus on the wheat sector only.

In the baseline, both the Ukraine and Russia increase wheat production, consumption and net exports between 2015 and 2030 in all models as shown in Table 2. In AGMEMOD, production in the Ukraine and Russia increases by 4.3 million tons and 4.9 million tons from 2015 to 2030, respectively. GLOBIOM projects a larger increase for the Ukraine and Russia with 6.8 million tons and 15.2 million tons, respectively. Here, MAGNET's projected production depends on the projections of AGMEMOD prior to the incorporation of MAGNET's trade data in AGMEMOD. Hence, if production adjusts in AGMEMOD due to new information from MAGNET and GLOBIOM in the second run, MAGNET and AGMEMOD production can differ. The increased production results in an increase in trade as well as consumption. While AGMEMOD mimics the net export developments of MAGNET between 2015 and 2030, GLOBIOM takes into account the net export changes of MAGNET between 2010 and 2030. This results in different developments of net exports between GLOBIOM and MAGNET/AGMEMOD when comparing it to the base year 2015.

Table 2 Development of the wheat sector in the baseline, percentage change from 2015 to 2030

	Ukraine			Russia		
	production	consumption	net exports	production	consumption	net exports
AGMEMOD	16	27	18	10	3	20
GLOBIOM[1)]	35	10	81	29	34	5
MAGNET	10	0	18	10	3	20

[1)]here 2015 is the average between 2010 and 2020 as GLOBIOM only has 10-year time steps starting in 2000

Production mainly depends on yield, area and price developments. These dependent variables are shown in Table 3. While yield developments between AGMEMOD and GLOBIOM are very similar, MAGNET yield developments deviate taking into account only the exogenous yield from GLOBIOM. Area development on the level of crop sectors, e.g. wheat, vary most between the models as these are the least harmonized. GLOBIOM and MAGNET stick to their original approach in determining cultivated area. AGMEMOD determines the total crop area based on GLOBIOM information, while the area specifically attributed to wheat is determined through the competitiveness of wheat compared to other crops within AGMEMOD. Prices across the models are hard to compare as they are reported in different units. However, the direction of prices is in the range of our expectations: nominal prices in AGMEMOD increase while real prices keep nearly constant over the projected period or slightly decrease in GLOBIOM and MAGNET.

Table 3 Development of the wheat yield, area and price in the baseline, percentage change from 2015 to 2030

	Ukraine			Russia		
	yield	area	price	yield	area	price
AGMEMOD	16	0	16*	27	-13	22*
GLOBIOM[1)]	30	3	-3**	26	2	-10**
MAGNET	19	-8	2***	16	-5	-3***

*AGMEMOD: based on nominal producer prices in national currency/kg

**GLOBIOM: real producer price in 2000 US$/ton

***MANGET: based on real market production price in 2007 US$ indexed so that 2007=1

[1)]here 2015 is the average between 2010 and 2020 as GLOBIOM only has 10-year time steps starting in 2000

Table 4 shows the percentage differences of the technology scenario compared to the baseline in 2030. The Ukrainian wheat sector does not benefit largely from the implemented institutional change and investments while other crop sectors do (not shown here). The Russian wheat sector increases production compared to the baseline in 2030 due to the institutional change and investments and net exports due to its improved global competitiveness. This is due to some specialization effects: Russia increases its wheat production to a great extent while Ukraine increases the production of other crops. Overall the three models show similar changes in the technology scenario i.e. the assumption changes in GLOBIOM are transferred to the other models through the exchange of data.

Table 4 Difference of the technology scenario to the baseline in 2030 in percentage changes

	production	area	yield	consumption	net exports	price
Ukraine						
AGMEMOD	-17	-18	1	-14	-19	0
GLOBIOM	1	-2	3	22	-23	-21
MAGNET	-13	-9	-4	-3	-19	-1
Russia						
AGMEMOD	52	9	40	38	81	-3
GLOBIOM	79	11	61	79	78	-11
MAGNET	40	2	38	8	79	-11

Table 5 shows the percentage differences of the trade scenario compared to the baseline in 2030. Counterintuitively, the Ukrainian and Russian wheat sector do not benefit from the liberalization in trade as production stays constant or even declines, depending on the model, and net exports are reduced. The main reason is the deviation from the general linkage approach as defined above. MAGNET does not take production changes of AGMEMOD into account. A second run of MAGNET, by taking into account AGMEMOD production, might result in a more similar outcome of all three models.

Table 5 Difference of the trade scenario to the baseline in 2030 in percentage changes

	production	area	yield	consumption	net exports	price
Ukraine						
AGMEMOD	0	0	0	23	-22	2
GLOBIOM	-11	-12	0	2	-27	-3
MAGNET	-15	-10	-5	-5	-22	6
Russia						
AGMEMOD	0	0	0	0	1	0
GLOBIOM	-3	-3	0	-2	-5	1
MAGNET	-1	-1	0	-3	1	-4

6 Conclusion

It should be clear, that projections are always based on assumptions and underlying theory and do not reflect actual real world development. However, they provide important insights of the effect of policy changes and the relationship between different markets.

As a result of the model combination exercise, each model is improved by incorporating the perceived strengths of the other models. Nevertheless, the model projections differ in the baseline as well as in the scenarios but show a similar development. Even though the common assumptions of the models are harmonized and data is exchanged between the models, their projected outcome with respect to the wheat markets in Russia and Ukraine vary. The main causes are the difference in the databases, the theoretical assumptions within the models, the underlying model characteristics, the regional and sectoral coverage and aggregation as well as parameter values of the three models. Through additional iterations – which have not taken place yet – the differences in the outcomes of the three models are expected to converge further. However results will never be exactly the same.

One major limitation of the approach is that the databases of the models are not comparable as they differ in period coverage, data accounting conventions, data sources, data units and data coverage. Hence, no common start year with harmonized starting values exist for our analysis. An artificial start year, 2015, had to be determined. Additionally, GDP development is only harmonized for the baseline but not for the scenarios. MAGNET endogenously determines GDP developments in the scenarios which will be transferred to GLOBIOM and AGMEMOD in future research. Also, the extension of the link towards other products and countries or regions is a topic of future research.

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Annex

Annex 1 Properties of AGMEMOD, MAGNET and GLOBIOM

	AGMEMOD	MAGNET	GLOBIOM
model type	partial equilibrium market model	general equilibrium market model	partial equilibrium model
economic theory	microeconomic theory and technological relations	microeconomic theory	optimizing the sum of consumer and demand surplus, linear programming, with a strong integration of biophysical parameters
parameterization	econometrical estimation of equations, calibration	calibration, elasticities	calibration, process based models
regional coverage	EU28 (25 regions), Turkey, Macedonia, Ukraine and Russia	global (27 regions)	global (34 regions)
sectoral coverage	agriculture and processing sectors	whole economy (highly aggregated)	agriculture, forestry and bioenergy sector
main exogenous drivers	GDP, population, exchange rates	GDP, population, technological change, taste changes	population, GDP, income and price elasticities, bioenergy demand, crop yield and feed conversion efficiencies, soil properties, water availability
main scenario analysis	agricultural market and trade policies	Trade, agricultural and biofuel policies	bioenergy and environmental policies, yield potential
main output focus	commodity balances and prices	trade, input use, demand, production, consumption, prices, land use	commodity balances and prices, land use change, CO_2 emission savings
trade representation	whole exports and imports of a country	bilateral trade (Armington assumption)	bilateral trade
units	tons, Euro per ton, hectare, head of livestock	percentage changes, values in US$, hectare	tons, US$, hectare, km^3
projection periods	yearly up to 2030	2015, 2020, 2030	2010, 2020, 2030
base year	historical time series till 2004 - 2015 (depending on country)	2007	2000
responsible institute in project	Thünen Institute (TI)	LEI Wageningen UR (LEI)	International Institute for Applied Systems Analysis (IIASA)

Annex 2 Mapping of countries and regions of the three models to common mnemonics

Descriptive name	Common mnemonics		AGMEMOD		MAGNET		GLOBIOM	
	Abb.	Agg.	Abb.	Agg.	Abb.	Agg.	Abb.	Agg.
Belgium	bel	EMW	BE	EMW				
Luxembourg	lux	EMW		EMW				
Netherlands	nld	EMW	NL	EMW				
Germany	deu	EMW	DE	EMW				
France	fra	EMW	FR	EMW				
United Kingdom	gbr	ENO	UK	ENO				
Italy	ita	ESO	IT	ESO				
Cyprus	cyp	ESO						
Malta	mlt	ESO						
Greece	grc	ESO	GR	ESO				
Czech Republic	cze	ECE	CZ	ECE				
Hungary	hun	ECE	HU	ECE				
Slovakia	svk	ECE	SK	ECE				
Slovenia	svn	ECE	SI	ECE				
Poland	pol	ECE	PL	ECE				
Austria	aut	EMW	AT	EMW				
Ireland	irl	ENO	IE	ENO				
Bulgaria	bgr	ECE	BG	ECE				
Romania	rou	ECE	RO	ECE				
Denmark	dnk	ENO	DK	ENO				
Estonia	est	EBA	EE	EBA				
Finland	fin	ENO	FI	ENO				
Latvia	lva	EBA	LV	EBA				
Lithuania	ltu	EBA	LT	EBA				
Sweden	swe	ENO	SE	ENO				
Portugal	prt	ESO	PT	ESO				
Spain	esp	ESO	ES	ESO				
Croatia	hrv	ECE	HR	ECE				
Russian Federation	rus	rus	RU		rus		RussiaReg	
Kazakhstan	kaz	kaz	KZ		kaz		KazakReg	
Belarus	blr	blr			blr		BelarusReg	
Ukraine	ukr	ukr	UA		ukr		UkraineReg	
Moldova Republic of	xee	CIS			mda	FSU		
Armenia	arm	CIS			arm	FSU		
Azerbaijan	aze	CIS			aze	FSU		
Georgia	geo	CIS			geo	FSU		
Australia	aus	OCE						

China	chn	CHN			CHN		ChinaReg	
India	ind	ind			ind		IndiaReg	
Japan	jpn	jpn			jpn		JapanReg	
Korea	kor	kor			kor		SouthKoreaReg	
Turkey	tur	TUR	TR		tur		TurkeyReg	
United States of America	usa	USC					USAReg	NAM
Canada	can	USC					CanadaReg	NAM
Mexico	mex	XAM					MexicoReg	OSA
Brazil	bra	bra			bra		BrazilReg	
EU_MidWest	EMW	TEU	EMW	TEU	EMW	TEU	EU_MidWestReg	TEU
EU_North	ENO	TEU	ENO	TEU	ENO	TEU	EU_NorthReg	TEU
EU_South	ESO	TEU	ESO	TEU	ESO	TEU	EU_SouthReg	TEU
EU_CentralEast	ECE	TEU	ECE	TEU	ECE	TEU	EU_CentralEastReg	TEU
EU_Baltic	EBA	TEU	EBA	TEU	EBA	TEU	EU_BalticReg	TEU
Rest of Europe and World	XER				XER		XER	
Rest of former USSR countries MAGNET	cisMagnet				CIS	FSU		
Rest of former USSR countries	CIS				FSU		Former_USSRReg	
Total EU 28	TEU		TEU		TEU		TEU	
Rest of America	XAM				XAM		OSA	
Rest of Asia	XAS				XAS		XAS	
Rest of Africa	AFR				AFR		SSA	
Oceania	OCE				OCE		OCE	
Middle East and North Africa	MEN				MEN		MidEastNorthAfrReg	
USA and Canada	USC				USC		NAM	
CongoBasin	CongoBasinReg	AFR					CongoBasinReg	SSA
SouthAfrReg	SouthAfrReg	AFR					SouthAfrReg	SSA
EasternAf	EasternAfreg	AFR					EasternAfreg	SSA
SouthernAf	SouthernAfreg	AFR					SouthernAfreg	SSA
WesternAf	WesternAfreg	AFR					WesternAfreg	SSA
RSAM	RSAMreg	XAM					RSAMreg	OSA
RCAM	RCAMreg	XAM					RCAMreg	OSA
RCEU	RCEUReg	XER					RCEUReg	XER
ROWE	ROWEReg	XER					ROWEReg	XER
RSAS	RSASReg	XAS					RSASReg	XAS
RSEA_PAC	RSEA_PACReg	XAS					RSEA_PACReg	XAS

RSEA_OPA	RSEA_OPAReg	XAS			RSEA_OPAReg	XAS
Australia and Newzealand	ANZ	OCE			ANZ	OCE
Pacific_Islands	Pacific_IslandsReg	OCE			Pacific_IslandsReg	OCE

Abb. = abbreviation

Agg. = aggregation

Annex 3 Mapping of sectors of the three models (existing at least in two models) to common mnemonics

Descriptive name	Common mnemonics	AGMEMOD		MAGNET		GLOBIOM	
		Abb.	Agg.	Abb.	Agg.	Abb.	Agg.
wheat	WHT	wht	GRAIN	wht	allGRAIN	WHT	GRAIN
barley	BAR	ba	othG			Barl	othGrain
corn	COR	co	othG			Corn	othGrain
rice	RIC	re	GRAIN	pdr	allGRAIN	RIC	GRAIN
soft wheat	ws	ws	wht				
durum wheat	wd	wd	wht				
oats	oa	oa	othG				
rye	ry	ry	othG				
triticale	tr	tr	othG				
other grains AGMEMOD	og	og	othG				
millet	Mill					Mill	othGrain
sorghum	Srgh					Srgh	othGrain
other grains GLOBIOM and AGMEMOD to MAGNET	ogr	othG	GRAIN	grain	allGRAIN	othGrain	GRAIN
Grains	GRAIN	GRAIN		allGRAIN		GRAIN	
rapeseed	RPS	rs	osd3			Rape	OSD
sunflower seed	SFS	uf	osd3			Sunf	OSD
soybeans	SBS	sb	osd3			Soya	OSD
oilseeds	OSD	osd3		oils		OSD	
rape meal	rl	rl	cake				
sun meal	um	um	cake				
soya meal	sm	sm	cake				
oil cakes	CAKE	cake		oilcake			
rape oil	ro	ro	vof				
sun oil	uo	uo	vof				
soya oil	so	so	vof				
vegetable oil	VOF	vof		vol			

Milk	MLK	WM		milk	ALMILK	
Ruminants	RUM_L	RUM		rum		
other animals than ruminants	NRM_L	HP		pigpoul		
Sugar beet and cane	sug	st		sug		
Cattle Meat	RUM_M	BV_LM		cmt	RUM	
Other Meat	RRM_M	o_meat		omt	NRM	
Dairy Products	dairy			dairy	DRY	
Sugar and Molasse	sugar	SU		sugar		
potato	PT	PT			Pota	
Cattle	CC	CC	RUM			
Beef and veal (meat)	BV	BV	BV_LM		BVMEAT	RUM
Pork (Pig meat)	PK	PK	o_meat		PGMEAT	NRM
Sheep total	SH	SH	RUM			
Mutton and Lamb (meat)	LM	LM	BV_LM		SGMEAT	RUM
Poultry meat	PO	PO	o_meat		PTMEAT	NRM
Cow's Milk	CM	CM	WM			
Other milk	OM	OM	WM			
eggs	EG	EG			PTEGGS	NRM
cotton	Cott				Cott	OSD
groundnut	Gnut				Gnut	OSD
oil palm	OPAL				OPAL	OSD
Grassland	GrsLnd	GL			GrsLnd	
Cropland	CrpLnd	CR			CrpLnd	
Forest/ wood land	Forest	AF			Forest	
Short rotation plantations	PltFor				PltFor	XL
other natural vegetation	NatLnd				NatLnd	XL
Abandoned land	AbnLand				AbnLand	XL
other land	XL	XL			XL	

Abb. = abbreviation

Agg. = aggregation

Annex 4 Mapping of variables of the three models to common mnemonics (units differ)

Descriptive name	Common mnemonics	AGMEMOD Abb.	MAGNET Abb.	GLOBIOM Abb.
area harvested	AREA	aha	AREA	AREA
yield	YILD	yha	YILD	YILD
production	PROD	spr	PROD	PROD
net exports	NETT	uxn	NETT	NETT
domestic use	CONS	udc	CONS	CONS
feed use	FEED	ufe	FEED	FEED
food use	FOOD	ufd	FOOD	FOOD
biofuel use	BFSU	uod	BFSU	
sum of other uses	OTHU	OTHU	OTHU	OTHU
population	POPT	pop	POPT	POPT
total GDP	GDPT	rgdpd	GDPT	GDPT
real production market price MAGNET	XPPR_M		XPPR	
nominal producer price AGMEMOD	pfn_A	pfn		
World price (baseyear=1)	XPRR		XPRR	XPRR
World merchandise exports prices	XPRX		XPRX	XPRX
world price, AGMEMOD	wmp	wmp		
Weighted average producer price GLOBIOM	XPRP_G		XPRP	XPRP
exogenous shifter on yields/ technical progress related to use of land	YEXO		YEXO	YEXO
Imports (with intra-trade)	IMP1	smt	IMP1	
Imports (without intra-trade)	IMP2		IMP2	IMPO
Exports (with intra-trade)	EXP1	uxt	EXP1	
Exports (without intra-trade)	EXP2		EXP2	EXPO

Abb. = abbreviation

Agg. = aggregation