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Economic and Mathematical Modeling of Food Security of the Subjects of the Russian Federation

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Abstract. The aim of the study is to use the methods of economic and mathematical modeling to assess food security. The article presents a methodological approach to the food security assessment, which enables one to determine a comprehensive indicator, i.e. food security index (I_{fs}). According to statistical data on the regions of the Southern Federal District, food security was assessed, it was found that in 2017 food security index was equal to 8 points, which corresponded to permissible level. The deviation from optimal level was due to a significant degree of income differentiation in the region and nonoptimal structure of the consumer basket. Theoretical relevance of developing a methodology and economic-mathematical model for assessing food security based on calculation of a complex multifactorial indicator is associated with the need to develop existing methodological approaches to assessing food security at macroeconomic level, with the analysis of systematic groups of factors affecting food security, as well as relevance of monitoring and evaluation of food security. The practical relevance of the presented approach to assessment of food security involves the possibility of using data obtained in the planning and development of agricultural policy, in order to improve its socio–economic and financial efficiency in the field of food security in the regions of Russia.

1. Introduction

Food security is the most important component of the country's economic security, provision of which is defined as the main priority of socio-economic and agricultural policy of Russia. A.I. Altukhova [1, 2], V.V. Miloserdova [2], A.V. Ulezko [3] and T.M. Yarkova [4] highlight some aspects of food security in context of the theory and practice of sustainable development of the regions of Russia. Definition and evaluation of the system of food security factors are of current importance. Several modern studies have been devoted to assessment of import substitution impact on food security and food supply in the regions of Russia [5; 6]. There is an independent area of study, that involves research contributions on the analysis of resource provision of agro-industrial complex and evaluation of its role in food supply, including at the regional level of the economy [7].

Theoretical and methodological foundations of modeling agro-industrial complex on regional and sectoral levels are presented in the works by S. B. Ognivtsev, S.O. Siptits: models of interaction for markets of various types of agricultural and food products (grain, meat products) have been developed. Of particular interest are the models of forecasting the prices in food markets as well as economic and mathematical model to justify the program of providing the region with food [8].

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M. Gill, A. Herforth [9], D. Grace, G. Mahuku, V. Hoffmann [10], H. Weikard [11] R. Capone, H. Bilali, F. Debs [12, 13] describe organization of food supply system, safety and quality control of food products in the countries of Europe, the USA, and Canada. The authors analyze in detail the measures of regulation and support of agricultural-food sector of the economy.

Economic and mathematical modeling in assessing and forecasting the level of food security allows us to develop formal, multi-criteria models for assessing food security. The modeling process includes a number of successive stages: to define the subject and purpose of the analysis; to define the object; to identify factors that affect its functioning; and to develop criteria of evaluation and optimization.

2. Materials and Methods

2.1. Cognitive economic and mathematical modeling

In order to determine the groups of factors and the system of indicators of food security, an expert method of analyzing hierarchies can be used. The obtained system of indicators forms the structure, connections and membership functions of fuzzy cognitive maps. To parameterize cognitive maps there have been constructed infological and information models; they provide justification for the relational database structure according to analyzed statistical indicators.

Specific indicators for food groups enable construction and verification of a family of predictive econometric models. Methods for integrating the obtained econometric models into the cognitive map can be developed based on membership functions and fuzzy logic. Construction, testing and debugging of a specialized software package that implements impulse modeling of the analyzed systems should be carried out according to incident matrices corresponding to cognitive maps. As a result, scenario analysis of the level of food security will be carried out using fuzzy cognitive maps.

A software package is needed to support numerical research and scenario analysis using the developed cognitive maps [14]. Such software package should include a computer program, a database to construct functions of factor membership and a statistical database for the research, using an intelligent system to assess and predict the integral level of food security.

To create an intelligent system of multi-criteria assessment and forecasting of the level of food security of the state and specific regions on the basis of fuzzy cognitive approach it is necessary:

- to specify theoretical and methodological basis of the integrated assessment of food security level;
- to form a system of indicators and methodology for construction of fuzzy production cognitive maps to assess the forecast of food security provision, considering the sphere of production, consumption, reservation and import;
- to develop methodology and build membership functions for factors of food security relevant for production cognitive maps;
- to build a system of fuzzy cognitive maps to assess level of food security at the level of the state and specific regions;
- to model self-development and controlled development of food security system with the help of cognitive maps for subjects at different levels;
- to develop a software package for monitoring, assessing the level of food security and forecasting its dynamics.

These subtasks will solve the problem of objective integrated assessment of food security level on the basis of intellectual cognitive system, as well as will assess the dynamics of its change, taking into account public authorities management.

2.2. Empirical model of food security assessment

To assess food security, it is proposed to use a methodology that involves the use of statistical indicators and analysis of:

- level of food self-sufficiency;
- degree of satisfaction of physiological needs of the population in food;

- level of economic access to food [15].

Food self-sufficiency for certain types of agricultural products is determined on the basis of self-sufficiency coefficients (C_s), the indicators are calculated as the ratio of factual production volumes to the necessary volumes of food production in accordance with rational consumption rate. Using these coefficients, it is possible to determine to what extent in the region the population needs are met based on domestic regional food production.

Satisfaction degree of physiological needs of the population in food is estimated using the coefficients of factual food consumption (C_{fc}) – the factual volume of consumption is compared with rational rate [3].

The level of economic access to food is determined by the ability of the population to buy food. Its characteristics should take into account the level of monetary income of the population and food price. Calculation of economic availability is based on a system of indicators [16]:

- poverty rate (C_p) – share of the population with incomes below the subsistence minimum;
- consumption ratio (C_c) – share of food expenditure in the structure of consumption expenditure;
- Gini coefficient (C_G).

To assess the level of food security, it is necessary to determine an integral indicator – the food security index:

$$(I_{fs}): = C_s + C_{fc} + C_p + C_c + C_G \quad (1)$$

as sum of values in points for each of the analyzed indicators and then to correlate the obtained value with criteria of food security (see table 1).

Table 1. Criteria and level of food security.

Points	Level of food security
> 9	optimal:
5-8	permissible:
< 5	low

Source: [17].

The proposed model allows us using official statistics to assess the achieved level of food security in context of certain regions of the Russian Federation, to compare them and to determine the degree of differentiation in food supply.

3. Results

The differentiation of Russia's regions, according to their sectoral specialization, determines priorities of socio-economic and agricultural policy to ensure food security and improve the living standards of the population. The Southern Federal District is traditionally one of the regions specializing in agriculture, its resource potential of agriculture and climatic features create favorable conditions for providing the population of the region with food products in amounts not lower than the established rational consumption rates. Data on the branches of agriculture in the Southern Federal District demonstrate higher growth rates in crop production sphere, compared with the results obtained in livestock products manufacturing. We can determine the level of self-sufficiency for food products in the subjects of the Southern Federal District in 2017 (table 2).

Table 2. Food self-sufficiency of SFD in 2017.

Food supply	Factual production, thousand tons, (q)	Necessary volume of production in accordance with number of rational rates of consumption, $(n^* q_p)$	$C_s = \frac{q}{n^* q_p}$
Potato	2109.3	1478.5	1.42
Vegetables	3892.5	2299.9	1.69
Milk	3578.2	5339.2	0.67
Meat	993.8	1199.3	0.82
Eggs, million pcs.	5573.1	4271.4	1.30

The value of the coefficient of self-sufficiency (Cs) for the analyzed types of food products was 1.18, which corresponds to the optimal level and while assessing the food security index can be estimated in 2 points for macro-region of the Southern Federal District.

4. Discussion

Analysis of food consumption in the Southern Federal District in 2017 allowed us to establish that on average in the Southern Federal District the volume of consumption of bread products (this category includes flour, cereals, rice, pasta and legumes) exceeded the rational consumption rate by 23.9%. In 2017, in the Southern Federal District the volume of consumption of meat and meat products on average exceeded the established rational consumption rate (73 kg/year) by 2 kg. At the same time, in 2017, in the subjects of the Southern Federal District the situation with the consumption of meat (beef, lamb, pork, poultry) was inhomogeneous. In certain regions, in particular in the Republic of Adygea, the Republic of Crimea, the city of Sevastopol, Rostov region, the volume of consumption was below established rational rates. [18, p. 248 – 252]. The situation with milk and dairy products consumption is still quite complicated. With the specified rational consumption rate of 325 kg per year, in 2017, in the Southern Federal District the volume of consumption on average amounted to 216 kg, which is only 66.5% of the recommended rational consumption rate (figure 1).

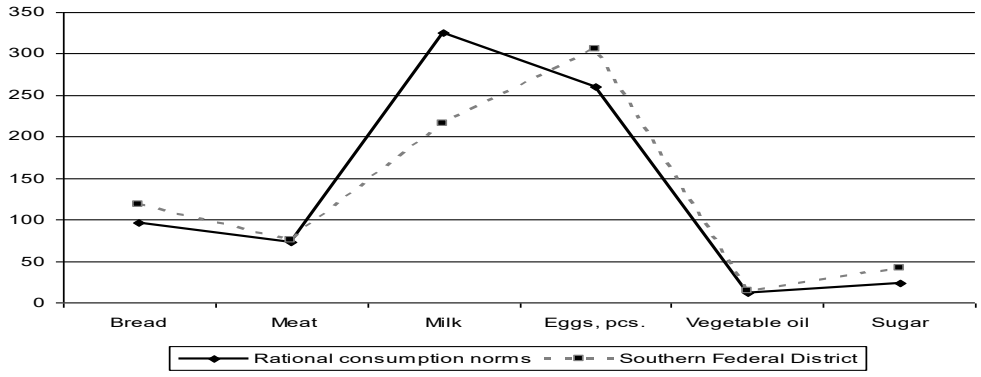

Figure 1. Volumes of food consumption in the Southern Federal District in 2017, in comparison with rational consumption rates (bread, meat, milk, eggs, oil, sugar).

In 2017, the established rational rate of sugar consumption (24 kg per year) was exceeded almost 2 times by the population of the Southern Federal District (table 3).

Table 3. Food Consumption in the Southern Federal District (per capita, kg per year)

Subject of the Russian Federation, rates and level of consumption	Bread	Meat	Milk	Eggs, pcs.	Sugar	Vegetable oil
Russian Federation	117	75	231	279	39	13.9
SFD	119	75	216	306	42	14.6
Sustainable rates of consumption [19]	96	73	325	260	24	12
C_{fc}	1.23	1.02	0.66	1.18	1.75	1.21

Such a significant excess of sugar consumption in comparison with the specified sustainable rates of consumption also indicates an imbalance in food diet of the population of the Southern Federal District. In 2017, the volume of vegetable oil consumption by the population of the Southern Federal District amounted to 14.6 kg, which slightly exceeded specified sustainable level of consumption – 12 kg. With the help of the obtained values (C_{fc}), average value is calculated and value of the indicator to form food security index is determined, in 2017, for the regions of the Southern Federal District the value corresponded to 2 points.

Among negative trends in the Southern Federal District it is worth noting high degree of polarization of the population in terms of income and high proportion of the population with incomes below the subsistence minimum (figure 2) [20]. Analysis of poverty ratio (C_p) showed that in 2017, the population with incomes below the subsistence minimum in the Southern Federal District amounted to 16.1% [18, 21]. The value *(C_p)* for determining the integral index of food security index of the Southern Federal District corresponds to 2 points.

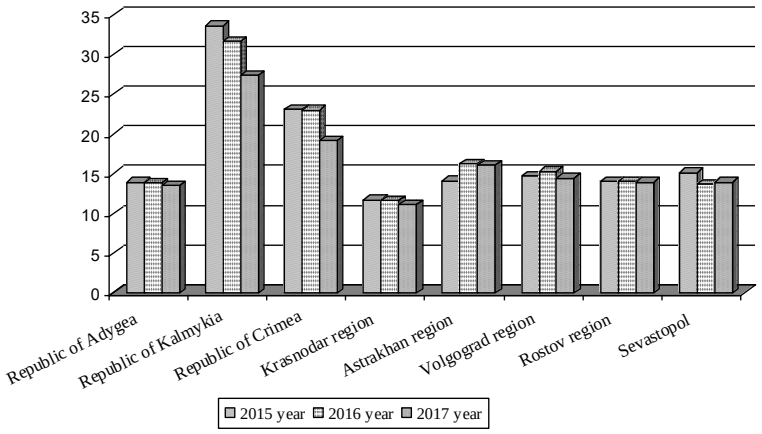

Figure 2. Population with incomes below the subsistence minimum in the Southern Federal District, % of the total population.

Share of food expenditures in the structure of household expenditures of the Southern Federal District amounted to 37.9% in 2017. Some regions of the Southern Federal District experience rather unfavorable situation in terms of consumer spending structure. In the Republic of Crimea and the city of Sevastopol, about half of household expenditure is spent on food. Value of consumption ratio (C_c) in the calculation of food security index (I_{fs}) corresponds to 1 point. In 2017, the Gini coefficient (C_G) for the Southern Federal District was equal to 0.362 [18, p. 220], respectively, when calculating food security index of the Southern Federal District, value of this indicator corresponds to 1 point.

We define an integral indicator: index of food security of the Southern Federal District:

$$(I_{fs}): = C_s + C_{fc} + C_p + C_c + C_G = 2 + 2 + 2 + 1 + 1 = 8 \text{ points.}$$

In 2017, food security index of the Southern Federal District did not correspond to the optimal level, that was due to a significant degree of income differentiation in the region and sub-optimal structure of the consumer basket, in which a significant part of the expenditure is spent on food.

5. Conclusion

The results of the analysis revealed several factors impeding optimal level of food security of the Southern Federal District and suggest measures for optimization. Promising directions of improving agricultural policy in the field of ensuring and maintaining an acceptable level of food security in the regions of the Southern Federal District could include: measures to increase the level of self-sufficiency in dairy and meat products; economic availability of food for the population, which requires action plan to ensure the growth of incomes of the population in the Southern Federal District. This evaluation model enables us to analyze food security based on real statistical data, to select measures to optimize agricultural policy in order to ensure an acceptable level of food security in the regions of Russia.

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