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AGRICULTURAL PRODUCTION AND MARKET MODELLING APPROACHES

Sandija Zeverte-Rivza[1], Dr.oec.; **Aleksejs Nipers**[2], Dr.oec.**; Irina Pilvere**[3], Dr.oec.
[1,2,3] Faculty of Economics and Social Development, Latvia University of Agriculture

Abstract. Agriculture is a specific industry of the national economy that is subject to permanent economic, political, environmental and other changes. For this reason, credible and unbiased projections of its development are necessary, which take into account various conditions, including climate change. Agricultural modelling is widely used to assess and simulate the development of the agricultural industry; it has two key purposes: to contribute to the scientific understanding of a particular system and to analyse and project the effects of policies made and support instruments applied. The scientific literature provides a lot of information on modelling and simulation of dynamic systems. Therefore, the **overall aim** of the present research is to examine the key agricultural production and market forecasting models employed in the EU. To achieve the aim, the following **specific research tasks** are defined: 1) to analyse the theoretical aspects of simulation modelling; 2) to examine the key agricultural simulation models employed in the EU, including Latvia. The research has found that in the European Union (EU) diverse models by the approach and scope are employed for developing outlook of agriculture or its individual sectors. However, the most widely-used global and EU level models not always meet all the needs to accurately simulate the agricultural changes in the Member States level. For these reasons, in 2015 and 2016 two agriculture simulation models were developed in Latvia in order to project the potential development of agriculture and the key challenges related to climate change policies more accurately.

Key words: agriculture, simulation, models, modelling.
JEL code: Q10; C50

Introduction

Agriculture is a specific industry that is affected by various, usually changeable conditions determined by climate, seasonality, the market, production opportunities and historical development, the regulatory framework, political, environmental and social developments etc. Since 1962 in the EU this industry has been regulated by the Common Agricultural Policy (CAP), which has undergone many reforms that farmers have to reckon with. But over the next 20–25 years, global food demand is expected to increase by around 50%, largely due to demand in developing countries. The challenge is to increase production without damaging the natural resource base (William, Twomlow, 2007). For these reasons, it is important to 1) follow the changes taking place in the agricultural industry; 2) seek to project the development of the industry. Models are created in many countries, by means of which their governments follow the situation in agriculture.

Agricultural modelling has two key purposes: to contribute to the scientific understanding of a particular system and to analyse and forecast the effects of policies made and support instruments applied (Boote, Jones, Pickering, 1996; Bouman, Van Keulen, Van Laar, 1996; Van Ittersum, Leffelaar et al., 2003; Ritchie, 1991; McCown, Hammer et al., 1996). According to the first purpose, agricultural modelling allows examining the performance of the agricultural industry's system components as a whole or individually and the system's interconnections. The second general purpose of creating models is to acquire information necessary for justifying agricultural policy decisions and simulating their potential effects. Models that show reactions of the agricultural industry's system to exogenous factors as well as planned agricultural and support policy changes have to be created to achieve this purpose. Users of such models wish to ascertain the potential reactions of the agricultural industry, which would help in making decisions or identifying how the system simulated by a model reacts to a particular decision made. By employing models, one can analyse both the alternative scenarios of planned decisions and the effects of the decisions on particular sectors – grain farming and livestock farming – as well as the structure of agricultural holdings and regional aspects (Thornton, Herrero, 2001; Van Ittersum,

[3] Tel.:+371 29217851, E-mail address: Irina.Pilvere@llu.lv

Rabbinge, Van Latesteijn, 1998). An essential advantage of models is the acquisition of credible information on a system's behaviour affected by decisions made, which could be used by agricultural policy makers.

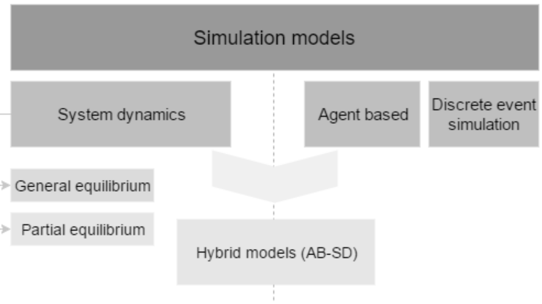
Therefore, the overall **aim of the present research** is to examine the key agricultural forecasting models employed in the EU. To achieve the aim, the following specific **research tasks are defined:** 1) to analyse the theoretical aspects of simulation modelling; 2) to examine the key agricultural simulation models employed in the EU, including Latvia.

Methodology and data. Analysis, synthesis, the logical and constructive methods, induction and deduction analysis methods were employed to execute the research tasks. Scientific literature review was used.

Research results and discussion
1. Theoretical aspects of agricultural modelling

An approach that may be classified as the simulation modelling of dynamic systems or system dynamics (SD) modelling is widely employed in agricultural modelling. System dynamics is an approach to examining the dynamics of complex systems, by means of which complicated problems could be solved (Dzene, 2011). System dynamics theory is based on examining associations between a system's behaviour and the underlying structure of the system (Martin, 1997). Analysing the structure of a system contributes to a deeper understanding of the causes of the system's behaviour, which allows effectively solving problems related to the behaviour of the system observed (Zeverte-Rivza, 2014). In dynamic models, changes in the state of an object over time are characterised by unknown variables and causal associations. For this reason, the results obtained by employing such dynamic models allow analysing potential changes in the functioning of the object and identifying the most typical trends in and causal relationships of it (Frolova, 2005). Unlike the statistical approach, such models involve functions that allow explaining the changes taking place in a system if the system reacts to exogenous factors (e.g. price changes, support instruments).

It is also possible to identify how the changes influence other system components (Wallach, Makowski et al., 2014). This approach is used in all types of models, including those for grain farming, livestock farming and farm systems. In the world, system dynamics is also used for analysis of renewable energy production, estimation of CO_2 and other GHG emissions from various industries and research on energy resources at national level and other complex processes. Although initial research investigations were started as early as the 1960s, this kind of modelling has been widely used since the 1990s (Gilbert, Troitzsch, 2006). The key problem is associated with data acquisition – to replace a research object with an artificially created system, in an ideal case accurate original system performance data are necessary (Pate-Cornell, 2002) –, which considerably hinders the modelling of economic and social systems, as the systems are quite uncertain and large in scope as well as involve the influencing factors that are difficult to define. A relatively new trend in the creation of models is agent-based (AB) modelling (Billari, Fent, et al., 2006; Berger, Troost, 2014), which is widely used to simulate interactive human behaviours and other individual element based processes (Antle, Basso et al., 2015). Discrete-event models, however, are employed to simulate individual events (Figure 1).



Source: authors' construction based on Borshchev, Filippov, 2004

Fig. 1. **Classification of simulation models**

[3] Tel.:+371 29217851, E-mail address: Irina.Pilvere@llu.lv

By employing the system dynamics approach, a model is developed as a reflection of a system; therefore, the model is created from top to bottom, showing the system's causal relationships and overall behaviour by means of cause-and-effect loops. Although system dynamics models may have micro-level elements such as, for example, agricultural holdings, yet no specific behaviour is set for individual elements within the model and the performance of the whole system is analysed instead. In contrast, agent-based models employ the bottom-up modelling approach. It means that developing such a model is begun with defining parameters and behaviours for individuals or agents, setting a number of characteristic parameters for each agent. Although causal associations between agent groups could be identified in agent-based models, however, unlike the system dynamics approach, such models are not usually employed for simulating macro-level systems (Table 1).

Table 1

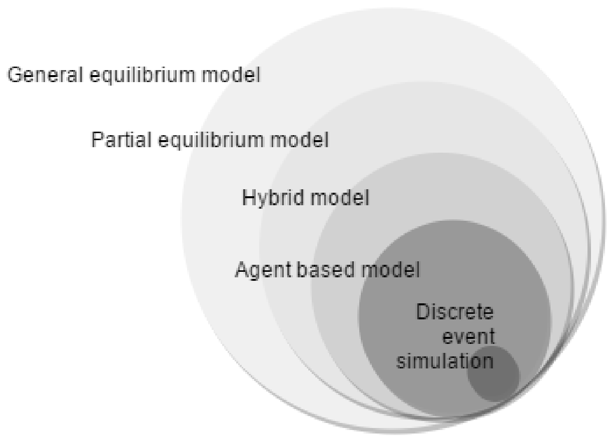
Comparison of system dynamics and agent-based models

Parameter	System dynamics models	Agent-based models
Modelling approach	Top-down	Bottom-up
Key structural elements	Casual loops	Individualized input data on agents
Units of analysis	System's structure	Agent behaviour rules
Modelling scale	System's overall behaviour	Individual agent behaviour

Source: authors' construction based on Martin, Schuler, 2015; Borshchev, Filippov, 2004

Hybrid models or agent-based system dynamics (AB-SD) models are developed by combining the advantages inherent in system dynamics models and agent-based models. They combine the features characteristic of both kinds of models – individualised agent behaviours are simulated by associating the models' systems with particular causal associations and systemic changes with changes in the agent behaviours. Such models are usually created from individual modules that involve data acquired from agent-based simulations and exogenous data on the particular system.

Classifying models according to their scale, one can find that the broadest systems examined are simulated by so-called general equilibrium models. They are mainly global-scale models that simulate macroeconomic processes. The scale of partial equilibrium models is different; there are some global-scale partial equilibrium models, yet most often they represent the models for countries or country groups (e.g. the EU, the USA) that focus on analysis of a particular industry or sector (agriculture, energy etc.). AB-SD models deal with the behaviour of individual agents, their links and their influence on a sector selected.



Source: authors' construction

Fig. 2. **Models divided according to their scale of application**

Agent-based models deal with the behaviour of agents on a small scale, while discrete-event models simulate individual events and therefore are not usually employed in tackling sectorial problems and simulating economic systems.

2. Models employed for projecting the agricultural sector in the EU

General equilibrium models

GEM-E3 is a general equilibrium model that simultaneously simulates the whole world's economy and the economies of the world's most important regions and 28 EU Member States. All these regions are interlinked through endogenous bilateral trade flows and environmental flows.

[3] Tel.:+371 29217851, E-mail address: Irina.Pilvere@llu.lv

The purpose of GEM-E3 is to cover the interactions between the economy, the energy system and the environment. It is a comprehensive model of the economy, the productive sectors, consumption, price formation of commodities, labour and capital, investment and dynamic growth. The model is dynamic and recursive over time. GEM-E3 is employed for acquiring the European Commission's reference scenario macro-assumptions. The model uses the GTAP and EUROSTAT databases.

MAGNET is a global general equilibrium model, and its main purpose is to provide a globally applied general equilibrium modelling framework, which may be tailored to specific research questions, including focusing on individual regions or products. MAGNET was designed based on the LEITAP model that was widely used for analysis of policies. MAGNET was developed because a more flexible and easily adjustable simulation system was necessary. The model employs the GTAP database.

Partial equilibrium models

The **CAPRI** model is currently employed for projecting the agricultural industry at the EU level. The full name of CAPRI is Common Agricultural Policy Regionalised Impact analysis. The name indicates the key purpose of the model – to evaluate the effects of CAP instruments not only at EU and Member State level but also at international level (Britz, Witzke, 2014). CAPRI is a static partial equilibrium model intended for the agricultural industry. It was designed to assess the impacts of policies and markets from global to regional and farm level. CAPRI is based on a link between a Europe-focused supply module and a global market module (Frank, Witzke et al., 2014). The CAPRI simulation system consists of a database, a methodology and a computer application. CAPRI uses data from the EUROSTAT, FAOSTAT, OECD and FADN databases. Its specific modules ensure that the data are mutually compatible. The data cover about 50 agricultural primary and processed products for the EU, from farm type to global scale coefficients (Britz, Witzke, 2014).

AGLINK is a part of the AGLINK-COSIMO model that was designed by the OECD Secretariat in cooperation with OECD member countries and selected non-OECD countries, thereby covering part of developing states. Since 1992 AGLINK has been used for making projections published in the OECD Agricultural Outlook. AGLINK is employed to provide analytical information for making annual medium- and long-term projections. The model's ability to perform alternative scenarios has made it one of the key OECD tools for forward-looking policy analysis. In 2004, it was decided to extend the AGLINK model to a larger number of developing countries and regions and to jointly undertake the annual medium-term outlook exercise in cooperation with the UN Food and Agriculture Organisation (FAO). The new component added to the model was named COSIMO (COmmodity SImulation MOdel). The general programming structure of COSIMO was taken over from AGLINK, while the behavioural parameters for the new country modules were taken from its predecessor, the World Food Model, employed by the FAO (Adenauer, 2008). The AGLINK model is widely employed for producing agricultural outlook in the EU.

AGMEMOD is an econometric, dynamic, multi-product partial equilibrium model that allows to make projections and simulations in order to evaluate measures, programmes and policies in agriculture at EU level as well as at Member State level (AGMEMOD, 2013). AGMEMOD covers all the EU Member States and some non-EU countries, e.g. Turkey, Russia and Ukraine. The Latvian State Institute of Agrarian Economics participated in developing AGMEMOD (AGMEMOD consortium, 2012), yet currently scientists from Latvia University of Agriculture are engaged in updating national data and renewing equations. AGMEMOD is employed for simulating the EU's agricultural industry.

[3] Tel.:+371 29217851, E-mail address: Irina.Pilvere@llu.lv

AGMEMOD was developed by using the FAPRI modelling system. FAPRI is widely used in the USA – annual baseline projections for the U.S. agricultural sector and international commodity markets are prepared by means of it, evaluating and comparing scenarios involving macroeconomic, policy, weather and technology variables (Fapri Models, s.a.).

ESIM is a partial equilibrium multi-country model of agricultural production, consumption of agricultural products (and some first-stage processing activities). It can be used in a comparative static as well as a recursive dynamic version. ESIM is programmed in the General Algebraic Modelling System (GAMS). Only the agricultural sector is simulated by means of ESIM, therefore such macroeconomic variables as income or exchange rates are exogenous. As a world model it covers all countries, although in greatly varying degrees of disaggregation. In its current version ESIM includes 25 EU Member States (including the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Slovakia, Slovenia, Malta and Cyprus), with Belgium and Luxembourg being summarised as one region, and also other states and regions- Turkey, USA Western-Balkans. All other countries are aggregated as the so-called rest of the world (Grethe H. (ed), Atavia et al., 2012). ESIM is employed to project the development of the EU agricultural industry.

GLOBIOM-EU is a global recursive, dynamic, partial bottom-up model, which integrates the agriculture, bioenergy and forestry sectors. The objective function calculates a global market equilibrium for agriculture and forestry by taking into account various land uses and product processing activities. The model forecasts the demand for and international trade in agricultural and forestry products for 53 world regions (28 EU Member States and 25 regions outside the EU) (Globiom model, 2012).

Agent-based models

AgriPoliS is an agent-based model of regional agricultural structures. The purpose of the model is to understand how farm structures change within a region in response to different policies, including evaluation of the effects of the CAP on agricultural landscapes, biodiversity and ecosystem services. Results generated by AgriPoliS at both the farm and regional levels include: areas and yields of crops, types and numbers of livestock, developments in farm specialisation and size, profits from agriculture and off-farm income, labour hours, input usage, land rental prices, investments and a full range of accounting data. Environmental results include changes in: land-use, landscape mosaic, number of species (biodiversity), nutrient balances, pesticide usage, soil carbon storage and soil fertility.

Researchers from the Netherlands, however, have developed an agent-based **model for the dairy sector of the Netherlands**, which simulates every dairy farm as an agent and analyses the effect of abolition of milk quotas on the structural change of the farms. The model simulates two government policy scenarios: 1) abolition of milk quotas; 2) use of agricultural land for sustainable dairy farming. Such input data as the location, the utilised agricultural area, fixed and variable costs and other data are entered into the model for every farm.

At present, the EC employs the CAPRI, AGLINK-COSIMO, AGMEMOD and ESIM models for preparing the outlook for the agricultural industry. Other specific models are also employed for preparing medium-term forecasts, such as, for example, "EU Agricultural Outlook Prospects for EU Agricultural Markets and Income, 2015-2025". The Directorate-General for Agriculture and Rural Development employs the **FeedMod** model for simulating feed consumption in the EU. The Directorate-General for Climate Action uses the **POLES** model for simulating fuel consumption. The **IHS Global Link Model**,

[3] Tel.:+371 29217851, E-mail address: Irina.Pilvere@llu.lv

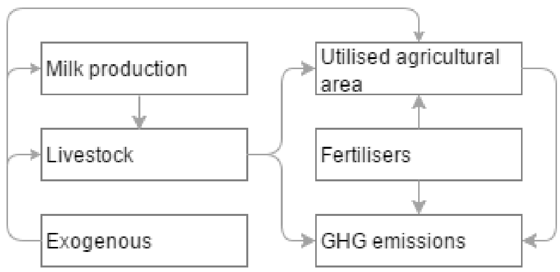
which is a global macroeconomic model, is also used for analysis of policies; it links 68 individual country models with each other and accounts for 95% of global GDP (EU Agricultural Outlook, 2015).

3. Models employed for analysis of Latvia's agricultural sector

Since the year 2000 the AGMEMOD model has been widely employed in the EU owing to funding available under the European Commission 6th Framework and contributions from the partners institutes throughout the EU. However, this 6th Framework project for the Institute for Prospective and Technological Studies (IPTS), part of the European Commission's Joint Research Centre project, was set to run until 2008 and was completed by 2007 (AGMEMOD, 2013). Some IPTS research studies provide information about Latvia after 2008, yet it is fragmented and covers selected agricultural sectors (Chantreuil, Salputra, Erjavec, 2013; Salputra, Chantreuil et al., 2011; Erjavec, Chantreuil et al., 2011).

Therefore, the necessity for creating appropriate models commissioned by the Ministry of Agriculture of the Republic of Latvia to project the agricultural sector increased in Latvia in recent years. In 2015, Latvia University of Agriculture designed a model for projecting agricultural indicators and GHG emissions from the agricultural sector for the years 2020, 2030 and 2050, which employed several approaches depending on a particular agricultural sector or a projected indicator: a) a semilogarithmic or linear trend model – to forecast crop yields and other selected indicators; b) a linear multifactor regression equation – to determine the numbers of cattle, sheep, goats, pigs, poultry and rabbits and the areas cropped with barley, oats and rye as well as permanent grasses; c) an S-shape curve (sigmoid) to determine the number of horses and the areas under wheat, rapeseed, maize and potato (LR Zemkopibas ministrija..., 2015).

In 2016, Latvia University of Agriculture developed the Latvian Agricultural Sector Analysis Model (LASAM), which was designed as a partial equilibrium econometric model that evaluated various development scenarios. The system dynamics modelling approach is employed by the model to simulate the agricultural industry of Latvia, which allows identifying the effect of change in agricultural policies on selected agricultural sectors. The model makes projections for such sectors as livestock farming (dairy cattle, beef cattle, sheep, goats, pigs, poultry and horses) and crop farming (grain, rapeseed, legumes, maize, vegetables and permanent grasses) as well as forecasts of UAA use and emissions from agriculture (Figure 3).



Source: Latvia University of Agriculture…, 2016

Fig. 3. **Key structural elements of the LASAM model**

Data for the model are acquired from the FADN and CSB databases, while projections of change in some indicators are employed by the model as exogenous variables obtained from the outlooks made by the EC and the FAO. To simulate macroeconomic indicators, the model employs macroeconomic projections for Latvia that are produced by the Ministry of Economics. Prices on goods are exogenous for the model. In the basic scenario, prices on agricultural goods are based on the European Commission's DG-AGRI projections for the period until 2025 and further projections are made by extrapolating from data-based trends. Support policy data are based on the distribution of financial aid until 2020, which is made by the Ministry of Agriculture. The amount of financial aid beyond

[3] Tel.:+371 29217851, E-mail address: Irina.Pilvere@llu.lv

2020 is assumed to be at the 2020 level (Latvijas Lauksaimniecibas universitate..., 2016). This model is employed to project development trends in the agriculture sector of Latvia for 2030 and 2050; it takes into account national and EU agricultural support policies as well as changes in prices on resources and products in the EU.

Conclusions, proposals, recommendations

1) The scientific literature refers to the simulation modelling of systems as a widely employed method. The most popular models for simulation are as follows: a) systems dynamic; b) agent-based; c) hybrid; d) discrete event models.
2) The scope of simulation by models differs– the smallest scope is specific to discrete-event models, while general equilibrium models are used to make global scale simulations.
3) Various models are employed for simulating the agricultural sector in the EU, which focus on simulating different aspects of agriculture. There are eight key models of different complexity, yet some Member States have created other models appropriate for a particular agricultural sector, region or issue.
4) The AGMEMOD model that is popular in the EU is employed for analysis of the agricultural sector of Latvia. However, two new models appropriate for the conditions in Latvia have been elaborated since 2015; each of the models have a different focus, jet both models produce projections and development scenarios, which allows applying policy instruments in a more accurate way in future, depending on the potential trend in the particular sector.

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[3] Tel.:+371 29217851, E-mail address: Irina.Pilvere@llu.lv