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Forecasting of Parameters of Human Capital Development in Agriculture in Voronezh Oblast

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***Abstract* — The purpose of the research was to forecast the parameters of human capital development in agriculture in Voronezh Oblast. In line with this objective the authors developed a long-term forecast of the total and rural population, and used the methods of economic and mathematical modeling to substantiate the promising parameters of human capital development in agriculture of the region by economic entities (agricultural enterprises and peasant farm enterprises). The performed research allowed determining the priorities for organizing the structure of economic activities, whereas reaching the design parameters will create the conditions for efficient economic activities, as well as for obtaining a greater mass of profit sufficient for expanded reproduction. Moreover, the use of a block mathematical economic model allows a multivariate determination of the optimal parameters of the number of workers employed in agricultural production. For instance, the forecast of rural population shows a decrease in both the total population and the number of workers employed in agricultural production with a simultaneous decrease in total rural population and working-age population. Prospective changes in the structure of the population predetermine a positive trend in the development of agricultural sector in Voronezh Oblast.**

Keywords — human capital; reproduction of human capital; mathematical economic modeling; block-diagonal structure; forecast of rural population.

I. INTRODUCTION

It is known that the economic system is a subsystem of the social system, in which the reproduction of material goods occurs. This subsystem also includes subsystems of a different nature and orientation (e.g. technical, biological, industrial, etc.), and has a comprehensive structure. Its specificity lies in the fact that functioning includes participation of a human person as a user, a labor resource, a carrier and converter of information. At the same time, humans are positioned above the economic system and predetermine the goals of its sustainable efficient functioning.

In the economic literature of recent years, it has been proved that the methods of mathematical economic modeling are the most effective in substantiating the optimal parameters of functioning of enterprises, taking into account the use of the scenario approach. The utilization of these methods using personal computers and a set of application software provides significant advantages compared to other methods and techniques.

According to Professor A.P. Kurnosov, the utilization of mathematical economic methods means that, firstly, the principle of a systematic approach is fully implemented; secondly, the speed and quality of development of plans increases; thirdly, the conditions for implementing a multivariate problem statement appear; fourthly, it is possible to make operational adjustments in accordance with changes in internal and external production conditions [1].

At the present stage the use of mathematical economic methods in forecasting the parameters of functioning of economic systems allows a more reasonable approach to improving management and planning in the agricultural sector of the economy, since it involves a mathematical description of internal and external relations of elements.

The use of optimization models provides not only optimization, but also the balance of agro-industrial production, which is accepted as the best of the whole variety of development options under given internal and external conditions.

The use of optimization models in forecasting the development of the agricultural sector of the economy, in contrast to industry, involves overcoming a number of difficulties. They are associated primarily with the multisectoral nature of agricultural enterprises, which leads to the use of a large number of variables and restrictions. Furthermore, modeling should take into account the features of organization of agro-industrial production, both biological and socio-economic.

Finally, it is quite difficult and challenging to model the conditions associated with pricing, forecasting financial results, etc. in the conditions of unstable external operational environment for agricultural enterprises, which is due to fluctuations in market conditions and weak state regulation and state support.

Optimization of development parameters of regional Agro-Industrial Complex is possible through the use of block mathematical economic models of linear programming. This problem is the subject of constant research conducted in Voronezh State Agrarian University named after Emperor Peter the Great.

On the one hand, the authors were interested in the fact that practically in most cases, each enterprise (at the level of district, Oblast or region) was represented as a separate block in the utilized mathematical economic models for optimizing development parameters of the Agro-Industrial Complex (AIC) at the level of an integrated structure or municipal district or region.

According to large part of agricultural economists, from the point of view of systematic approach, enterprises are a subsystem of the hierarchical structure of the economic system [2–4].

On the other hand, the authors believe that forecasting of rural population using mathematical economic methods is impossible without taking into account a number of economic factors that have a significant impact on the reproduction of human capital. This is not only about the incomes of the population and their ratio to the subsistence level or the average level in the region's economy as a whole, but also about the dynamic impact of the use of resources (e.g. land, material, technical, financial, etc.) on the process of human capital reproduction.

In the course of research, the authors have developed a mathematical economic model with a block-diagonal structure, in which (unlike the previously used similar models) two blocks represented agricultural enterprises and peasant farm economies, and the connecting block described the relationship between them.

Modeling of conditions by blocks was performed according to a unified methodology that included a description of general provisions and differences.

First of all, in each block the land will be fully utilized, and restrictions on material, monetary and labor resources imply determining the need for them in the process of solving the mathematical economic model (MEM).

The differences in the blocks relate to production conditions, agrotechnical requirements with the account of crop rotation, etc.

Modeling of economic processes in agriculture in the long term was performed by blocks that were represented by separate categories of agricultural producers, and each block was calculated according to a unified methodology.

The model contained the following variables:

- arable land area;
- sowing crop area;
- livestock population;
- material and monetary costs;
- labor costs, etc.

The system of restrictions is based on blocks. The main restrictions include the conditions for resources consumption for the production and sale of products, as well as the conditions for fulfilling the agrotechnical, zootechnic, organizational and economic requirements, etc.

The mathematical economic model for optimizing the development of regional Agro-Industrial Complex is a set of linear equations and inequalities for each block, i.e. for each category of agricultural producers.

Maximization of the amount of profit was taken as the optimality criterion due to the fact that at the current stage this criterion is the most appropriate for the purpose of functioning of any economic system.

In modeling of economic processes in agriculture one of the main issues is the compliance with crop cultivation conditions.

A study of agrotechnical conditions of crops cultivation in the Central Chernozem Region allowed establishing that the share of grain crops in the structure of utilized agricultural area should range from 50 to 60 %, while the share of winter grain cultures should be from 20 to 30 %. Exceeding this threshold is unacceptable due to the fact that it will be problematic to allocate the sowing cultures by optimal preceding crops. The area of fallow land can reach 5-10 %, according to the system of production in the Agro-Industrial Complex of Voronezh Oblast [5].

Input information was gathered from official statistical publications of the Federal State Statistics Service of the Russian Federation and its territorial authority in Voronezh Oblast, the Ministry of Agriculture of the Russian Federation, the Department of Agrarian Policy of Voronezh Oblast Administration, production and financial plans, and annual reports of agricultural producers (business and financial performance indicators) [5–8].

The preparation of input information for technical and economic coefficients for variables was carried out in the context of economic categories based on actual information over a number of years according to the performance results and taking into account the biological and socio-economic conditions of the region, strategic directions for the development of crop production and animal husbandry, as well as reasonable scenarios (pessimistic, conventional, and optimistic).

For instance, in order to substantiate the prospective level of crop yields and livestock and poultry productivity the authors used conventional methods that took into account the level achieved over the previous 3–6 years, the achievements of the region's leading enterprises and the implementation of innovative technologies. Therein, the pessimistic scenario took into account the conditions of 2010, which was the most severe year for crop production in terms of climatic conditions (drought).

The level of labor, material and monetary costs was planned on the basis of flow process charts developed by the staff of the Department of Farm Production Management and Entrepreneurial Business in Agro-Industrial Complex of Voronezh State Agrarian University.

Selling cost indicators were determined on the basis of current sales prices for various types of agricultural products.

The mathematical economic model developed by the authors was tested on the example of certain categories of farms in Voronezh Oblast.

II. Results and Discussion

The analysis of results of solving the mathematical economic model (MEM) showed that the proposed changes in the structure of production of agricultural sectors would allow for an increase in the level of production efficiency both in agriculture as a whole and in separate categories of economic management (Table I).

As it is shown in Table I, the profitability level will be 16.9, 24.9, and 29.2 % within the pessimistic scenario, within the conventional scenario, and within the optimistic scenario, respectively.

In the forecast period the authors register slight changes in the structure of marketable products; in particular, there is an increase in the share of crop industry with a decrease in the share of livestock industry in all forecast variants (Table II), which is to some extent predetermined by changes in the structure of sowing crops (Table III).

TABLE I. Economic features of agricultural production efficiency in enterprises and business units of all categories of Voronezh Oblast

Performance indicators	Actual data	Forecast variants		
		I	II	III
Utilized agricultural area, hectares	3,260,315	3,260,315	3,260,315	3,260,315
Arable land area, hectares	2,945,465	2,945,465	2,945,465	2,945,465
Pattern of crops, %				
cereal crops	58.9	59.7	59.7	65.2
industrial crops	20.2	30.8	30.9	24.6
potato, vegetables & cucurbit crops	0.2	1.4	1.4	1.5
forage crops	12.5	8.0	8.0	8.7
Livestock population, thousand heads				
Cattle	342.3	370.9	374.4	353.9
of which cows	95.9	104.2	105.2	97.7
Pigs	677.6	711.4	718.2	684.4
sheep and female goats	97.7	107.5	108.4	100.4
Poultry	8,703.4	9,030.4	9,073.8	9,055.8
laying hens	2,097.6	2,161.2	2,203.0	2,119.1
Profit, total, million rubles	8,827.7	32,543.7	38,251.0	22,364.9
Material & monetary costs, total, million rubles	111,263.9	130,560.0	131,075.1	132,688.6
Sales proceeds, total, million rubles	120,091.6	163,103.7	169,326.1	155,053.5
Level of profitability, %	7.9	24.9	29.2	16.9

The composition of commodity output of agricultural sector of economy in Voronezh Oblast is presented in Table II. The composition of arable land area in enterprises and economic units of all categories of Voronezh Oblast is presented in Table III.

TABLE II. COMPOSITION OF COMMODITY OUTPUT OF AGRICULTURAL SECTOR OF ECONOMY OF VORONEZH OBLAST

Types of products	Actual data		Forecast variants					
			I		II		III	
	million rubles	%	million rubles	%	million rubles	%	million rubles	%
Crop production, total	46,869.2	48.4	84,122.8	60.1	87,385.6	59.8	70,278.8	54.1
Grain growing	20,219.4	20.9	34,143.0	24.4	35,296.4	24.2	32,267.7	24.8
Sugar beet	8,950.6	9.2	13,052.7	9.3	13,783.5	9.4	11,875.4	9.1
Sun flower	15,394.7	15.9	16,676.2	11.9	17,305.4	11.9	14,002.7	10.8
Soya beans	1,313.7	1.4	10,778.3	7.7	11,247.7	7.7	3,836.2	3.0
Potato	496.7	0.5	7,486.4	5.3	7,702.9	5.3	6,474.5	5.0
Vegetables	494.0	0.5	1,986.2	1.4	2,049.9	1.4	1,822.3	1.4
Livestock farming, total	50,043.1	51.6	55,918.7	39.9	58,627.9	40.2	59,670.1	45.9
Dairy products	13,210.6	13.6	15,653.6	11.2	16,022.2	11.0	14,926.9	11.5
Beef	8,992.1	9.3	10,276.6	7.3	10,505.5	7.2	10,537.4	8.1
Pork	16,766.3	17.3	18,106.9	12.9	19,789.2	13.6	18,561.7	14.3
Mutton	258.2	0.3	293.5	0.2	297.9	0.2	2,752.2	2.1
Poultry	8,293.5	8.6	8,872.0	6.3	9,084.1	6.2	9,912.9	7.6
Wool	52.7	0.05	56.1	0.04	57.8	0.04	53.5	0.04
Eggs	2,469.7	2.5	2,660.1	1.9	2,871.3	2.0	2,925.6	2.3
Total for agricultural sector as a whole	96,912.2	100.0	140,041.5	100.0	146,013.6	100.0	129,948.9	100.0

TABLE III. COMPOSITION OF ARABLE LAND AREA IN ENTERPRISES AND ECONOMIC UNITS OF ALL CATEGORIES OF VORONEZH OBLAST

Agricultural crops	Actual data		Forecast variants					
			I		II		III	
	hectares	%	hectares	%	hectares	%	hectares	%
Grain crops, total:	1,454,976	49.4	1,637,959	55.6	1,636,754	55.6	1,767,279	60.0
winter wheat	611,409	20.8	681,433	23.1	671,984	22.8	700,270	23.8
Rye	16,308	0.6	9,759	0.3	9,487	0.3	13,203	0.4
spring wheat	54,111	1.8	30,753	1.0	29,893	1.0	41,596	1.4
grain maize	228,366	7.8	223,838	7.6	223,838	7.6	223,838	7.6
spring barley	393,657	13.4	222,297	7.5	220,000	7.5	304,347	10.3
Oat	29,534	1.0	9,407	0.3	9,216	0.3	12,880	0.4
Millet	16,237	0.6	9,072	0.3	8,923	0.3	104,668	3.6
Buckwheat	31,598	1.1	437,817	14.9	450,068	15.3	24,784	0.8
Pea	22,723	0.8	13,583	0.5	13,346	0.5	341,693	11.6
Industrial crops, total:	669,455	22.7	845,474	28.7	846,480	28.7	666,455	22.6
sugar beet	119,443	4.1	127,505	4.3	127,505	4.3	127,505	4.3
sun flower	407,768	13.8	383,854	13.0	383,854	13.0	383,854	13.0
soya beans	77,800	2.6	334,115	11.3	335,121	11.4	155,096	5.3
Potato	4,006	0.1	32,400	1.1	32,400	1.1	32,400	1.1
Vegetables	2,163	0.1	7,000	0.2	7,000	0.2	7,000	0.2
Forage crops, total:	309,680	10.5	220,317	7.5	220,767	7.5	237,083	8.0
feeding root crops	388	0.0	14,020	0.5	14,009	0.5	17,746	0.6
maize for silage and green maize	82,512	2.8	65,529	2.2	65,842	2.2	77,977	2.6
annual grasses	102,195	3.5	62,709	2.1	62,848	2.1	62,665	2.1
perennial grasses	113,911	3.9	72,321	2.5	72,299	2.5	73,064	2.5
green winter cultures	7,737	0.3	5,737	0.2	5,770	0.2	5,632	0.2
Sowing area, total	2,470,579	83.9	2,743,150	93.1	2,743,402	93.1	2,710,217	92.0
Fallow land	410,273	13.9	202,315	6.9	202,063	6.9	235,248	8.0
Arable land area, total	2,945,465	100.0	2,945,465	100.0	2,945,465	100.0	2,945,465	100.0

TABLE IV. ECONOMIC EFFICIENCY OF PRODUCTION IN ENTERPRISES AND ECONOMIC UNITS OF ALL CATEGORIES OF VORONEZH OBLAST

Performance indicators	Actual data		Forecast variants					
			I		II		III	
	AO	PFE	AO	PFE	AO	PFE	AO	PFE
Output produced per 100 hectares of arable land, c:								
Grain	1,615.1	1,737.7	1,986.2	1,598.5	2,016.7	1,628.4	1,713.2	1,508.8
of which commercial	842.1	1,365.3	1,352.2	1,469.5	1,374.0	1,498.8	1,078.3	1,366.4
sugar beet	2294.9	1,002.7	2,549.6	1,643.7	2,594.6	1,672.8	1,917.4	1,236.3
sun flower	329.6	397.7	361.9	351.0	368.1	357.6	271.3	264.4
Potato	19.1	37.8	398.8	35.7	405.8	36.3	299.5	26.7
Vegetables	9.1	64.0	84.5	80.6	86.0	82.0	63.6	60.6
Pork	53.5	0.8	57.9	0.9	59.1	0.9	55.4	0.8
Output produced per 100 hectares of utilized agricultural area:								
dairy products, c	214.7	49.5	255.7	54.8	260.4	56.3	226.2	51.2
gain in weight per beast of cattle, c	16.8	6.3	19.3	7.0	19.6	7.1	18.3	6.5
gain in weight per beast of sheep, c	0.14	1.60	0.16	1.81	0.16	1.83	0.14	1.70
marketable products, RUB000's	3,169.0	2,319.6	4,527.4	3,524.2	4,724.4	3,661.5	4,247.8	3,115.0
of which crop production	1,264.0	2,014.3	2,400.5	3,177.2	2,492.6	3,303.8	2,048.9	2,509.9
of which livestock farming	1,905.0	305.3	2,126.9	347.0	2,231.8	357.7	2,198.9	605.1
profit, RUB000's	316.3	119.6	1,044.4	844.6	1,231.7	978.9	697.2	648.6
Level of profitability, %	8.4	5.2	23.9	30.5	28.0	35.4	15.4	25.4
crop production	12.1	5.4	34.9	31.8	39.1	36.8	23.4	15.6
livestock farming	4.6	3.7	10.0	20.1	14.2	22.6	6.0	96.6

The performed research allowed establishing priority directions for the development of economic activities in the region's agriculture. The top priorities among them are the development of dairy and beef cattle breeding, as well as vegetable growing.

The analysis of economic efficiency of agricultural production by categories of farms revealed that in the forecast period there would be an increase in efficiency for the three forecast variants presented (Table IV). Explanation of abbreviation used in Table IV: AO means agricultural organizations, PEF means peasant farm enterprises.

As it is shown in Table IV, for forecast variants I and II, there is an increase in both physical and monetary indicators of efficiency. For instance, there is an increase in production volumes per 100 hectares of arable land for most crops, and the profitability level is 24.9 % within the conventional scenario, and 29.2 % within the optimistic scenario, which is respectively 17.0 and 21.3 percentage points higher than the actual level.

However, the noted increase in economic efficiency will be insufficient for the purpose of ensuring the possibility of expanded reproduction, which determines the need to increase the level of state support for economic entities operating in the agricultural sectors. It should be noted that the development of peasant farm enterprises will occur at a higher rate than in agricultural organizations, which is largely due to the initially different qualitative level of development of these categories of farms.

From the point of view of economic efficiency, the conventional forecast variant will be preferable, since it corresponds to the average level of development of agriculture.

It should also be noted that the methodological approach utilized in the calculations with mathematical economic modeling can be used not only to forecast the level of development of industries and search for the optimal combination of resources, but it also allows determining the prospective need for agricultural workers in a multivariate setting. Moreover, the data obtained during the implementation of this forecast will contribute to increasing the sustainability of reproduction of human capital in rural areas. The forecast of the rural population made with the methods of mathematical economic modeling also shows that there is a decrease in both the total population and the number of workers employed in agricultural production (Table V).

TABLE V. FORECAST OF THE RURAL POPULATION IN THE AGRICULTURAL SECTOR OF VORONEZH OBLAST

Performance indicators	Forecast variants		
	I	II	III
Number of workers employed in all categories of farms	144,969	145,964	138,042
of which in agricultural enterprises	126,311	127,228	121,287
in peasant farm enterprises	18,658	18,736	16,755
working-age population	315,804	337,262	318,956
total rural population	683,558	730,004	690,380
Average monthly wage in agriculture, rubles	38,714.0	40,191.0	36,804.0

The performed analysis showed that in the forecast period there is a decrease in both the total rural population and the number of workers employed in agriculture within all forecast variants. Therein, the number of employees in agricultural organizations will decrease by 14.4 % in forecast variant I, by 13.7 % in variant II, and by 17.8 % in variant III. In the conventional variant the total rural population will decrease by 8.8 %, and the working-age population will decrease by 19.3 %. At the same time, there is an increase in the average level of nominal wages: by 10,209 rubles (35.8 %) within scenario I, by 11,686 rubles (41.0 %) within scenario II, and by 8,299 rubles (29.1 %) within scenario III.

According to the results of solving the MEM, there is an increase in labor productivity expressed in the amount of revenue per average annual worker employed in agriculture. In particular, this increase amounts to 58.6 % within forecast variant I, 63.5 % within forecast variant II, and 57.0 % within forecast variant III (Table VI).

TABLE VI. FORECAST OF KEY PERFORMANCE INDICATORS OF AGRICULTURAL ORGANIZATIONS OF VORONEZH OBLAST

Performance indicators	Actual data	Forecast variants		
		I	II	III
Number of workers employed in agricultural organizations	147,500	126,311	127,228	121,287
Balance sheet profit, million rubles	8,827.7	32,543.7	38,251.0	22,364.9
Profit/loss (-) of all economic activities, %	7.9	24.9	29.2	16.9
Revenues from sales of agricultural products (in current effective prices) – million rubles in total	120,091.6	163,103.7	169,326.1	155,053.5
of which per average annual worker employed in agricultural production, thousand rubles	814.2	1291.3	1330.9	1278.4

III. CONCLUSION

Summing up the results of research, it can be noted that the forecast made using the methods of mathematical economic modeling revealed a downward trend in both the total rural population and the number of workers employed in agricultural sector of economy of Voronezh Oblast.

At the same time, some positive aspects are observed, such as an increase in the overall level of development of agricultural sectors, as well as an increase in the level of wages of workers, which to a large extent can serve as the basis for the development of rural areas, subject to due attention from the authorities.

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