A STATISTICAL APPROACH TO ANALYZING THE EFFICIENCY OF AGRICULTURAL PRODUCTION: THE EXAMPLE OF CENTRAL RUSSIA

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The article presents the analysis of indicators of agricultural output in Central Russia during the period from 2000 to 2014. Time series of output in current prices are approximated by exponential model and evaluated by the method of least squares (estimated value of production output in 2014 and its rate of increment). The dynamics of the consumer price index of agricultural production in the Central Russia can be as well analyzed by exponential models and their estimations. The increment rate of agriculture output and the CPI correlate negatively. The agricultural producer price index can therefore be a valuable indicator of the regional rural economy level.

Keywords: regions of the Central Federal District, agricultural production, agricultural output, time series, current prices, exponential models, least squares estimation, consumer price index, increment rate, correlation

The following article discusses the issue of statistical analysis of agricultural economics of the Central Federal District (CFD) in Russia. Value index of agricultural production expressed in current prices serves as basis indicator. Data on the regions of the CFD over the period of 2000–2014 published in statistical collections of Rosstat is the empirical basis, whereas the SPSS software Base 8.0 for Windows is a toolkit for the analysis [1].

The question of agricultural efficiency is a subject for many an articles. For instance, the publication [3] has a review of studies on the theme and clarifies a set of questions and problems dealing with efficiency growth in the agrarian sector of Russian economy. In [2] the authors highlight the overall importance of quality methods and complex researches in the field of actual agricultural economics. Thus the significance of precise agricultural output estimation is a concern of a vast number of authors, so that factor defines the high level of actuality of the theme of agricultural efficiency.

This research logically continues the article [7] and develops the study proposed in it. The present article is based on the analysis of panel data, i.e. spatial selections presented in a form of time series. Analysis of this type of data is of remarkable interest, because it allows us not only to estimate growth rates of agricultural output, but also to perform a regional comparison. We decided to use the innovatory methodological approach for analysis of panel data proposed in [6], which has the following stages:

1) organization of time series of three indicators (agricultural production value index, consumer price index (CPI), and agricultural output index, further referred as indicators 1, 2, and 3 respectively) for all the regions of the CFD over the period of 2000–2014; this lets us analyze the time impact and tendencies;

2) approximate the panel data with the help of two-parameter models (exponential, hyperbolic, parabolic ones according to the character of indicator's dynamics);

3) use the OLS-estimations of the parameters of the aforementioned models for further analysis of dynamics in different regions, thus analyzing the spatial tendency. Such type of approach saves the visibility, which is crucially important for an adequate analysis of efficiency, and hence it is an appropriate method of analyzing the processes of agricultural output in other regions.

We aim to verify if the following models can be used for analysis of agricultural production efficiency, so an analysis of the regions of the CFD has been preformed as an example for the approach.

The dynamics of agricultural output expressed in current prices are characterized by accelerated growth. This pattern of dynamics corresponds to an exponential model

$$AO = b_0\exp(b_1 t), \quad (1)$$

where AO stands for agricultural output, and t – a time variable. This model can take nonpositive values of the time variable, so as far as we are interested the indicator's value of the final year of the time span (2014), we define the time variable as follows

$$t = \text{year} - 2014. \quad (2)$$

According to (2), the final year of the analyzed period corresponds to the value $t = 0$, thus we can interpret the parameter b_0 as the estimated value of production volume in 2014, and the parameter $100b_1$ – as the average annual increment rate.

The results of approximation of dynamics of agricultural production value index, consumer price index, and agricultural producer price indices in both the Central Federal district and the Russian Federation by exponential models are demonstrated in the Table, where they are represented by their OLS estimations. Furthermore, all the three indicators have similar dynamics; this fact confirms the adequacy of the prerequisite for using them for analysis.

dency. Among the other regions Bryansk, Kaluga, Oryol, and Ryazan oblasts have the increment rates close to national average. Thereby we can distinguish and characterize six typological syndromes (term and concept proposed by mathematician and sociologist G.G. Tatarova [8]).

Parameters of exponential models of dynamics of agricultural production value index (indicator 1), fixed base consumer price index (indicator 2), and fixed base agricultural producer price index (indicator 3) over the period of 2000–2014

Region	OLS-estimation of the indicator 1		OLS-estimation of the indicator 2		OLS-estimation of the indicator 3	
	Calculated value in 2014, mln RUB	Increment coefficient	Calculated value in 2014, %	Increment coefficient	Calculated value in 2014	Increment coefficient
Belgorod obl.	209016	0,1928	489,7	0,0568	3,66	0,0841
Bryansk obl.	46246	0,1239	527,3	0,0638	3,90	0,0856
Vladimir obl.	32456	0,1064	504,5	0,0616	5,44	0,1146
Voronezh obl.	158312	0,1602	477,5	0,0549	5,20	0,1089
Ivanovo obl.	15900	0,0968	524,3	0,0659	4,80	0,1039
Kaluga obl.	33418	0,1198	542,9	0,0695	4,90	0,1064
Kostroma obl.	19572	0,0922	507,6	0,0637	4,37	0,0949
Kursk obl.	88319	0,1464	548,4	0,0551	5,37	0,1138
Lipetsk obl.	76532	0,1444	482,4	0,0544	3,75	0,0877
Moscow obl.	106181	0,1047	505,9	0,0588	4,57	0,0970
Oryol obl.	48645	0,1248	453,6	0,0622	5,80	0,1241
Ryazan obl.	45003	0,1180	497,0	0,0641	4,94	0,1117
Smolensk obl.	22337	0,0958	543,4	0,0619	5,84	0,1213
Tambov obl.	82650	0,1564	462,9	0,0610	3,58	0,0846
Tver obl.	25318	0,0853	479,6	0,0592	4,69	0,1042
Tula obl.	42512	0,1043	543,3	0,0628	4,46	0,1012
Yaroslavl obl.	28698	0,1040	531,8	0,0652	4,14	0,0928
RUSSIA	4456340	0,1254	475,2	0,0614	4,84	0,1056

All the exponential models of the first indicator are characterized by high values of quality criteria: they are adequate (statistical significance of F-test does not exceed 0,0005) and explain from 93,6 to 99,1 % of common variance. The parameters of the exponential models of agricultural productivity correlate positively, the Pearson sample correlation coefficient $R = 0,864$ is statistically significant on the p-level $< 0,0005$.

The trend shows that the parameters of the models change proportionally to each other. Against this background that three regions are excelling from the others – Belgorod, Voronezh, and Moscow oblast have leader places in rankings by both parameters. Kursk, Tambov, and Lipetsk oblasts belong to the regions of the prevailing ten-

Further study of the regional groups was performed with hierarchical cluster analysis (HCA) with the Ward's method with squared Euclidean distance and z-scores of the variables [4]. There are six clusters on the level of similarity 95 %, three of them comprise one region (Belgorod, Voronezh, and Moscow oblasts), while the others are identical to the aforementioned typical syndromes. Iterative k-means cluster analysis with $k = 6$ (a number of clusters) showed two discrepancies (for Vladimir and Tula oblasts). Nevertheless, these discrepancies are minor, and relation «match/mismatch» is equal to 15/2, so that it is possible to accept the results of hierarchical cluster analysis.

It is noteworthy that the scatter of average annual increment rates of agricultural output is considerable (minimum – 8,5 % in Tver oblast, maximum – 19,3 % in Belgorod oblast). Even if the truncated series is analyzed (without the leader – Belgorod oblast), the coefficient of variation is equal to 19,8 %. This fact indicates the high information level of the parameter.

The above-mentioned in Table estimations of average annual increment rates of agricultural output expressed in current prices include an inflation impact; therefore it is necessary to compare them with those of inflation indices, which notably differ in regions. In the publication [5] discussing the analysis of inflation processes in Central Russia, a relatively high variability of regional inflation indices was revealed: coefficient of variation of food component was equal to 4,7 %, that of non-food component was equal to 9,0 %, and that of tariff component – to 13,4 %; whilst the overall coefficient of variation was equal to 5,0 %.

These estimations refer to the period of 2008–2011, whereas the study of dynamics of agricultural output in the CFD regions covers the period to 2014, thereat the modeling of base inflation indicator – consumer prices index (CPI) – has been prolonged for the period from 2000 to 2014. The following stages have been performed for the modeling: firstly, the chain indices of inflation process (in percentage to December of the previous year) were substituted by the fixed base indices (in percentage to December of the basis year, 1999), thereafter the time series were approximated by models of the same type.

The dynamics of chain CPIs for the Russian Federation is clearly cyclical: during the period 2000–2006 inflation was decreasing by about 10 % in total, then it was growing to its local maximum in 2008, afterwards it was again decreasing up to 2011, after a period of stability from 2011 to 2013 a new cycle of inflation growth began.

The dynamics of time series of fixed base inflation indices is more «smooth», their cycle changes are expressed correspondingly to the rates of change of the indicators. In consideration of the characteristics of dynamics of fixed base CPIs, the authors accept the time span 2000–2014 for the modeling.

During the process of modeling with the statistical procedure *Curve Estimation* of the software *SPSS* we found out that the dynamics of base CPIs over the period 2000–2014 could be described with high degree of precision by exponential models: the coefficient of determination demonstrated that the models explained from 98,1 to 100,0 % of common variance, statistical significance of *F*-test (*p*-level) of all the models is not more than 0,0005 (with the exception of a model for Voronezh oblast, which's *p*-value is equal to 0,001). The coefficients of these models can be seen in the Table (indicator 2).

All the exponential models are adequate, they explain from 98,1 to 100,0 % of common variance. This lets interpret the parameter b_0 as the estimated value of consumer prices in 2014 (in percentage to December 1999), and the parameter $100b_1$ – as the average annual inflation level.

The analysis demonstrated the high level of variability of the indicators: inflation rate varied from the minimum value 5,44 % in Lipetsk oblast to the maximal one 6,95 % in Kaluga oblast; CPI – from the minimal 453,6 % in Oryol oblast to the maximal 548,4 % in Kursk oblast.

The obtained results make it possible to correct the previously calculated estimation of the average annual increment rate of agricultural output in the regions of the CFD. It is clearly seen that considering of inflation process hasn't affected the regional agricultural output ranking – meanwhile leaders and outsiders remained the same, several ranks were changed only in the middle of the ranking list of the regions.

Comparison of average annual agricultural output increment rates with consumer price indices in the CFD regions shows a negative dependence of the ranks – if inflation rate grows, increment rate of agricultural output decreases. This tendency is verified by correlation analysis: there was a statistically significant correlation between the two indicators with the Pearson sample correlation coefficient equal to $R = -0{,}642$.

The article [5] discusses territorial consumer price indices on the example of the CFD and indicates that they are mainly influenced by food component, secondly – non-food component, thirdly, CPIs are defined by changes of tariffs and service costs. Non-food and goods inflation is also defined by producers' prices of agricultural production, so that it is important to analyze the dynamics of producers' prices of agricultural production in the regions of the CFD.

The similar method of analysis is used for the period 2000–2014; firstly we calculated fixed base agricultural producer price indices, then performed an approximation of the time data with the procedure *Curve Estimation* of the software package *SPSS.*

Time series of fixed base agricultural producer price indices both in the regions of the CFD and in Russia over the period

2000–2014 can be approximated by exponential models (1). Their OLS-estimations are shown in the Table (indicator 3).

All the exponential models of dynamics are adequate and statistically significant on the p-level < 0,0005; they explain from 94,4 to 98,6 % of common variance. This lets us interpret the parameter b_0 as the estimated value of base agricultural producer price indices in 2014 to the level of 2000; the parameter $100b_1$ – as its average annual increase rate.

The next part of our study is the analysis of spatial tendencies and comparison of the models' parameters with the regions of the CFD serving as the units of analysis.

The ranking of the CFD regions according to the parameters of exponential models of agricultural producer price dynamics and its increment rate unveiled a positive correlation between the two parameters. Belgorod, Tambov, Bryansk, Lipetsk, Yaroslavl oblasts are the leaders in both rankings (price index and its increment rate), and, opposite to them, Oryol, Kursk, Smolensk, and Vladimir oblasts are characterized by notably lesser level of dynamics of these indicators. If we compare the rankings by producer prices growth and by rate of increment of agricultural production, we can notice a negative correlation (the less is the level of producer prices, the more is its increment rate).

However, correlation between these parameters appears only as a tendency: the Pearson sample correlation coefficient $R = -0{,}339$ is statistically significant on a one-tailed p-level equal to 0,092 (or 9,2 %), consequently the risk of accepting this tendency as a statistically significant fact exceeds the normative barrier of 5 %. It is more soundly to identify the regions according to the parameters of financial indicators. It can potentially be performed by comparison of the marks of a region with that of the national level.

From the conducted research on the example of the CFD we deduce the fact that agricultural producer price indices estimated with the help of the proposed methodology can be employed as an indicator of the level of regional agriculture management. The analysis of other regions with this model will be the subject of our forthcoming publications.

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