Advances in Economics, Business and Management Research, volume 164
Proceedings of International Scientific and Practical Conference "Russia 2020 - a new reality: economy and society" (ISPCR 2020)

Forecasting Food Prices in the AnyLogic Information System

Belova T.N.
Academy of the FPS of Russia
Ryazan, Russia
belova_t_n@mail.ru

Kupriyanov V.V.
Ryazan State University
Ryazan, Russia
kvicvl@yandex.ru

Konkina V.S.
Ryazan State Agrotechnological University
Ryazan, Russia
konkina_v@mail.ru

Kupriyanova M.V.
Ryazan State Radio Engineering University
Ryazan, Russia
mvkupriyanova@gmail.com

***Abstract*—The article describes an original approach to modelling the food market with the use of the developed by Russian scientists AnyLogic software. The authors propose a model of system dynamics simulating the behavior of the meat and meat products market in the time period from 2000 to 2019. The acquired results include balance consumer prices for the three basic products: poultry, beef, and pork. The calculation of the mid-term forecast of consumer prices in these markets confirms the reliability of the simulation model. The original model illustrates the historic dynamics of the market situation. The research shows that food markets are highly variable in such characteristics as the level of protection from import, the amount of state support, the level of competition, and the entry and exit barriers. As a result, the retrospective survey reveals a volatile growth rate of production volumes in this segment of the food market (poultry, beef, and pork). Thus, the poultry market is saturated with domestic products that have substituted imported goods. At the same time, the low growth tempo of the cattle meat production has brought to import dependence. The obtained results of the survey may be applied as tools for developing the economic regulation policy in the agro production markets.**

Keywords—Forecasting, systemdynamicmodelling, food markets, effective market management, AnyLogic

I. INTRODUCTION

The contemporary market situation in the markets of food and agrarian products is complicated and even critical in several segments. The import substitution processes, with the imported goods driven out from the market, and the growth of domestic production differ in various food market segments. The differentiation of the agro-production markets can be analyzed by such criteria as the growth rate of domestic production volumes, the share of import in the resources, the level of market saturation, the share of exported goods, and the level of state support [4, 6]. These are complex processes that need to be studied and evaluated. They influence the dynamics of the most significant market indicators, the food consumer prices. Starting from 2014 the growth rate of the price index for food products have been higher than the inflation rate and outpaced the average income growth considerably. The decline in food demand in 2015-2017 is an alarming symptom of the food market development [2].

Forecasting the development of the situation in the food markets is a complicated and challenging task. To solve the research problem it is necessary to apply the methodology of mathematic modeling both for the total food market and its separate components as single- or multi-product models. These models have become urgent for the Russian national economy in the period of economic reformation. Russian scientists relied on the parity models presented by OESD and the World Bank for agro markets of the emerging economies. These models include RUNS (Rural-Urban North South) [Goldin at al., 1990], MRT (Regional Trade MRT, Harrison), AGLINK and other. The AGLINK-COSIMO model (Commodity Simulation Model) has become widely known and was used in forecasting by researchers [Fock at al., (2000); Krylatykh et al, 2012; Krylatykh et al, 2015; Prokopiev, 1999]. The recursive dynamic model of partial parityAGLINK-COSIMO is described in detail in [9]. It has been developed to forecast the key parameters of food markets including the prices. Notably, the upgrade of the Russian module of the model AGLINK-COSIMO has been terminated after the introduced economic sanctions against Russia and have not been restarted until present. In this situation it is either necessary to resume the development of the AGLINK-COSIMO model or to develop new national models [9, 15].

We propose an original approach to modeling the dynamics of the food market segments. Developed by Russian scientists, the Any Logic software can be used for simulation modeling. The authors have worked out an original SAFMD (simulation of agri-food market dynamics) model that describes the

situation in the food market of meat and meat products in 2000-2019. The results of running the model include short-term forecast and parity consumer prices for the markets of poultry, beef, and pork. The comparison of actual prices with the results of simulation has confirmed the adequacy of the further described model [10, 14].

II. PROBLEM STATEMENT AND A DESCRIPTION OF THE COMPUTER MODEL

The SAFMD model consists of several parts or modules, each of them being developed for corresponding tasks. The data processing module (DPM) is developed to import data from a MS Excel file to table-valued functions of AnyLogic. The core is the module of data evaluation that includes a system of differential equations for prices, reserves, and the price correction. Besides, there is an agent model of a regulator. This module incorporates the functions of analysis and decision making according to the accepted managerial strategy [5, 11].

ThemathematicSAFMDmodelincludesdifferentialequations andisdescribedindetail in the Journal of Economics and Mathematic Methods [Kupriyanov et al, 2020], a single-product variant of the model is described in [3]. It reflects complex interrelations and interconnections underlying the market processes in the market of meat and meat products. Further described are the modules of the SAFMD model with a detailed commentary on their specific functions. The data processing module (DPM) is developed to work with empirical data. This module imports information from MS Excel format to table-valued functions of AnyLogic which include econometric methods of aligning time series. DPM in the AnyLogic software is visualized as shown in Fig. 1. It consists of the interface element that includes 58 dynamic variables. These variables enable the interaction with the system dynamic element of the module and the AnyLogic tables with the imported data from the MS Excel file.

The series of four elements in the left part of the visualized DPM module stands for the basic statistic data and their econometric dynamic models. An example of the description in the model is the following:

- N_RF_tfun_d , N_RF_tfun , N_Rf_d , N_Rf –the population size of the Russian Federation, persons;
- n1_tfun_d, n1_tfun, n_1_d, n_1 –the consumption of meat and meat products (evaluated in terms of meat per capita per year, kilograms;
- D_cons_tfun_d, D_cons_tfun, d_cons_d, d_cons –the expenses on the final consumption per a member of a household per month, roubles;
- Qp_i_b_tfun_d, Qp_i_b_tfun, Qp_i_b_d, Qp_i_b –the volume of production (livestock in carcass weight per year), thousands of tons;

…and other.

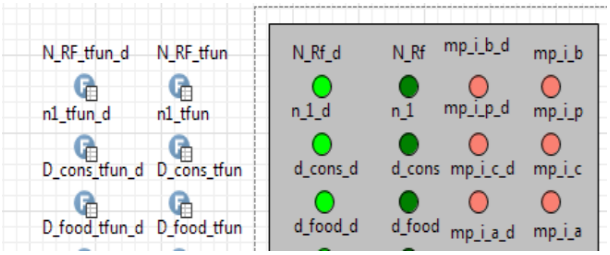

Fig. 1. A fragment of the data processing module in the SAFMD model.

The dynamic variables that indicate the cost price, the domestic prices of the producers, and the contract prices at customs (import and export) are described as follows:

- cp_i_b, cp_i_p , cp_i_c, cp_i_a –the cost price of a product item of the domestic producer;
- cp_e_b, cp_e_p , cp_e_c, cp_e_ –the cost price of a product item of the external producer;
- mp_i_b, mp_i_p , mp_i_c, mp_i_a – consumer prices in the domestic market;
- mp_e_b, mp_e_p , mp_e_c, mp_e_a –consumer prices in the external market (at customs).

The data evaluation module is a system of seven non-linear differential equations for prices, reserves, and the price correction in the computer program AnyLogic PLE 8.1.0. This module is visualized as it is shown in Fig. 2.

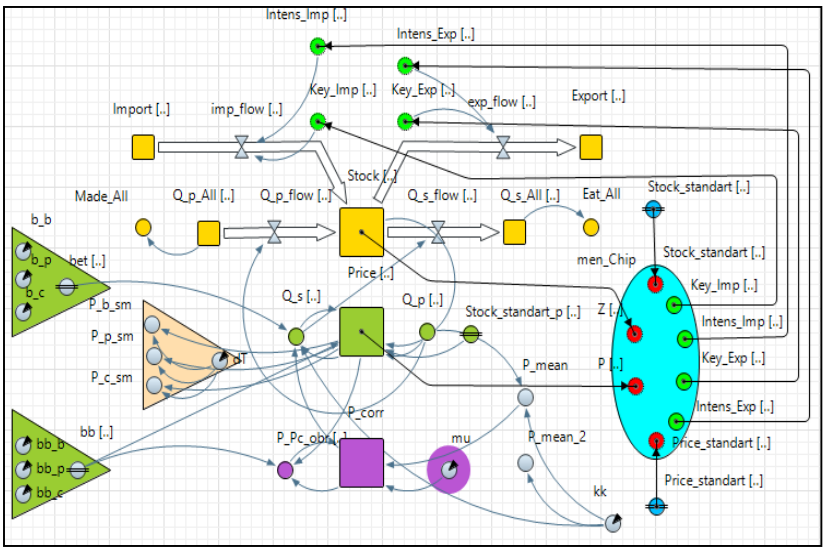

Fig. 2. The visualization of the SAFMD model in the AnyLogic information system.

The modules of the SAFMD model are marked with different colours. For a black-and-white printed version of the text, their location is further described. The two green triangles on the left with storage elements in the centre are a dynamic representation of the third-order differential equations system. It describes the price behavior according to the rule of supply and demand. The elements are marked as follows:

Price[..] – a storage element;

Q_s[..] –a dynamic unit of the demand functions; Q_p[..] –a dynamic unit of the supply functions. The dynamic unit Stock_standart_p[..] includes information about the critical level of suppliers' reserves of beef, pork, and poultry. The prerequisites bb_b, bb_p, bb_c and the dynamic unit bb[..] – contain relaxation parameters of the β system. The prerequisites b_b, b_p, b_c and the dynamic unit bet[..] include relative elasticity of the utility function.

The upper part of figure 2 (coloured yellow) reflects a system dynamic representation of the third-order differential equations system that describes the behavior of the meat and the meat product reserves.

The elements are marked as follows:

Stock [..] –a storage element that describes the reserves;

Q_p_flow[..] = Q_p[..] – a dynamic flow of supply per month;

Q_s_flow[..]=Q_s[..]; – a dynamic flow of demand per month;

Made_All=-Q_p_All[..] – a dynamic unit of the aggregate supply of meat and meat products within the total period of the numeric experiment. The storage element of reserves is an integral unit of the incoming flows of supply.

Eat_All=- Q_s_All [..] – a dynamic unit of the aggregate demand (consumption) of meat and meat products within the total period of the numeric experiment.

imp_flow[..] andexp_flow[..] – regulating flows of import and export.

The lower part of the figure (coloured violet) reflects the dynamic representation of the first-order differential equation that describes the calculation of the correction price.

The regulator agent module of the SAFMD model (the large green ellipsis in the right side of the figure) is developed for analysis and decision making according to the accepted managerial strategy. This module works in a downward direction as in a 'black box' system model [12, 13].

The parameters of the model are evaluated through using a neural network optimizer according to the price discrepancies acquired by modelling, and to the price statistics.

The SAFMD model makes it possible to forecast the prices, the volume of supply and demand, import and export, state budget income and expenses in the following 2-4 years. The authors consider a longer time lag of forecast inappropriate under the conditions of uncertainty of the socio-economic environment and the political situation.

III. RESULTS OF FORECASTING

The SAFMD model describes the behavior of the meat products market. It has revealed the expected price dynamics in the three types of meat products. The results of the experiments demonstrate stability in the parity levels of the supply and demand flows. This serves as a confirmation to the adequacy of the model and reliability of the forecast about the perspective time series of consumer prices [1].

The analysis of the model experiments indicates the different saturation of the beef, pork, and poultry markets, as well as the different import share. The research shows that the beef market is the most import-dependent. This influences the price dynamics. The evaluated beef price in 2001-2014 is below the actual level. This denotes additional expenses of the consumer. The results of the modeling for 2019 evaluate the beef price (except the boneless beef) at the level of 415.7 rubles per kilogram with a consistent upward trend. The Russian Statistics Bureau evaluates the average price lower, at the level of 350.05 rubles per kilogram. This is below the forecast of the model.

The pork market is different from the import-dependent market of beef. It demonstrates a downward tendency in price dynamics in several previous years. The domestic pork production has increased in 2019 by 2.5 times as compared to 2001. An important factor that has influenced the market situation was the economic embargo and the limited imported volume of pork from the EU countries. The largest spike in the pork prices was observed in 2015. The price per kilogram grew from 214.18 rubles per kilogram to 272.36 rubles. It was further followed by a decrease in prices. The forecast of the model showed the pork price at the level of 274.03 rubles per kilogram. The Russian Statistic Bureau evaluated the average price at the level of 264.6 rubles. The discrepancy was at the level of 3.6%.

The poultry market has benefitted from the long period of protective measures. At present, it is fully saturated with domestic production. The volume of domestic production has increased by 5.6 times starting from 2001 [3, 8]. As a result, the volume of the market reached its critical level by 2017, and the average price started to decrease. In the past decade, the volume of export has grown inconsiderably. The forecast of the price was 154.7 rubles per kilogram in 2019. It was calculated with a hypothesis of a perspective export growth. This scenario failed and as a result of market collusion, the price started to grow. In 2019 it was at the level of 143.13 rubles per kilogram (a discrepancy of 8.1%).

IV. CONCLUSION

To conclude, the methodological approach to modeling the agro production market based on the system dynamics using the AnyLogic software has demonstrated positive results. The SAFMD model is adequate for the actual situation in the food market. It is based on the analysis of such key factors as the growth rate of the disposable income of the population, the dynamics of the domestic production, import and export, characteristics of the market competition, the transformation of the consumer preferences and other. Notably, market segments are not always competitive, and the mathematic model may change according to the actual market situation. Nevertheless, the proposed approach with the use of AnyLogic modeling may provide acceptable forecast results.

Acknowledgments

The reported study was funded by RFBR, project no. 18-010-00843.

References

[1] N.V.Byshov, S.N.Borychev, D.E.Kashirin, G.D. Kokorev, M.Yu.Kostenko, G.K. Rembalovich, A.A. Simdyankin, I.A. Uspenskiy, A.I.Ryadnov, R.A. Kosulnikov, I.A.Yukhin and I.K.Danilov, "Theoretical Studies Of The Damage Process Of Easily Damaged Products In Transport Vehicle Body During The On-Farm Transportation", ARPN J. of Engin. and Appl. Sc., 2018, vol. 13(10), pp. 3502-3508.

[2] G.Bakulina, V. Fedoskin, M. Pikushina, V. Kukhar and E. Kot, "Factor Analysis Models In Enterprise Costs Management", International journal of circuits, systems and signal processing, 2020, vol. 14, pp. 232-240.

[3] T.N.Belova, "Processes of import substitution in the agro-food sector", Economy of the region, 2019, vol. 15(1), pp. 285-297.

[4] P.C.Beukes, P. Gregorini, A.J. Romera, G. Levy and G.C.Waghorn, "Improving Production Efficiency As A Strategy To Mitigate Greenhouse Gas Emissions On Pastoral Dairy Farms In New Zealand", Agriculture, Ecosystems and Environment, 2010, vol. 136(3-4), pp. 358-365.

[5] N.V.Byshov, S.N.Borychev, I.A.Uspenskiy, A.V.Shemyakin, I.A.Yukhin, D.A.Fedyashov and I.A.Piskachev, "Development prospects of transportation in the agroindustrial complex by reducing the damage of fruit and vegetable products when using the pneumatic container", Intern. J. of Engin. And Tech., 2018, vol. 7(4.36), pp. 914-919.

[6] B. Khaleghipour, H. Khosravinia, M. Toghiyani, "Azarfar Efficacy Of Silymarin-Nanohydrogle Complex In Attenuation Of Aflatoxins Toxicity In Japanese Quails", Italian Journal of Animal Science, 2011, vol. 19(1), pp. 351-359.

[7] V.S.Konkina and A.B.Martynushkin, "Analysis Of Import Substitution Processes In The Milk And Dairy Products Market Using Cluster Analysis", International transaction journal of engineering management & applied sciences & technologies, 2020, vol. 11(10).

[8] E.N.Krylatykh, "Multifunctionality Of The Agro-Food Sector: Theoretical Concept, Practical Implementation", Economics of the region, 2011, vol. 4(28), pp. 21-35.

[9] E.N.Krylatykh and V.P. Fedorov, "Food Security In The Context Of Integration: Trends, Achievements, Threats", Modern Europe, 2013, vol. 2(54), pp. 138-142.

[10] S. Kuhl, L.Flach and M.Gauly, "Economic assessment of small-scale mountain dairy farms in South Tyrol depending on feed intake and breed", Italian Journal of Animal Science, 2020, vol. 19(1), pp. 41-50.

[11] E.P.Polikarpova and I.E.Mizikovskiy, "Preparing Accounting Information On Costs For Manufactured Crop Production", Custos e Agronegocio, 2018, vol. 14(4), pp. 149-166.

[12] S.D. Polischuk, G.I. Churilov, S.N. Borychev, N.V. Byshov and A.A. Nazarova, "Nanopowders Of Cuprum, Cobalt And Their Oxides Used In The Intensive Technology For Growing Cucumbers", Intern. J. of Nanotechnology, 2018, vol. 15(4-5), pp. 352-369.

[13] G.M. Tunikov, N.I. Morozova, F.A. Musaev et al., "Economic And Biological Features Of The Holstein Cows Selected In Hungary When Year-Round Stable System", Int. J. of Engineer. and Technol., 2018, vol. 7(4.36), pp. 935-940.

[14] R.N. Ushakov, A.V. Ruchkina, V.I. Levin, O.A. Zakharova and N.A. Golovina, "Sustainability Of Agro-Gray Soil To Pollution And Acidification, And Its Biodiagnostics", Intern. J. of Engin. AndTech., 2018, vol. 7(4.36), pp. 929-934.

[15] A.S. Zavgorodnyaya, I.G. Shashkova,V.S. Konkina, L.V. Romanova, E.I. Mashkova and M.Yu. Pikushina, "Adaptive Management Of The Agricultural Enterprise In The Conditions Of Environmental Uncertainty", Journal of Advanced Research in Dynamical and Control Systems, 2018, vol. 7, pp. 2022-2031.