SYSTEM DYNAMICS MODELLING OF A NATIONAL BIOETHANOL COMPLEX-A CASE STUDY OF HUNGARY

József Popp, Agricultural Economics, Phone +36 30 297 3163, E-mail: popp.jozsef@econ.unideb.hu
Judit Oláh, Agricultural Economics, Phone +36 20 286 9085, E-mail: olah.judit@econ.unideb.hu
Anna Kiss, Food Science, Phone +36 1305 7293, E-mail: kiss.anna@etk.szie.hu
Zoltán Lakner, Food Economics, Phone +36 20 458 4736, E-mail: lakner.zoltan@etk.szie.hu

Overview

All over the world there is a rapidly increasing level of interest for the utilisation of bio-based raw materials as additives for gasohol (Anđelković et al., 2017). The extremely high level of complexity of these systems lends itself for the application of system-dynamics modelling because e.g. the increasing share of utilisation of agricultural raw materials – at least in theory – could lead to a declining agro-food supply thus to rising food prices (Küüt et al., 2017). This putative feedback has been a focal point in debates of the last decade. Obviously, the existence of vast complexity of lagged feedbacks makes it necessary to apply the methods of system dynamics and the sophisticated tools of computational realisation of system-dynamics models for the forecasting of future path of development of bioethanol projects.

During the last decades we have seen a mushrooming of application of system dynamics models for the biofuel sector in different countries (Lakner et al., 2017) but the overwhelming majority of these models has been focusing on the most developed countries (e.g. US) or on sugar-cane based ethanol production. There is a lack of knowledge on the regulation of the bioethanol sectors of small, open European economies, however, the development of biofuel sector is a priority in these countries, too.

The scarcity of natural resources in Hungary and the relatively high abundance of arable land (0,56 ha/cap, this is the highest value in the EU) motivates the development of biomass-based energy projects. The goal of this research is to analyse the interdependencies between arable-land use dynamics, agro-food exports, farmer's income, as well as state budget and the bioethanol-projects. Based on comparative analysis of more than 80 different system dynamics model concerning the biofuel sector description in different regions of the world, a conceptual framework for a bioethanol – system dynamics model has been constructed.

Based on analysis of agro-ecological conditions and their future trajectories of Hungarian bioethanol system we are setting up a stochastic system – model for the prediction of it. We applied a relatively complex model because future development of bioethanol production in Hungary is influenced by a complex set of natural (e.g. global climate change and its local conditions), economic and social factors. Their dynamics is determined by a combination of these factors. However, the exact future values of these factors are hard to quantify and predict. To circumvent this problem, we employ a system dynamics approach to analyse the future development trajectories of the Hungarian bioethanol system. Sterman (2001) outlined the most important features of systems characterised by dynamic complexity of phenomena. The main features of a dynamic system can be summarised as follows: (1) constantly changing character; (2) tightly coupled sub-systems; (3) governed by feedback; (4) nonlinearity; (5) history-dependence; (6) self-organising character; (7) adaptive behaviour; (8) characterisation by trade-offs; (9) counterintuitive character; (10) policy resistant feature. All of these criteria are true for the bioethanol sector, which is the main motivation for applying the dynamic system modelling. Setting up a conceptual framework of an agro-food system it is always an open-ended question which agricultural management system to assume.

Methods

In preparation of input-database two approaches have been used. (1) On one hand, we have applied a wide range of statistical databases [WTO, WB, FAO, Hungarian Central Statistical Office] to estimate the time-series dynamics of the system under investigation; (2) Relevant scientific articles published from 2007 to 2017 were identified through electronic searches from SCOPUS and databases of symposium proceedings on future forecast for renewable energy. As a total, more than 200 articles have been analysed. (3) In some cases we could not find reliable information necessary for the determination of stochastic relations between the variables. In these cases a panel of experts, consisting of seven specialist (5 experts in field of agricultural economics, 2 in public policy analysis) was used for eliciting of probability distribution of different parameters applying the SHELF R-package. Based on model-parametrisation the model has been tested by Vensim software for system analysis.

The model follows a building block principle. In this way the sub-models can be modified if another factors should be taken into consideration. The modules of the model are as follows: (1) global petrol sector sub-model; (2) agriculture sector sub-model; (3) Production sector sub-model; (4) byproduct and animal husbandry sub-model; (5) market sector sub-model. Different model-runnings up to time-horizon 2050 supported the practical applicability of the model to describe the future trajectory of the system offering a possibility for sensitivity analysis of the model variables as well as Kalman-filtering for optimisation of policy interventions.

Results

Results of the model highlight the practical importance of bioethanol projects in environmental management as well as in utilisation of Hungarian agro-ecologic potential. It has been proven that under current and foreseeable market conditions no conflict between energy and food supply is envisaged. The application of by-products for animal feed is a key factor of economic sustainability of the bioethanol projects.

Conclusions

The food versus fuel debate has been discussed very intensively in the last decade and mainly the link between crude oil price and food price changes. The analysis focus on whether food price change is the result of crude oil price changes and/or increasing biofuel production. We present evidence on the link between variances of maize price and ethanol production.

References

Lakner, Z. Oláh, J. Kiss, A. Balogh, P. and Popp, J. (2017): "Reuslt of application of system dynamics in analysis of biofuel systems-a review," International Food and Agribusiness Management Review, (manuscript, under review) (English language)

Anđelković, D. Antić, B. Vujanić, M. Subotić, M. and Radovanović, L. (2017): "The perspectives of applying ethanol as an alternate fuel," Energy Sources, Part B: Economics, Planning, and Policy, 15, 1-10. (English language)

Küüt, A. Ilves, R. Küüt, K. Raide, V. Ritslaid, K. and Olt, J. (2017): "Influence of European Union Directives on the Use of Liquid Biofuel in the Transport Sector," Procedia Engineering, 187, 30-39. (English language)

Sterman, J. D. (2001): "System dynamics modeling: tools for learning in a complex world," California Management Review, 43, 8-25. (English language)