The Influence of Technical Efficiency and Weather Risk on Crop Production in Russian Agriculture

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Abstract. Over the last years due to macroeconomic and domestic policy factors in Russian agriculture and in plant growing in particular, there have been significant changes resulting in expansion of production and increased efficiency in productive capacity use. The issue of influence power of factors of the agricultural producers efficiency remains open; and the factors related to technical efficiency are of the outstanding interest. However, under determining influence of the weather factor on the crop production output it is necessary to differentiate between the influence of weather risk and technical efficiency changes. The Stochastic Frontier Analysis (SFA) was applied by researchers at different times for technical efficiency evaluating of agricultural production in Russia at the level of regions and at the farm level. However, these studies were conducted for the transition period of the Russian economy in the 1990s and early 2000s, as well as for the post-crisis period of 2008-2012. Therefore, the analysis of trends developed over the recent years is of scientific and practical interest. This paper introduces the research findings in technical efficiency of agricultural producers with its key factors detecting for the period of 2011-2017, using SFA with variables reflecting the weather risk. The technical efficiency of agricultural producers in Saratov region, specializing in grain, was chosen as a research target due to their high share in the total number of farm units. According to the specified feature, 396 farms were included into sampling, the activity analysis of which was carried out for the period of 2011-2017.

1. Introduction
Despite the positive changes of recent years in Russian agricultural sector which have taken place and resulted in the productivity progress of particular products types, a number of systemic issues still remains, primarily due to the low effectiveness of using resources and the insufficient level of technological support of production process. These facts prevent from balancing the endogenous and exogenous industry related factors and appear to be crucial for supporting sustainable processing of crop production.

The period between the years 2012 and 2017 is characterized by sustainable growth of grain and oilseeds production (Figure 1), which is largely due to the crop yields improving. As a result, grain production in 2016 exceeded the level of 1990 for the first time. However, the conditions of 2018 (weather conditions among them) adversely affected the gross yield of grain which again fell below the crop yield of 1990.
The indicated period of stable growth in grain production could be due to favorable weather conditions and low production risks, as well as the progressive technological change of the industry, which ensured the crop yield growth. However, gross output reducing in 2018 which stopped the positive trend, suggests maintaining high volatility of crop yields and output of products instability. This forms the basis for assuming that a high level of production risk remains and it cannot be properly reduced by technical and technological means available to agricultural producers.

To confirm or refute this assumption, it is necessary to find out due to what factors the productivity progress has been ensured in recent years and whether the technological change of the industry, increase of technical efficiency or favorable weather conditions and low production risks take a leading role in this process.

In this connection, this paper is aimed to study the growth trend setters as well as factors determining the grain production volatility in Russian agricultural sector exemplified by the Saratov Region using the approach based on the Stochastic Frontier Analysis (SFA).

2. Literature Review
The major task of managing business entities is to increase their activities efficiency. The development of approaches to the concept of efficiency in the middle of the last century was explored in the works of Debreu (1951) [2], Koopmans (1951) [3], Farrell (1957) [4], whose names are associated with the development of the production possibility frontier and technical efficiency concepts. Seeing the problem of measuring the productive efficiency in the choice of a base for comparing the calculated ratios of inputs and outputs of a specified object from what the evaluations result depended significantly, Farrell indicated the possibility to evaluate the effectiveness, comparing the observed performance of a firm with some postulated standard of perfect efficiency. Technical efficiency in this case is success in producing as large as possible an output from a given set of inputs [4] or the ratio of actual productivity to the greatest possible. The peak output corresponds to the efficiency production function, which reflects the frontier of production capabilities. If the value of the enterprise’s products output lies on the curve, then the ratio between the actual and maximum productivity is 1. If the actual output does not match the production possibility frontier, technical efficiency has lower values, ranging from 0 to 1.
Thus, Farrell contributed to a change in views on the production functions study, shifting the focus from factor productivity analysis to deviations from it and the development of appropriate models and estimation methods. By now, a large number of models for technical efficiency valuating have been developed using the apparatus of deterministic and stochastic production functions.

The conceptual idea of stochastic frontier production function has been independently developed by Aigner at all (1977) [5] and Meeussen and Van den Broeck (1977) [6].

According to Aigner at all (1977) in the frontier production function

$$y_i = f(x_i; \alpha) + \varepsilon_i \quad i = 1, ..., N ,$$

(1) where $y_i$ is the maximum output of $i$th firm obtainable from $x_i$, a vector of (non-stochastic) inputs, and $\alpha$ is an unknown parameter vector to be estimated, error structure is written as:

$$\varepsilon_i = v_i + u_i \quad (u_i \leq 0) .$$

(2)

The non-positive disturbance $u_i$ reflects the fact that each firm’s output must lie on or below its frontier. But the frontier itself can vary randomly across firms, or over time for the same firm. The frontier is stochastic, with random disturbance $v_i$ being the result of favorable as well as unfavorable external events such as luck, climate, topography, and machine performance (Aigner at all, 1977) [5]. The developed approach is called Stochastic Frontier Approach (SFA).

It is expected that an inefficiency term $u_i$ has unsymmetrical distribution (half normal or truncated above at zero), whereas $v_i$ has normal distribution $N(0, \sigma^2_v)$. The error components are distributed independently.

In any economic activity and production process risk plays an important role, the level of risk in agriculture is especially high. Based on the statement that production risk is measured by output variation, Just and Pope (1978) [7] devised a production function specification that takes into account production risk. The key feature of this specification was the assumption that inputs can be either risk-increasing or risk-decreasing. Accordingly, the production function should combine two functions – the one, reflecting the influence of inputs on the mean of output, and the second, reflecting the influence of inputs on the variance of the output:

$$y_i = f(x_i; \alpha) + g(x_i; \beta)v_i ,$$

(3) where, $f(x_i; \alpha)$ is the mean production function and $g(x_i; \beta)$ is the variance production function (published according to Bokusheva and Hockmann, 2006 [8]).

Further development of SFA models followed the path of using more general types of the inefficiency term distribution, cost function modeling, panel data estimation methods developing (Battese, 1989 [9], Kumbhakar and Lovell, 2004 [10]).

Further works by Battese and Coelli described two approaches to technical efficiency factors estimation: the first, which consists of two stages – estimate of the production function parameters and the subsequent estimate of technical efficiency factors (Battese and Coelli, 1992 [11]); and the second is the technical efficiency factors estimation simultaneously with the production function construction (Battese and Coelli, 1995 [12]).

Kumbhakar devised a generalized additive model:

$$y = f(x; \alpha) + g(x; \beta)v - q(x; \gamma)u ,$$

(4) in which $g(x; \beta)$ is the (production) risk function and the $q(x; \gamma)$ function explains technical inefficiency. Depending on the choice of the $q(x; \gamma)$ function, the model (4) can be transformed to its special cases.

At different times, the attempts to study the technical efficiency of Russian agriculture, among them using the SFA, were made. Sotnikov (1998) [13] and Sedik et al. (1999) [14] estimated the regional rates of technical efficiency. Studies have shown a decrease in technical efficiency for the
period 1991–1995. Voigt (2002) [15], evaluating the technical efficiency of agriculture in 75 regions, did not find significant changes at the national level for the period 1993–2000. A number of publications is devoted to technical efficiency estimating at the goods producers level. For example, Bezlepkina (2004) [16] studied technical efficiency of dairy farms in the Moscow Region from 1996 to 2000, Bokusheva and Hockmann (2006) [8] investigated production risk and technical inefficiency of large agricultural enterprises from Oryol, Krasnodar and Samara Regions from 1996 to 2001. The results of both studies indicate an increase in the technical efficiency. Moreover, Bokusheva and Hockmann (2006) remarked that production risk contributes considerably to the volatility of Russian agricultural production. Hockmann and Gataulina (2012) [17] analyzed implication of risk and technical efficiency to production of Tatarstan agricultural enterprises for the period 2006–2008. The estimates provided that risk is more relevant for the variation of production than inefficiency. Ponkina and Kurochkin (2014) [18] evaluated technical efficiency in crop production of Altai Region farms for 2008–2012 and revealed factors that affect the technical efficiency in crop production: size of the sown land, grain yields and legume crops, number of workers employed in a farm, age of a farm head, and type of ownership.

The above-mentioned research was conducted for the transition period of the Russian economy in the 1990s and early 2000s, as well as for the post-crisis period of 2008–2012. Therefore, the analysis of trends developed over the recent years is of scientific and practical interest.

3. Estimation Procedure

In this study the model specifications applied by Bokusheva and Hockmann (2006) and based on the extended Kumbhakar model (4) is used. This model appeals to input variables, a trend variable that enables the technological change rate to be estimated, dummy variables for the conditions evaluation of an individual year (Bokusheva and Hockmann, 2006 [8]):

\[ y_{it} = f(x_i; \alpha) + \exp(\mathbf{D} \beta_i) g(x_i; \gamma) u_{it}, \]

where \( i = 1,\ldots,N \) denotes farm, \( t = 1,\ldots,T \) denotes the time period, \( g(x_i; \gamma) u_{it} \) represents the idiosyncratic component of production risk, vector \( \mathbf{D} \) consists of dummy variables and captures systemic production risk.

In this study two types of the mean production function are considered: Cobb-Douglas production function and Translog production function.

Thus, the model parameters estimation and obtaining individual values of technical efficiency was carried out on the basis of application of Cobb-Douglas and Translog production frontier with non-constant and non-neutral technological change and time-variant individual efficiencies.

4. Data

The sample included grain-crops growing farms of the Saratov Region. The total number of farms in the sample made 396, including farms relevant to different types of legal entity and differ in the cropland acres.

The study period covers 2011–2017. It should be noted that during the indicated period there were circumstances that could potentially affect the technical efficiency of grain production, the production risk of farms and the general trends in the technological change of farming industry.

Such circumstances can include the drought seasons of 2012 and 2015, a significant ruble depreciation in 2014–2015, decreased access to credit resources due to sanction restrictions in the financial sector and, in general, the deteriorating economic environment in the country, the start of the State Program for Development of Agriculture and Regulation of Agricultural Commodity Markets for 2013–2020 [19] in 2013 which changed many of the principles of state support providing.

For sampling the data of accounting (finance) statements and industry specific report forms have been used. There are some cases, where facts of data missing or its incorrect presentation of some farms for certain periods without being included into population of analysis have been identified. As
a result, an unbalanced panel data including information on 396 farms with a total number of 2354 observations for the period of 2011–2017 has been formed.

The produced quantity of grain ($Y$) was used as a measure of output. The fixed-capital assets charges aggregating depreciation, repair costs and expenses for fuels and lubricants ($Capital$), labor costs ($Labor$), seed costs ($Seed$), fertilizer costs ($Fertilizer$), as well as sown land ($Land$) have been placed into the model as factors and a proxy for inputs. All cost indicators are in rubles.

Material costs were adjusted to the level of 2011 by using price indices for manufactured goods and services purchased by farm organizations, annually calculated and published by the Russian Federal State Statistics Service (Rosstat) [20, 21]. Labor costs were adjusted for the calculated values of the nominal wage indices, calculated according to the average monthly nominal wage in agricultural sector of the Saratov Region [22].

Summary statistics of these variables are given in Table 1.

| Variable                                | Minimum | Mean   | Maximum    | Standard deviation | Variation coefficient |
|-----------------------------------------|---------|--------|------------|--------------------|----------------------|
| 2011, number of observation – 314       |         |        |            |                    |                      |
| Grain production, hwt                   | 28.00   | 29420.79 | 536574.00 | 46864.14           | 1.59                 |
| Sown land, ha                          | 24.00   | 2725.34 | 53120.00  | 4266.79            | 0.64                 |
| Fixed-capital assets charges, thousand rubles | 2.24   | 3886.86 | 103440.96 | 8310.14            | 0.47                 |
| Labor costs, thousand rubles           | 12.36   | 2296.51 | 44821.28  | 4438.25            | 0.52                 |
| Seed costs, thousand rubles            | 21.28   | 3159.19 | 55786.00  | 5779.84            | 0.55                 |
| Fertilizer costs, thousand rubles      | 0.00    | 370.83  | 13100.64  | 1411.13            | 0.26                 |
| 2012, number of observation – 329       |         |        |            |                    |                      |
| Grain production, hwt                   | 160.00  | 33868.67 | 542302.00 | 51639.15           | 1.52                 |
| Sown land, ha                          | 25.00   | 3484.77 | 85485.00  | 6277.65            | 0.56                 |
| Fixed-capital assets charges, thousand rubles | 5.95   | 5041.97 | 66837.01  | 8043.34            | 0.63                 |
| Labor costs, thousand rubles           | 13.08   | 3126.83 | 45265.33  | 5273.66            | 0.59                 |
| Seed costs, thousand rubles            | 17.65   | 3421.77 | 67258.07  | 5493.21            | 0.62                 |
| Fertilizer costs, thousand rubles      | 0.00    | 403.15  | 6842.85   | 1103.94            | 0.37                 |
| 2013, number of observation – 325       |         |        |            |                    |                      |
| Grain production, hwt                   | 340.00  | 39782.00 | 472627.00 | 49463.62           | 1.24                 |
| Sown land, ha                          | 14.00   | 3225.52 | 79255.00  | 6271.73            | 0.51                 |
| Fixed-capital assets charges, thousand rubles | 3.93   | 6197.45 | 92437.33  | 10300.28           | 0.60                 |
| Labor costs, thousand rubles           | 19.63   | 3159.24 | 56908.16  | 5315.01            | 0.59                 |
| Seed costs, thousand rubles            | 20.93   | 4047.89 | 55048.95  | 6277.95            | 0.64                 |
| Fertilizer costs, thousand rubles      | 0.00    | 596.73  | 23332.41  | 2125.86            | 0.28                 |
| 2014, number of observation – 332       |         |        |            |                    |                      |
| Grain production, hwt                   | 340.00  | 49307.48 | 1132610.00 | 87572.53           | 1.78                 |
| Sown land, ha                          | 20.00   | 2822.60 | 70792.00  | 5308.87            | 0.53                 |
| Fixed-capital assets charges, thousand rubles | 6.86   | 8726.44 | 250656.99 | 22015.57           | 0.40                 |
| Labor costs, thousand rubles           | 32.91   | 4463.99 | 162303.22 | 10969.05           | 0.41                 |
| Seed costs, thousand rubles            | 31.54   | 4036.65 | 74278.54  | 7233.53            | 0.56                 |
| Fertilizer costs, thousand rubles      | 0.00    | 717.52  | 20299.04  | 2013.53            | 0.36                 |
Table 1.

| Variable                                      | Minimum | Mean   | Maximum  | Standard deviation | Variation coefficient |
|-----------------------------------------------|---------|--------|----------|-------------------|------------------------|
| **2015, number of observation – 348**         |         |        |          |                   |                        |
| Grain production, hwt                         | 124.00  | 27721.50 | 407495.00 | 45834.56          | 1.65                   |
| Sown land, ha                                | 17.00   | 2825.70 | 65775.00 | 4946.63           | 0.57                   |
| Fixed-capital assets charges, thousand rubles| 3.17    | 8096.37 | 262648.93 | 19725.33          | 0.41                   |
| Labor costs, thousand rubles                 | 26.92   | 5820.37 | 228787.41 | 16161.50          | 0.36                   |
| Seed costs, thousand rubles                  | 9.50    | 4171.61 | 74457.03 | 6806.42           | 0.61                   |
| Fertilizer costs, thousand rubles            | 0.00    | 1155.21 | 42948.91 | 3986.05           | 0.29                   |
| **2016, number of observation – 365**         |         |        |          |                   |                        |
| Grain production, hwt                         | 241.00  | 49991.45 | 981132.00 | 86541.35          | 1.73                   |
| Sown land, ha                                | 22.00   | 2552.32 | 64306.00 | 4741.97           | 0.54                   |
| Fixed-capital assets charges, thousand rubles| 13.23   | 12354.33 | 356789.71 | 28697.37          | 0.43                   |
| Labor costs, thousand rubles                 | 26.45   | 5743.06 | 255579.89 | 15129.74          | 0.38                   |
| Seed costs, thousand rubles                  | 29.76   | 5866.36 | 140000.33 | 12396.21          | 0.47                   |
| Fertilizer costs, thousand rubles            | 0.00    | 1679.63 | 82060.10 | 6207.11           | 0.27                   |
| **2017, number of observation – 341**         |         |        |          |                   |                        |
| Grain production, hwt                         | 460.00  | 73953.60 | 1748029.00 | 132904.57         | 1.80                   |
| Sown land, ha                                | 15.00   | 2870.66 | 68293.00 | 5152.75           | 0.56                   |
| Fixed-capital assets charges, thousand rubles| 10.22   | 13295.38 | 356350.63 | 30236.20          | 0.44                   |
| Labor costs, thousand rubles                 | 34.06   | 8579.40 | 374933.83 | 23667.71          | 0.36                   |
| Seed costs, thousand rubles                  | 28.95   | 6810.38 | 115584.73 | 12614.63          | 0.54                   |
| Fertilizer costs, thousand rubles            | 0.00    | 1965.13 | 33622.45 | 4911.37           | 0.40                   |

Source: Authors’ calculations

Over the study period there was observed a fairly buoyant growth in grain productivity (with the exception of 2015) – from 29 to 74 ths hwt by an average of one farm. Therein, the cropped lands did not show sustainable rate, falling within the limits of 2.5–2.8 ths ha and exceeding 3.0 ths ha only in 2012 and 2013. Therefore, the average grain productivity in sampling and, accordingly, plough land productivity, increased. A single output decline in 2015 reflects prevailing unfavorable weather conditions. This is also evidenced by the ratio of productivity progress and sown area in 2011–2012: the average gross output increased by 15 % and the average sown area by 61 %. It follows that the crop yield was significantly far below the expected value.

The average values of costs increased throughout the period, which reflects the growth in volumes and quality changes in the resources expended, taking into account indexing the specified rates. Thus, in sampling the average fixed-capital assets charges increased by 242 %, labor costs by 274 %, seed costs did not grow at such a high rate (the growth made 116 %). One of the most effective ways to tactically increase crop yields without significant investments in modernizing and changing production methods is to use fertilizers. Therefore, taking into consideration the fact that during the years of reform and in the transition period most farms experienced difficulties in production process financing and were unable to fertilize to the extent required, the financial situation improvement caused a considerable increase of the relevant costs. This increasing went up 430 % over the period of 2011–2017.
However, it is noteworthy that enterprises have no fertilizer costs in the category of minimum values. This is due to the insufficient financial resources for the full provision of the operational procedures for individual enterprises.

5. Estimation results
For obtaining a general idea about the relationship of output to inputs, the characteristics of the technological change dynamics in grain production in the Saratov Region, the Cobb-Douglas specification of production function was constructed with a trend variable that accounts for Hicksian neutral technological change. Models are estimated with mean-scaled variables. The function was linearized by taking the natural logarithm on both sides:

\[
\ln(Y_t) = \alpha_0 + \alpha_1 \ln(Land_t) + \alpha_2 \ln(Capital_t) + \alpha_3 \ln(Labor_t) + \alpha_4 \ln(Seed_t) + \\
+ \alpha_5 \ln(Fertilizer_t) + \alpha_6 (Time)
\]

The model estimation was performed in R software environment (R Core Team, 2019 [23]). The results are included in Table 2.

| Table 2. Parameter estimates of the Cobb-Douglas production function with technological change.a. |
| Variable | Estimate | Std. Error |
| Intercept | 0.081301** | 0.030966 |
| Land | 0.499104*** | 0.026602 |
| Capital | 0.232094*** | 0.014718 |
| Labor | 0.138870*** | 0.015534 |
| Seed | 0.108389*** | 0.018447 |
| Fertilizer | 0.012992*** | 0.002020 |
| Time | 0.043125*** | 0.008593 |

aSignificance codes: *** – 0.001, ** – 0.01.

Source: Authors' calculations

The derived estimates of the model parameters are statistically significant, adjusted $R^2 = 0.79$, residual standard error – 0.65, p-value of F-statistic – <0.001. Taking the specification into account, the model coefficients are output elasticities characterizing the marginal productivity of individual factors or the degree of their influence on the change in the resulting indicator. The size of the sown land wields the most considerable influence on the output – with increase in the size of the sown land by 1.00 %, output increases by 0.50 %. With increase in fixed-capital assets charges and labor costs by 1.00 %, output increases by 0.23 and 0.14 %, respectively.

The variable Time held constant indicates positive technological change in the industry, an estimate of their growth rate is 4.31 % per year. Elasticity of scale is equal to the sum of all output elasticities and almost equal one (0.991449), indicating approximately constant returns to scale.

It has been assumed that the term $\nu$ follows a normal distribution and the inefficiency term $\mu$ follows a positive half-normal or positive truncated normal distribution. This assumption results in a left-skewed distribution of the total error term $\varepsilon = \nu + \mu$. The histogram of the residuals taken from Cobb-Douglas production function is shown in Figure 3. The residuals are left-skewed and skewness is equal –2.85. A negative skewness means that the residuals are left-skewed, and that makes in favor of the hypothesis for the inefficiency error in the model, therefore, not all farms are fully technical efficient (Henningsen, 2015 [24]). Thus, the technical efficiency estimation using SFA seems appropriate.
Figure 2. Residuals of Cobb-Douglas production function.

Source: Authors’ calculations

Model estimations (5) obtained by the maximum likelihood procedure, among them using the package frontier 1.1-2 for the R software environment (Coelli and Henningsen, 2017 [25]), are presented in Table 3.

The parameters of production risk functions and technical inefficiency functions of both specifications have close values, differing in some cases with the significance level; the parameters of mean production functions have differences related to the variables in the Translog function that reflect the combined influence of factors on output.

All the estimated parameters in Cobb-Douglas mean production function are significant, except for the variable associated with seed costs. The most significant factors after the size of the sown land are the fixed-capital assets charges ratio and the labor costs ratio.

Contrary to the Table 1, in the presented models the influence of the size of the sown land on output significantly increases – with an increase in the size of the sown land by 1 %, output increases to 0.76 %; the impact of the fixed-capital assets charges ratio and the labor costs ratio on output is reduced.
Table 3. Parameter estimates of the model a.

| Variable | Cobb-Douglas functional form | Translog functional form |
|----------|------------------------------|--------------------------|
| Intercept | 0.443430 ** ** | 0.468050 ** ** |
| Land     | 0.762700 ** ** | 0.760120 ** ** |
| Capital  | 0.082995 ** ** | 0.008957 ** ** |
| Labor    | 0.044906 ** | 0.058477 * |
| Seed     | 0.009395 | 0.003027 |
| Fertilizer | 0.004522 ** | 0.074641 *** |
| Land × Land | -0.129850 ** |  |
| Capital × Capital | -0.16465 |  |
| Labor × Labor | 0.002845 |  |
| Seed × Seed | 0.024647 ** |  |
| Fertilizer × Fertilizer | 0.008477 *** |  |
| Land × Capital | 0.019780 |  |
| Land × Labor | 0.055638 ** |  |
| Land × Seed | 0.052740 * |  |
| Land × Fertilizer | 0.000479 |  |
| Capital × Labor | -0.019714 |  |
| Capital × Seed | -0.022340 |  |
| Capital × Fertilizer | 0.000139 |  |
| Labor × Seed | -0.039994 ** |  |
| Labor × Fertilizer | 0.001945 |  |
| Seed × Fertilizer | -0.003905 |  |
| Time     | 0.059808 *** | 0.055330 *** |
| Dummy 2011 | -0.457550 ** ** | -0.443310 ** ** |
| Dummy 2012 | -0.501330 ** ** | -0.488980 ** ** |
| Dummy 2013 | -0.168360 ** | -0.175990 ** ** |
| Dummy 2014 | -0.091982 | -0.111320 * |
| Dummy 2015 | -0.771850 ** ** | -0.748100 ** ** |
| Dummy 2016 | -0.259430 ** ** | -0.265490 ** ** |
| Land     | -0.000009 ** | -0.000009 * |
| Capital  | 0.000000 | 0.000002 . |
| Labor    | 0.000001 | 0.000001 |
| Seed     | 0.000000 | 0.000000 |
| Fertilizer | 0.000008 *** | 0.000000 |
| Land     | 0.000415 *** | 0.000287 *** |
| Capital  | -0.000153 *** | -0.000161 *** |
| Labor    | -0.000251 *** | -0.000201 *** |
| Seed     | -0.000221 *** | -0.000081 . |
| Fertilizer | -0.000573 *** | -0.000242 * |
| σ²       | 1.506900 *** | 1.343000 *** |
| γ        | 0.945810 *** | 0.944450 *** |
| σ² wn    | 1.425200 *** | 1.268400 *** |
| σ² v     | 0.081654 *** | 0.074602 *** |
| σ        | 1.227600 *** | 1.158900 *** |
| σ a      | 1.193800 *** | 1.126200 *** |
| σ v      | 0.285750 *** | 0.273130 *** |
| λ²       | 17.455000 *** | 17.003000 *** |
| λ        | 4.177900 *** | 4.123400 *** |

*Significance codes: ** – 0.001, *– 0.01, – 0.05, . – 0.1.
Source: Authors’ calculations

Fertilizer costs increase output to a lesser extent. In our opinion, this trend is a consequence of the fact that during the study period many farms did not apply fertilizers or did not apply much.
Particular coefficients are significant with the parameters reflecting the dependence of the rate of the result increase on the factor: the return on increasing seed costs grows faster than on fertilizer costs; the return on growing sown land grows with decreasing rates.

The variable *Time* indicates a positive trend in changing the production frontier efficiency, the growth rate is 5.98 and 5.53 % per year. This fact indicates increasing output, provided that the amount of inputs remains constant and reflects technological change in the industry.

The model contains two components of production risk: systemic risk, represented by the dummy variables for the individual years, and idiosyncratic risk associated with the individual characteristics of the resources use by a farm. Systemic risk is observed in the farms of the region being investigated in 2011, 2012 and 2015, which is due to the marginal weather conditions of those years for grain growing. In most years of the period the parameters of systemic risk are great in magnitude, which indicates a significant effect on variation, and therefore on production risk. Among the idiosyncratic risk components, two parameters have a significant impact on the production risk level: an increase in the sown land reduces production risk, an increase in the fixed-capital assets charges increases it.

Since the technical inefficiency is the opposite of technical efficiency, negative values of the TI function parameters indicate the positive influence of model factors on the technical efficiency of production. In the model with Cobb-Douglas functional form, as well as in the model with Translog functional form, a negative coefficient value is observed for a variable that reflects the level of fertilizer costs, therefore this factor has the greatest positive effect on technical efficiency.

An estimate of the parameter $\gamma$, which is 0.95, brings us to the conclusion that the influence of inefficiency variables on the grain output is strong.

In the models under consideration, the average values of technical efficiency indicators show an increase over the period of study in the Cobb-Douglas functional form model by 0.15 or 24.8 %, which is 3.5 % per year; in the Translog functional form model – by 0.14 or 22.6 % (3.2 % per year). A noticeable reduction of technical efficiency took place in 2012 and 2015 (Table 4).

|          | 2011   | 2012   | 2013   | 2014   | 2015   | 2016   | 2017   | Mean   |
|----------|--------|--------|--------|--------|--------|--------|--------|--------|
| Cobb-Douglas functional form | 0.6119 | 0.5443 | 0.6655 | 0.7107 | 0.4827 | 0.6742 | 0.7638 | 0.6390 |
| Translog functional form    | 0.6137 | 0.5435 | 0.6619 | 0.7057 | 0.4710 | 0.6594 | 0.7526 | 0.6315 |

*Source: Authors' calculations*

The climate of the Saratov Region is characterized by such dangerous agrometeorological phenomena as frosts, dry hotwinds, atmospheric and soil droughts, and waterlogging of the soil. According to the data of Saratov Center for Hydrometeorology and Environmental Monitoring in the Region, atmospheric and soil droughts, causing the greatest damage to agricultural production, were observed in 2011, 2012, 2015. So, in 2015, as a result of soil drought and in connection with the agricultural crops failure a regional emergency situation regime was installed in 24 municipal districts of the Saratov Region; the amount of financial damage made up 1991 million rubles. Thus, production risk associated with adverse weather conditions affects not only output, but also the technical efficiency of goods producers.

Figure 3 graphically illustrates changes in values of mean technical efficiency.
Both models indicate that in years with favorable weather conditions there is a strongly pronounced increase in technical efficiency, and, conversely, in years with dangerous agrometeorological phenomena, there is technical efficiency decrease.

6. References
[1] Rosstat 2019a Crops Gross Outputs in the Russian Federation Russian Federal State Statistics Service http://www.gks.ru/free_doc/new_site/business/sx/val_1.xls
[2] Debreu G 1951 The Coefficient of Resource Utilization Econometrica 19:3 July pp 273–292
[3] Koopmans T C 1951 An Analysis of Production as an Efficient Combination of Activities Activity Analysis of Production and Allocation Cowles Commission for Research in Economics: Monograph № 13 (N.Y., Wiley)
[4] Farrell M J 1957 The Measurement of Productive Efficiency Journal of the Royal Statistica Society Series A 120 pp 253–281
[5] Aigner D, Lovell C A K and Schmidt P 1977 Formulation and Estimation of Stochastic Frontier function models Journal of Econometrics 6 (1) pp 21–37
[6] Meesusen W and Van den Broeck J 1977 Efficiency Estimation from Cobb-Douglas Production Functions with Composed Error International Economic Review 18 (2) pp 435–444
[7] Just R E and Pope R D 1978 Stochastic Representation of Production Functions and Econometric Implications Journal of Econometrics 7 pp 67–86
[8] Bokusheva R and Hockmann H 2006 Production Risk and Technical Inefficiency in Russian Agriculture European Review of Agricultural Economics 33 pp 93–118
[9] Battese G E, Coelli T J and Colby T C 1989 Estimation of Frontier Production Functions and the Efficiencies of Indian Farms Using Panel Data from ICRISAT's Village Level Studies Journal of Quantitative Economics 5 pp 327–348
[10] Kumbhakar S C and Lovell C A K 2000 Stochastic Frontier Analysis (Cambridge:
Battese G E 1992 Frontier Production Functions, Technical Efficiency and Panel Data: With Application to Paddy Farmers in India Journal of Productivity Analysis 3 pp 153–169

Battese G E and Coelli T J 1995 Model for Technical Inefficiency Effects in a Stochastic Frontier Production Function for Panel Data Empirical Economics 20 pp 325–332

Sotnikov S 1998 Evaluating the Effects of Price and Trade Liberalisation on the Technical Efficiency of Agricultural Production in a Transition Economy: the Case of Russia European Review of Agricultural Economics 25 pp 412–431

Sedik D, Trueblood M and Arnade C 1999 Corporate Farm Performance in Russia, 1991–95: an Efficiency Analysis Journal of Comparative Economics 27 pp 514–533

Voigt P 2002 Russia’s Agriculture in Transition: a Cross-Sectoral Comparison of Productivity and Efficiency Selected paper, the Conference Success and Failures of Transition: Russian Agriculture between Fall and Resurrection (Halle/Saale: Agrimedia)

Bezlepkina I 2004 Microeconomic Analysis of Russian Agricultural Enterprises with Special Reference to Subsidies and Debts PhD thesis (Wageningen University)

Hockmann H and Gataulina E 2012 Technology, Risk and Technical Efficiency in Agriculture: Evidence from Tatarstan XII International Academic Conference on Economic and Social Development (HSE Publishing House) pp 110-119

Ponkina E V and Kurochkin D V 2014 Technical Efficiency in Crop Production: Measurement Based on Econometric Methods of Data Envelopment Analysis and Stochastic Frontier Analysis Izvestiya of Altai State University 1 (81) pp 170–178

State Program for Development of Agriculture and Regulation of Agricultural Commodity Markets for 2013–2020 http://mcx.ru/activity/state-support/programs/program-2013-2020/

Rosstat 2017 Indeces of Wholesale Prices of Manufactured Goods and Services Purchased by Farm Organizations in Russian Federation in 2002–2016 Russian Federal State Statistics Service http://www.gks.ru/free_doc/new_site/prices/s-x/pri-cx_ind.xls

Rosstat 2019b Indeces of Wholesale Prices of Manufactured Goods and Services Purchased by Farm Organizations in Russian Federation in 2017–2018 Russian Federal State Statistics Service http://www.gks.ru/free_doc/new_site/prices/s-x/pri-cx_ind2017.xls

Saratovstat 2019 The Saratov Region Digitally – 2015, 2016, 2017, 2018 Local Government Agency of the Federal State Statistics Service of the Saratov Region http://srvt.gks.ru/wps/wcm/connect/rosstat_ts/srvt/ru/publications/offical_publications/electronic_versions/

R Core Team 2019 R: A language and Environment for Statistical Computing. R Foundation for Statistical Computing (Vienna, Austria) URL https://www.R-project.org/

HenningSEN A 2015 Introduction to Econometric Production Analysis with R Collection of Lecture Notes (Electronic Materials) (Department of Food and Resource Economics, University of Copenhagen) http://leanpub.com/ProdEconR/

Coelli T and HenningSEN A 2017. frontier: Stochastic Frontier Analysis. R package version 1.1-2. https://CRAN.R-Project.org/package=frontier