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Mathematical modeling of economic factors impact: reproduction of personnel potential in agriculture sector of Russia

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Abstract. The paper presents an approach which allows obtaining quantitative characteristics and assessing the impact of economic factors on the reproduction rate of personnel potential providing objective forecasting of trends and problems in the industry. Based on the PEST analysis and the results of a sociological survey using the index analysis method, the article developed a methodology for calculating the integral indicator of changes in economic conditions in Russian agriculture. By means of mathematical modeling, their influence on the reproduction of personnel potential in the industry is proved. One of the elements of the proof of the obtained results is a multi-factor mathematical model built and tested in real time, which allows obtaining a high-quality predicted result. Based on the forecasts, we can state the need to adjust certain factors that are actively affecting the reproduction of personnel potential in agriculture, which is a mathematical justification for making managerial decisions.

1. Introduction

At the beginning of the XXI century, the new realities of the economy revealed an urgent need for modern technologies for studying the process of reproducing personnel potential, both in the national economy as a whole and in agriculture, since pre-reform methods are hopelessly outdated [1]. We analyzed foreign publications over the past four years (where instead of “personnel potential” the concepts of “human resources” and “human capital” are used) [2-7] and similar work on these issues in Russia [8-10] and we came to the conclusion that the research technologies used in them were based only on analysis, which does not allow forecasting. In contrast to the publications presented, in this paper, it is proposed to use the mathematical apparatus to study reproductive processes and, based on the forecasts obtained from the developed mathematical models, to carry out effective agricultural management. We believe that this topic will be interesting to foreign scientists in connection with the special research technology in solving applied problems that has no analogues in the world.

Analyzing the results of our previous studies, and having developed a technology for assessing the impact of social factors on the reproduction of personnel potential in agriculture to solve current problems, we developed an algorithm for assessing the impact of economic factors on this process [11]. The research methods used by the authors in this paper are: index analysis, calculation of integral



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indicators, correlation-regression analysis, theory of multivariate regression, moving average method, analysis of variance.

So, “the reproduction of personnel potential is a combination of a continuous process of translational movement of a set of explicit and latent characteristics (in the context of this study - agriculture) (repeating phases of oscillatory movements, usually resonant that are important for the development of an object) with a discontinuous phase that includes separate phases (discrete) development” [1]. The purpose of the paper is to assess the impact of economic factors on the reproduction of personnel potential in agriculture.

2. Methodology

During the PEST analysis (political, economic, social, and technical factors), the Ministry of Agriculture of the Chuvash Republic, Russia), we used the group of “economic factors” (Table 1), previously used in [1].

Table 1. Average value of economic factors effecting the reproduction process personnel potential in agriculture [1].

Description of the factor	Average value of the factor
<i>Financial factors</i>	
The state tax policy, the level of taxation of enterprises by federal, regional (republican) taxes and their collection	1,600
The balance of the relationship of the republican budget with the federal	1,400
Dynamics of the gross regional product, the rate of economic growth	1,400
Inflation rate	1,600
Investment policy and state financing of projects in agriculture	2,600
Investment activity of the region	2,600
Concessional lending to agricultural organizations and rural residents	2,600
The number of banks in the region, the amount of assets of regional banks, their dependence on centralized loans, the legal and financial independence of local banks, etc.	1,600
<i>Production</i>	
Dynamics of production volumes in agriculture and the level of labor productivity	1,800
The share of unprofitable agricultural organizations and the dynamics of their bankruptcy	1,800
Overdue receivables and payables of agricultural enterprises	1,600
Restructuring of agricultural production	2,200
High degree of depreciation of fixed assets in the agrarian sector of the economy and social sectors	2,400
Low competitiveness of agricultural products	1,600

Thus, we used investment policy and state financing of projects in agriculture; investment activity of the region; preferential lending to agricultural organizations and rural residents; a high degree of depreciation of fixed assets in the agricultural sector of the economy and social sectors; restructuring of agricultural production in the region; the dynamics of production in the region and the level of labor productivity; and the share of unprofitable agricultural organizations and the dynamics of their bankruptcy (Table 1).

At the initial stage of the assessment, a sample of the most significant criteria was formed to calculate the influence of economic factors on the rate of reproduction of personnel potential in Russian agriculture, which were the objects of this study. In an enlarged form, it included many diverse indicators, but to simplify and efficiently calculate based on correlation and PEST analysis, ten factors

were identified that had a significant impact on the reproduction process (Table 2). The selected factors were provided with accessible information on the website of the Federal State Statistics Service and were reduced to the index value (in % of the previous year, Table 3) to be able to take them into account when calculating the integral indicator.

Table 2. The main economic indicators characterizing opportunities reproduction of personnel potential in agriculture in Russia in 2010-2015 [12-13].

Indicator	2010	2011	2012	2013	2014	2015
<i>Financial factors:</i>						
1. Investment policy and public financing of projects in agriculture						
Financial investments of organizations in agriculture, billion rub.	188,900	177,500	193,800	222,600	374,100	582,600
Investments in fixed capital of agriculture in actual prices, billion rub.	303,800	446,900	476,400	516,600	510,300	505,800
2. Dynamics of the gross regional product, the rate of economic growth						
Balanced financial result (profit minus loss), mln. rub.	61,050	94,809	108,931	151,637	160,936	256,838
<i>Production factors:</i>						
1. High degree of depreciation of fixed assets in the agricultural sector and branches of the social sphere						
Fixed assets of agriculture, billion rubles	2,859	3,127	3,335	3,671	3,886	4,285
Degree of depreciation of fixed assets of agriculture, %	32,7	33,2	34,6	35,5	36,6	36,1
2. Restructuring of agricultural production						
Sown area, million ha	76.4	76.7	76.3	78.1	78.5	79.3
Livestock and poultry (at the end of the year), million heads	522.1	533.2	558.0	558.0	590.8	615.4
3. Dynamics of production volumes in agriculture and the level of labor productivity						
Rural products economy in actual prices, billion rub., total	2,588	3,262	3,340	3,687	4,319	5,166
Index of labor productivity in agriculture, %	88.3	115.1	98.2	106.0	102.9	104.5
4. The share of unprofitable agricultural organizations and the dynamics of their bankruptcy						
The level of profitability, unprofitability of all activities, including subsidies, %	9.1	11.8	12.1	7.3	16.1	20.7

Based on the selected indicators (Table 3) characterizing the economic factors affecting the reproduction of personnel potential in agriculture in Russia, a number of indicators are calculated. The first is an integral indicator reflecting investment policy and state financing of projects in the industry, Formula 1 includes index values of two factors (Table 3): financial investments of organizations and investments in fixed assets of agriculture.

$$Z_1 = \sqrt{f_1 \cdot f_2} \quad (1)$$

where, Z_1 – integral indicator characterizing the investment policy and state financing of projects in agriculture, points; f_1 – index of financial investments of organizations in agriculture, %; f_2 – index of investment in fixed capital of agriculture, %.

Integral indicators are calculated according to a similar principle, characterizing: a factor of a high degree of depreciation of fixed assets in the agricultural sector of the economy and social sectors (second indicator); restructuring of agricultural production (third); the dynamics of agricultural production and labor productivity (fourth) (table 2). The data are entered in table 3. To calculate the integral indicator of changes in economic conditions in agriculture, formula 2 is proposed.

Table 3. Dynamics of changes in economic indicators affecting on the reproduction of personnel potential in agriculture in Russia in 2011-2015.

Indicators	2011	2012	2013	2014	2015
<i>Financial factors:</i>					
1. Index of financial investments of organizations in agriculture (in % to previous year)	93.6	108.4	112.9	140.5	135.8
2. Index of investments in fixed capital of agriculture (in% to previous year)	134.8	101.0	103.9	93.8	88.1
3. The integral indicator characterizing the investment policy and state financing of projects in agriculture, points	112.3	104.6	108.3	114.8	109.4
4. The index of the net financial result in agriculture (in % to previous year)	135.6	113.0	128.2	167.9	137.3
<i>Production factors:</i>					
5. The index of fixed assets of agriculture (in % to previous year)	108.5	106.2	109.2	105.5	109.3
6. Index of depreciation of fixed assets of agriculture (in % to previous year)	101.5	104.2	102.6	103.1	98.6
7. Integral indicator characterizing the factor of high degree of depreciation of fixed assets in the agricultural sector and industries social sphere, points	104.9	105.2	105.8	104.3	103.8
8. Index of acreage (in % to previous year)	100.4	99.5	102.3	100.6	101.0
9. Index of livestock and poultry (in % to previous year)	102.1	104.4	100.0	105.6	104.0
10. Integral indicator characterizing restructuring of agricultural production points	101.2	101.9	101.1	103.1	102.5
11. Index of production in agriculture (in % to previous year)	123.0	95.2	105.8	103.5	102.6
12. Index of labor productivity in agriculture (in % to previous year)	115.1	98.2	106.0	102.9	104.5
13. Integral indicator characterizing the dynamics of production volumes in rural farm and level of labor productivity, points	119.0	96.7	105.9	103.2	103.5
14. Index of profitability, unprofitability of all activities, including subsidies (in % to previous year)	129.7	102.5	60.3	220.5	128.6
15. Integral indicator of change of the economic conditions in agriculture, points	114.0	103.2	101.8	123.6	110.4
Index of the reproduction of personnel potential in agriculture (in % to previous year) [14]	104.5	91.3	92.7	117.1	103.2

$$Z_5 = \frac{\sqrt{f_3 \cdot f_4} + Z_1 + Z_2 + Z_3 + Z_4}{5}, \quad (2)$$

where Z_5 – integral indicator of changes in economic conditions in agriculture, points; f_3 – index of balanced financial result in agriculture, %; f_4 – index of profitability, unprofitability of all activities, including subsidies, %; Z_1 – integral indicator characterizing the investment policy and state financing of projects in agriculture, points; Z_2 – integral indicator characterizing the factor of high degree of depreciation of fixed assets in the agrarian sector of the economy and social sectors, points; Z_3 – integral indicator characterizing the restructuring of agricultural production, points; Z_4 – integral indicator

characterizing the dynamics of production volumes in agriculture and the level of labor productivity, points.

Developed and tested by the author, methodological tools for determining motives for potential staff turnover from agriculture have also confirmed the dependence of the reproduction of personnel potential on economic factors. The specifics of the process of reproducing personnel potential determined the necessity of organizing a sociological survey in four stages (the first study was conducted in 2002-2003, the second in 2015-2016): graduates of comprehensive rural schools, students of higher and secondary agricultural educational institutions, employees of agricultural organizations, unemployed rural residents [15]. So, students, among the reasons for their unwillingness to work in agriculture, put them in the first place – “wages are not satisfied” [14]. Managers, specialists, cadres of mass professions of agricultural organizations, answering the question: “Do you have a desire to move up the career ladder?” In the case of a negative answer, put in the first place – “lack of material incentives”. Unemployed rural citizens, temporary and seasonal workers also note that the primary factor in their unwillingness to work in agriculture is low wages. Thus, all categories of respondents consider economic factors to be decisive in deciding on employment and effective employment in agriculture.

3. Calculations

It is proposed to carry out further details of the problem under study by means of mathematical modeling to study the influence of economic conditions that are forming in Russian agriculture on the reproduction of personnel potential. It should be noted publications in which mathematical modeling is actively used for research in complex technical processes [16], in economics [17], in agriculture [11,18].

To study the process of reproduction of personnel potential in agriculture, it is proposed to use multivariate correlation analysis. Based on the method of ten index indicators (Table 3) and their statistics from 2011 to 2015 were added to 10 selected from the website of the Federal State Statistics Service.

At the first stage, for the selected 15 indicators, an inter-factor correlation relationship was analyzed, which showed a high correlation of the first, second, third, fourth, eleventh and fourteenth factors in Table 3. To construct a multifactor model, the following indicators were used: 6; 9; 13; 15 (Table 3). The integral indicator of changes in economic conditions in agriculture. We introduce the notation of these factors, respectively: X_6 , X_9 , X_{13} , X_{15} . Based on the theory of multivariate regression, a multivariate model was calculated (formula 3):

$$Y = 148.6876 - 0.5889 \cdot x_6 - 1.0853 \cdot x_9 - 0.2594 \cdot x_{13} + 1.3794 \cdot x_{15}, \quad (3)$$

where, Y is the index of the indicator of reproduction of personnel potential in agriculture. The quality indicator of the constructed model R^2 is the coefficient of multiple determination, $R^2 = 0.9999$. The significance of the model was confirmed using the Fisher statistical test at a significance level of $\alpha = 0.05$ and $F_{crit} = 4.49$; $F_{obsev} = 159984.0$. Geometric interpretation of the initial information and the constructed model are presented in figure 1.

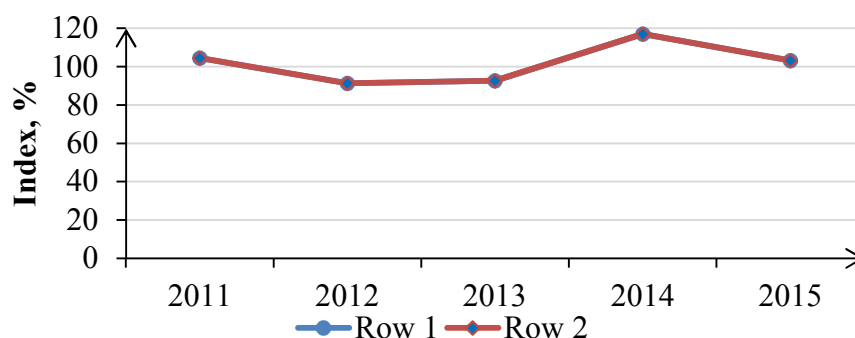


Figure 1. Index of the reproduction of personnel potential in agriculture ([14], %): Row 1 – initial information of factor Y . Row 2 – geometric interpretation of the multifactor mathematical model Y .

4. Results and discussion

The structure of the multifactor model implicitly indicates the connection of the fifteenth factor with the third fourth, tenth and fourteenth. To obtain a point forecast for the constructed multivariate model, calculations of the point prediction for each factor of the multivariate model were preliminarily performed. Information of each factor was considered as a time series. The additive structure of time series and the processing technology based on the moving average method were chosen. The quality indicator of models is calculated on the basis of analysis of variance [19]. Characteristics of the models are shown in Table 4.

Table 4. Description of mathematical models.

Factor X_i	Model structure	The structure of the trend components T	Model quality score R^2	Spot forecast for factor a X_i
X_6	$X_6 = S+T+E$	$T=104.1325-0.69t$	$R^2=0.6850$	$X_6=100.9425$
X_9	$X_9 = S+T+E$	$T=100.9167+0.5167t$	$R^2=0.6933$	$X_9=100.25$
X_{13}	$X_{13} = S+T+E$	$T=112.5042-2.45t$	$R^2=0.6050$	$X_{13}=93.9375$
X_{15}	$X_{15} = S+T+E$	$T=100.6+2.8t$	$R^2=0.9928$	$X_{15}=109.4$

Figures 2-5, respectively, show the geometric interpretation of models for factors X_6 , X_9 , X_{13} , X_{15} .

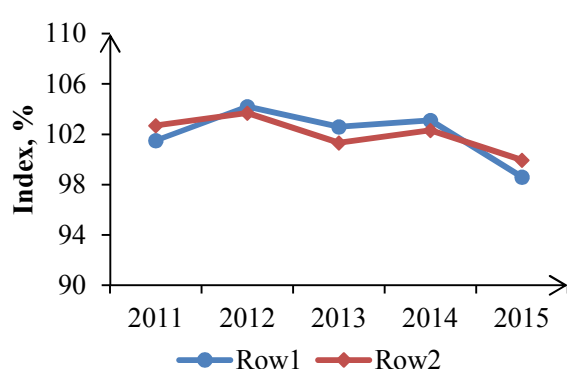


Figure 2. Index of depreciation of fixed assets of agriculture, %: Row 1 – baseline information of factor X_6 . Row 2 – geometric interpretation of the mathematical model.

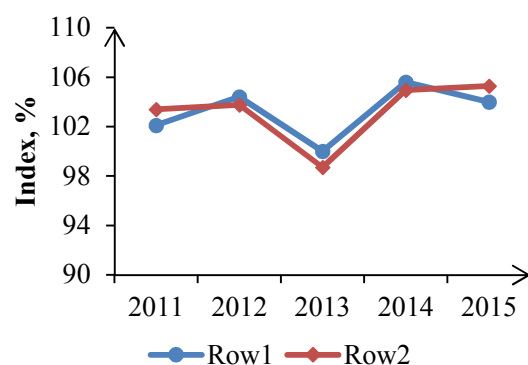


Figure 3. Index of livestock and poultry, %: Row 1 – baseline information of factor X_9 . Row 2 is a geometric interpretation of a mathematical model.

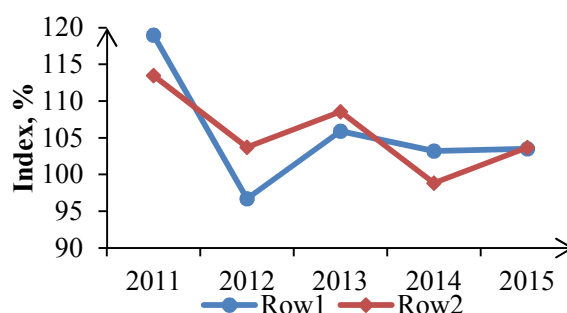


Figure 4. Integral indicator characterizing the dynamics of production volumes in rural farm and level of labor productivity, points: Row 1 – baseline information factor X_{13} . Row 2 is a geometric interpretation of a mathematical model.

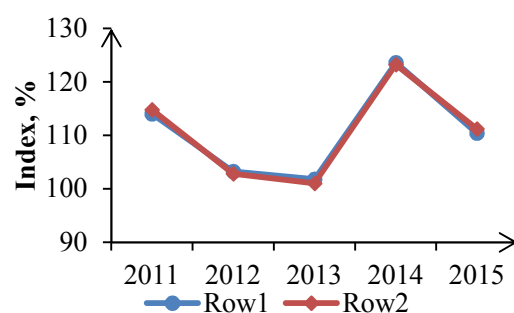


Figure 5. Integral indicator of change of the economic conditions in agriculture, points: Row 1 – baseline information factor X_{15} . Row 2 is a geometric interpretation of a mathematical model.

Based on the obtained point forecasts of factors, we can calculate the point forecast for the multifactor model $Y_{forecast} = 106.9802$. Then, based on the analysis of variance [19], we obtain the confidence interval of the predicted value of the multivariate model.

$$106.9695 \leq Y_{forecast} \leq 106.9909.$$

Summing up, it should be noted that the authors for the first time developed an algorithm for assessing the impact of economic factors on the reproduction of personnel potential in agriculture. The novelty of the development consists in the sequence of the following actions: firstly, on the basis of the PEST analysis and the results of the sociological survey, it was revealed that economic factors are of paramount importance for the reproduction of personnel potential in agriculture; secondly, a sample is formed, identified by means of correlation and regression analysis, of the most significant criteria for calculating their impact on the rate of reproduction of personnel potential in agriculture, which are reduced to an index value; thirdly, the first multifactor model was built on their basis and the interfactor correlation relationship between them was analyzed; fourthly, after eliminating multicollinearity between factors, an optimal multiple model is constructed on the basis of the theory of multivariate regression. To obtain a point forecast for it, preliminary calculations of a point forecast for each factor of this model have been carried out; the information of each factor was considered as a time series (the additive structure of time series and the processing technology based on the moving average method were chosen); an indicator of the quality of the models and the confidence interval of the predicted value of the multifactor model are calculated on the basis of analysis of variance.

It should also be emphasized that the reproduction of personnel potential in agriculture is determined by the conditions under which, how and where, its consumption and use occurs. Based on the constructed mathematical models, it is proved that the essential economic factors affecting the index of change in the indicator of reproduction of the personnel indicator in the industry are: the index of the degree of depreciation of fixed assets of agriculture; livestock and poultry livestock index; an integral indicator characterizing the dynamics of production volumes in agriculture and the level of labor productivity.

So, with a change in the index of the degree of depreciation of fixed assets of the agricultural sector of the Russia in 2015 - by 98.6%, livestock and poultry – by 104.0%, the integral indicator characterizing the dynamics of production volumes in the industry and the level of labor productivity - by 103.5%, the integral indicator of changes in economic conditions in agriculture - by 110, 4%, the index of changes in the reproduction of the personnel potential was 103.2%. In 2014 the index of the integral indicator of changes in economic conditions in agriculture in Russia was 123.6%, while the index of reproduction of the personnel potential in the industry changed by 117.1%. That is, there is a direct correlation between the level of development of economic factors in agriculture and the rate of reproduction of personnel potential in the industry; with a decrease in the first in 2015 in comparison with 2014 by 13.2 p.p., the second one has decreased over the given period - by 13.9 p.p. Accordingly, you can track this process in the opposite direction (for 2013-2014). This proves that the proposed methodology allows an objective assessment of the influence of economic factors on the reproduction of personnel potential in agriculture of the Russia and is one of the grounds for legislative and executive authorities in the development of socio-economic projects and programs.

5. Conclusion

Thus, the algorithm we developed is a unique tool for translating qualitative values of factors into quantitative ones, which was done for the first time in modern science. It is a universal and accurate means of predicting the onset of various stages of reproduction for the next period and has great potential for further research. With its help it is possible not only to assess the influence of economic, social, technical, political and other factors on the reproduction of personnel potential in agriculture, but also to manage its stages, combining the necessary combinations of factors. That is, the calculation method takes into account the possibility of not only taking into account the qualitative values of factors, but also the personnel resource, namely, taking into account the achieved and probabilistic potential of agricultural workers, which was also done for the first time.

References

- [1] Ivanova T V 2018 System management of the reproduction of personnel potential in agriculture (Cheboksary: Chuvash University) p 362
- [2] Anderson J R and J L Dillon 1989 International agricultural research systems. *Agr. Econ.* **3(4)** 257
- [3] Rodgers J L 1994 Differential human capital and structural evolution in agriculture. *Agr. Econ.* **11(1)** 1
- [4] Shariff I 1998 World agricultural development – the paradox of human organization *Agr. Econ.* **18** 209
- [5] Huffman W E 2001 Human capital: education and agriculture in *Handbook of Agricultural Economics* (Amsterdam: Elsevier) vol 1 Chapter 07 pp 333-381
- [6] Taylor J E and Martin P L 2001 Human capital: migration and rural population change in *Handbook of Agricultural Economics* (Amsterdam, Elsevier) vol 1 chapter 9 pp 457-511
- [7] Huffman W E and Orazem P F 2007 Agriculture and Human Capital in Economic Growth: Farmers, Schooling and Nutrition in *Handbook of Agricultural Economics* (Amsterdam, Elsevier) vol 3 chapter 9 pp 2281-2231
- [8] Vasilevska D 2015 Education as a factor in the development of human capital: case of Latvia *Universal Journal of Management* **3(2)** 79 doi: 10.13189/ujm.2015.030205
- [9] Musaeva F, Gulaliev M and Alyshova Ch 2016 Assessing the relationship between human capital and some macroeconomic indicators in Azerbaijan *Human Capital and Professional Education* **2(18)** 28
- [10] Bulkhaierova Z S, Alenova K T, Nukesheva A Z and Ismailova A S 2016 Assessment of human capital in the agricultural enterprises of the Republic of Kazakhstan *International Journal of Economics and Financial Issues* **6(S5)** 53
- [11] Orlov V N, Ivanova T V, Arkhipova V A and Ivanitskaya I P 2019 Assessment of the influence of social factors on reproduction of personnel potential in agriculture of Russia *E3S Web of Conferences* **110** 02143 doi.org/10.1051/e3sconf/201911002143
- [12] Website of the Federal State Statistics Service. Agriculture, hunting and hunting, forestry in Russia: Stat. Comp. (Electronic Materials) 2019 <http://www.gks.ru>
- [13] Chernetsova N A and Kisileva E B 2016 *Agro-industrial Complex in the Russian Federation in 2015* (Moscow: RosInformagrotekh) p 706
- [14] Ivanova T V, Orlov V N and Sokolova G N 2017 Methods for assessing personnel potential in agriculture *Economics of Agriculture of Russia* **7** 47
- [15] Ivanova T V and Ivanova A A 2017 *Prac. Int. Conf. Strategies of Modern Scientific Development* (North Charleston: Create Space) pp 46-51
- [16] Taranchuk V B New computer technologies, analysis and interpretation of geodata *MATEC Web of Conferences* **251** 04059 doi: <https://doi.org/10.1051/matecconf/201825104059>
- [17] Kameneva S A and Boriskina I P 2016 Mathematical models in economy *Vestnik of Volzhsky University named V.N. Tatischev* **2(2)** 25
- [18] Skabelkin E V and Yurochkin A I 2016 Economic and mathematical modeling of production processes in agriculture *Young scientist* **6(3)** 36
- [19] Orlov V N 2014 On one variant of the confidence interval of the predicted value of a mathematical model. *Bulletin of the RSSU (Branch of the city of Cheboksary)* **30** 128