Production Risk and Technical Inefficiency in Russian Agriculture

Raushan Bokusheva, Heinrich Hockmann
Institute of Agricultural Development in Central and Eastern Europe (IAMO), Halle
Germany

Corresponding author:
Raushan Bokusheva
Institute of Agricultural Development in Central and Eastern Europe (IAMO)
Theodor-Lieser-Str.2
06120 Halle
Germany
Phone: +49 345 29 28 134, Fax: +49 345 29 28 399, e-mail: bokusheva@iamo.de

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Summary
This paper aims to contribute to a better understanding of possible causes of the considerable production volatility that has characterised Russian agriculture during the last decade. Using panel data from 1995 to 2001, it presents an empirical analysis of production risk and technical inefficiency of 447 large agricultural enterprises from three regions in Central, Southern and Volga Russia. Two sources of production variability, production risk and technical inefficiency, are considered.

Key words: Production risk, Technical efficiency, Panel data, Russian agriculture
JEL Classification: D81, Q12
1. Introduction

The development of Russian agricultural production during the reform period has been inconsistent in character. In general, production declined over a considerable period while at the same time serious output variations were observable\(^1\). Many studies have been conducted in order to reveal the possible causes of agricultural production decline in the post-soviet Russia (Sotnikov, 1998; Sedik at al., 1999; Voigt and Uvarovsky, 2001; Osborne and Trueblood, 2002; Bezlepkina and Lansink, 2003). Among others, the deterioration in terms of trade, elimination of producer and consumer subsidies, a weak institutional environment and undeveloped infrastructure, through their impact on technical efficiency, were revealed as important factors of production decline. However, thus far the literature has not paid much attention to production volatility in Russian agriculture.

In recent years (from 1999 to 2002) Russian agricultural production has exhibited substantial growth followed by a deceleration in 2003. In this context it is of great interest to identify factors which have contributed to such positive development in Russian agriculture. The central question of this study is: Have Russian farms improved their performance by increasing their technical efficiency and productivity or might this growth be explained by some reduction in production risk due to favourable weather conditions in this period as some experts assert (Gaidar, 2002)?

Sotnikov (1998) and Sedik et al. (1999) were the first who studied technical efficiency in Russian agriculture during the reform era. In both studies, the authors estimate the magnitudes of technical efficiency on the oblast level. The estimations are conducted by employing the stochastic frontier approach. Furthermore, Sedik at al., (1999) carry out data envelopment analysis. The studies provide analogue results and show that technical efficiency declined from 1991 to 1995. Moreover, a study by Osborne and Trueblood (2002) concerns the efficiency of Russian crop output in the successive period, from 1995 to 1998, and shows that the trend revealed in the earlier studies has slowed down but not been reversed. In contrast, the estimates of technical efficiency over 75 Russian regions obtained by Voigt (2002) do not suggest serious changes in technical efficiency at the national level during the period from 1993 to 2000. However, the author found that the development of technical efficiency in different regions does not have any common trend.

Recently, several studies were conducted to estimate technical efficiency using farm level data. Bezlepkina and Lansink (2003) study technical efficiency of dairy farms in the Moscow region and consider its development with regard to capital structure and subsidising programs

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\(^1\) In the Appendix, Figure 1 demonstrates the development of grain production from 1985 to 2003, while Table 1 provides additional information on yield and yield variability of the main agricultural products in this period.
from 1996 to 2000. The study results show that even though technical efficiency decreases considerably in the year of financial crisis, 1998, in general it has a positive trend in the analysed period. These results are in compliance with the findings by Stange and Lissitsa (2004) who compare technical efficiency of farms in the same region with regard to their specialization, size and form of organization in the years 1993 and 2000. The results of both studies suggest an increase in technical efficiency of the considered farms in recent years. However, the farms of the Moscow region located near to the city are rather less representative for Russian agriculture and cannot represent the situation in the other regions. In this context, further investigation is necessary to assess the current stage of technical efficiency development in Russian agriculture.

The studies of technical efficiency of Russian agricultural producers differ with respect to estimation techniques and subject of investigation. Additionally, many particularities are found with regard to the objectives and background of the individual studies. However, neither of these studies considered the production development in Russia to be explained by the presence of risk and the farmers’ responses to it. This, however, undermines the fact that normally economic units make their decisions under conditions of risk. The presence of risk not only influences production output but also producers’ behaviour, primarily with regard to input use. If risk mitigation plays a principal role in decision-making, then technical efficiency may alter significantly. Therefore, technical efficiency assessed considering a producer's response to uncertainty is not the same in a setting where no effect of risk on input-use decisions is concerned. Thus, in the case that uncertainty is pervasive, the theoretical framework for studying technical efficiency is to be extended with respect to risk and producers’ responses to risk. In this study production risk is assumed to be an important factor in Russian agriculture and to influence production decisions of Russian farmers. Hence, the present study aims to estimate the magnitudes of both technical inefficiency and production risk faced by agricultural producers in Russia and therefore explain the pattern of Russian agricultural production development in the last decade.

Two approaches are employed in the study: the Just and Pope model (1978), and a Kumbhakar extension of this model to introduce technical efficiency (Kumbhakar, 2002). The Just and Pope model allows to distinguish between the effects of input use decisions on production output and production risk (1978). Technical efficiency explained by a complementary function presents an additional source of production variability (Kumbhakar, 2002). Both models are extended to consider systemic production risk and estimated using panel data (from 1995 to 2001) of 447 large agricultural enterprises from three regions in
Central, Southern and Volga Russia. Based on the estimation results three hypotheses with respect to study objectives will be discussed:

- Production risk is a significant factor in Russian agriculture.
- Production risk includes a regional systemic component.
- Technical inefficiency in production enhances the production uncertainty of Russian agriculture.

The paper is organized as follows: Section 2 outlines the methodology applied to distinguish and assess two sources of production variability: production risk and technical inefficiency. Section 3 presents the specification of the models used in the study. Estimation results with regard to the objectives of the study are discussed in section 4. Conclusions are drawn in the final section.

2. Methodology

The study employs a stochastic production frontier approach. Empirical studies on efficiency usually utilize either Data Envelopment Analysis (DEA) or Stochastic Frontier Analysis (SFA). DEA is a non-parametric approach and employs linear programming to construct a piecewise-linear, best-practice frontier for each economic unit (Färe et al., 1985). No functional form for the frontier is imposed on the data. However, this technique considers production to be deterministic. The stochastic parametric approach, SFA, is founded on the traditional stochastic specification and takes into account output uncertainty by means of a two-part error term (Aigner et al., 1977). The distribution assumptions for both part of the error term have to be imposed.

The traditional stochastic frontier production model was first proposed by Aigner, Lovell and Schmidt (1977) and the general notification of the model is the following:

\[ y_i = f(x_i; \alpha)e^{\nu_i}TE_i, \quad (1) \]

where \( y_i \) is the output of producer \( i \) \( (i \in I) \), \( x_i \) is a vector of inputs used by producer \( i \), \( \alpha \) represents a vector of technology parameters, \( f(x_i; \alpha) \) is the production frontier, and \( TE_i \) is the output-oriented technical efficiency of producer \( i \). In addition, \( \nu_i \) represents a producer-specific random component.

Technical efficiency is defined as the ratio of observed output to maximum feasible output in a state of nature depicted by \( \exp\{\nu_i\} \):

\[ TE_i = \frac{y_i}{f(x_i; \alpha)e^{\nu_i}}. \quad (2) \]
Since stochastic specification of the production frontier model permits taking into account random shocks that affect production but lie outside of producer control, SFA is a more appropriate approach for an environment characterized by considerable random effects.

However, the traditional specification of a stochastic production function has a feature which may seriously restrict its potential to depict production technology appropriately. An important disadvantage of the traditional multiplicative stochastic specification of production technology lies in an implicit assumption: if any input has a positive effect on output, then a positive effect of this input on variability of output is also imposed. Just and Pope (1978) showed that the effects of input on output should not be tied to the effects of input on output variability a priori. Instead, they proposed a stochastic specification which has been more generally compared to the traditional econometric production function. Accordingly, the adequate production function specification has to include two general functions: one which specifies the effects of the input on the mean of output and another which specifies the effect of input 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. Furthermore, \( \alpha \) is a vector of the mean production function parameters, \( \beta \) is a vector of the variance production function parameters and \( v_i \) is a stochastic term assumed to be i.i.d. \( N(0,1) \). Thus, \( E(y) = f(x) \), and \( V(y) = g^2(x) \). In this manner, the effect of input changes has been separated into two effects - the effect on mean and the effect on variance. Since variance of \( y \) is specified as a function of the production inputs \( g(x_i; \beta) \), the Just-Pope production function exhibits heteroscedasticity. The marginal production risk, defined as

\[ \frac{\partial \text{var}(y)}{\partial x_j} = 2g(x; \beta)g_j(x; \beta) \]  

(4)

can be positive as well as negative, or zero, subject to the signs of \( g(x_i; \beta) \), and \( g_j(x_i; \beta) \), where the latter is the partial derivative of \( g \) with respect to input \( j \).

Generally, there are 3 possibilities for integrating technical efficiency into the Just-Pope production function:

(i) in additive form (Battese et al., 1997). In this case it is attached to the variance production function, together with the random term representing production uncertainty:

\[ y_i = f(x_{ij}; \alpha_j) + g(x_{ij}; \beta_j)(v_i - u_i); \]  

(5)
(ii) in multiplicative form. Then technical efficiency is attached to the mean production function (Kumbhakar, 2002):

\[ y_i = f(x_{ij}; \alpha_j)(1-u_i) + g(x_{ij}; \beta_j)v_i, \]

(6)

In this case an additional assumption: \( \exp\{-u\}=1-u \) has to be introduced.

(iii) in the more flexible form suggested by Kumbhakar (2002), where an additional function \( q(x) \) for explaining technical inefficiency is introduced:

\[ y_i = f(x_{ij}; \alpha_j) + g(x_{ij}; \beta_j)v_i - q(x_{ij}; \gamma_j)u_i. \]

(7)

Equations (5) and (6) are special cases of (7). Depending on the choice of \( q(x) \) function the model in (7) can be reduced to (5) when \( q(x)=g(x) \) or to (6) when \( q(x)=f(x) \).

3. Model specification

In this study two model specifications are considered: the Just and Pope model (JP-model), and a Kumbhakar's extension of the model by considering technical efficiency as provided by (7). These specifications are extended by introducing variables that account for a systemic part of production risk (SPR) and by application them to panel data. In the following the subscripts \( i \) and \( t \) denote the producer and the time period, respectively. Defining \( x = [x_1, ..., x_J] \) the production function can be written as

\[ y_{it} = f(x_{it}; \alpha) + \exp(\beta_i D_t)g(x_{it}; \beta)\nu_{it} \quad \text{(Just and Pope with SPR)} \]

(8)

\[ y_{it} = f(x_{it}; \alpha) + \exp(\beta_i D_t)g(x_{it}; \beta)\nu_{it} - q(x_{it}; \gamma)u_{it} \quad \text{(Kumbhakar with SPR)} \]

(9)

where, \( \nu_{it} \) is assumed to be \( i.i.d. N(0,1) \), i.e., independent identically-distributed standard normal random variables, and \( u_{it} \) is \( i.i.d. N^t(0, \sigma^2_{u_t}) \), i.e., independent identically-distributed and half-normal. The function \( g(x_{it}; \beta)\nu_{it} \) represents the idiosyncratic component of production risk faced by selected farms. Systemic production risk is captured by matrix \( (D_t) \) which consist of dummy variables for the individual years (Hsiao, 1986). Thus, \( \beta_i \) can be viewed as a proxy for the systemic component of risk, which expresses a spatial effect of annual weather conditions on production variance for the entire group of the analysed farms.

In the case of the model specification with TI, the mean production function and production variance function are defined at the frontier, i.e., \( u_{it}=0 \). Thus, for both approaches

\[ E(y_{it}|u=0) = f(x), \quad V(y_{it}|u=0) = g^2(x). \]

(10)

A single-step maximum likelihood (ML) procedure was employed to estimate the parameters of the specified models. Taking into consideration the distributional assumptions on \( \nu \) und \( u \),
the likelihood function of \( TN \) observations is formulated as the product of the probability density functions \( f(\varepsilon_i) \) of \( TN \) single observations and the Jacobian \(|J|\) of the undertaken transformation (\( \varepsilon \) from \( y \)):

\[
L = \prod_{i=1}^{N} f(\varepsilon_i) \cdot |J|, \text{ with } \varepsilon_i = [\varepsilon_{it_1}, \ldots, \varepsilon_{iT}] \text{ and } f(\varepsilon_i) = \prod_{i=1}^{T} f(\varepsilon_{it})
\]  

where \( \varepsilon_{it} = \frac{y_{it} - f(x_{it})}{\exp(\beta_i D_i) g(x_{it})} = [y_{it} - h(x_{it})u_{it}] \) with \( h(x_{it}) = \frac{q(x_{it})}{\exp(\beta_i D_i) g(x_{it})} \).

The probability density function of \( \varepsilon_{it} \) is

\[
f(\varepsilon_{it}) = \sqrt{\frac{2}{\pi}} \frac{1}{\sigma_{it}} \Phi \left( -\frac{\varepsilon_{it} \sigma_{it} h(x_{it})}{\sigma_{it}^2} \right) \exp \left( -\frac{\varepsilon_{it}^2}{2 \sigma_{it}^2} \right)
\]

with \( \sigma_{it}^2 = 1 + h^2(x_{it}) \sigma_{u}^2 \) and \( \Phi(\cdot) \) being the distribution function of the standard normal random variable (Kumbhakar, 2002). The Jacobian in our case is a \( TN \times TN \) diagonal matrix with the elements \( \frac{1}{g(x_{it})} \).

Then the log-likelihood function to be estimated is

\[
\ln(L) = \text{const} - \sum_{t=1}^{T} \left( \frac{1}{2} \sum_{i=1}^{N} \ln \sigma_{it}^2 + \sum_{i=1}^{N} \ln \left[ \Phi \left( -\frac{\varepsilon_{it} \sigma_{it} h(x_{it})}{\sigma_{it}^2} \right) \right] - \frac{1}{2} \sum_{i=1}^{N} \frac{\varepsilon_{it}^2}{\sigma_{it}^2} - \sum_{i=1}^{N} \ln g(x_{it}) \right).
\]

The maximization of the log-likelihood function in (13) provides the ML estimates of the parameters in \( f(x) \), \( g(x) \) and \( q(x) \), as well as of \( \sigma_u \) (Greene, 2003). They can be used to calculate the technical inefficiency measures of individual producers in a particular year by employing the conditional distribution of \( u_{it} \), given \( \varepsilon_{it} \), which were derived by Jondrow et al., (1982):

\[
E[u|\varepsilon - u] = \sigma_0 \left\{ \mu_0 / \sigma_0 + \{\phi(\mu_0 / \sigma_0) / \Phi(\mu_0 / \sigma_0) \} \right\}
\]

where \( \mu_0 / \sigma_0 = -\{\varepsilon_{it} \cdot \sigma_u \cdot h(x_{it})\} / \sigma_u \) and \( \sigma_0^2 = \{\sigma_u^2 h^2(x_{it})\} / \sigma_u^2 \).

4. Estimation and Empirical Results

4.1 Data and Estimation

The model is estimated using balanced panel data of 447 large agricultural enterprises from three Russian regions. 74 farms are located in Oroel (Central Russia), 180 farms in Krasnodar (South Russia) and 193 in Samara (Volga Russia). The data set covers the period from 1995
to 2001. To be able to assess the dependence of production on weather conditions, crop production is focused on. All enterprises included in the sample are large scale farms with a crop area of more than 200 ha, which extensively grow grain for commercial use. On average, the sample represents between 22 and 45 per cent of the total crop area in the individual regions. In the view of experts, Krasnodar and Samara are regions with a higher exposure to natural hazards. Samara and Oroel belong to a small group of Russian regions that have recently been very active in introducing Western production technologies (Schüle and Zimmermann, 2002).

Production output is measured as annual farm revenues from crop production plus the value of unsold grain \(Y\). The mean output function is a function of labor \(\text{Labor}\), seed \(\text{Seed}\), fertilizer \(\text{Fertilizer}\), depreciation \(\text{Capital}\), other costs \(\text{Suppl}\) (usually cost of plant protection) and time \(t\) as an indicator of technical change. Production risk and technical inefficiency (TI) are functions of the same variables except \(t\). The variable farm size \(\text{Size}\) is introduced into \(q(x_i,\gamma)\) to detect how technical efficiency varies with the scale of agricultural production. In this study output and all inputs were normalized by the input \(\text{Land}\), therefore constant returns to scale are assumed.

The data set was provided by Goskomstat - the Russian State Committee of Statistics. All monetary key data were adjusted to the year 2001 by the regional price indices for agricultural inputs and output. However, for fertilizer and capital these indices were not obtainable. Two options were available to adjust this data: using product-specific price indices defined on the country level or using regional price indices defined for a wide range of products. The first does not reflect regional price movements, while the latter is unable to identify changes in regional price relations since the deflator represents a movement of average regional prices. Since the goal was to identify regional production patterns, the second option was expected to cause a larger bias in the variables than the first option. Thus, monetary values were adjusted by product-specific indices. Unfortunately, distinguishing between seed produced on the farm and purchased seed was not possible. However, as many farms use seed produced themselves, it was decided to employ the regional agricultural output price index in this case. Certainly for the farms, purchasing high quality seed this leads to some distortions.

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2 The value of unsold grain was reckoned as a difference between a farm's annual grain production and grain sales multiplied by grain prices in the year 2001.
3 Whereas other costs are calculated as the difference of total production costs of crop production and costs of labor, seed, fertilizer, equipment and machine maintenance, and fuel.
4 Farm’s crop land.
5 In order to avoid problems with multicollinearity conducting estimations.
6 Another important point of the analysis: it is assumed that all farms in the regions have the same price risk, although in our opinion this may be rather restrictive.
A Cobb-Douglas specification is used on mean production and production variance, as well as the technical inefficiency (TI) function. This functional form is highly restrictive, however, other functional forms such as translog and linear-quadratic provided poor estimates. In the case of translog function, many of the parameter’s estimates were insignificant. Moreover, monotonicity was not fulfilled for the farms in Oroel, and quasi-concavity was also not satisfied in general.

The parameters $\alpha_j$, $\beta_j$ and $\gamma_j$ are elasticities of the factor $j$ in the mean, output risk and TI function, respectively. Positive values of the coefficients $\beta_j$ in the production risk function mean that the corresponding factor increases production variability, whereas negative values signal that the factor is a risk-decreasing one. Negative signs of the coefficients $\gamma_j$ indicate that a factor reduces technical inefficiency, otherwise a factor is TI increasing.

The Just and Pope formulation was estimated by adding time effects (JP with SPR) and then was adapted to take into account technical inefficiency (Kumbhakar with SPR). The parameter estimates are presented in Table 1.

### 4.2 Estimation Results

As the purpose of the study is to examine the effects of TI and production risk on agricultural production development, the discussion of the parameter estimates is confined to a general extent. Table 1 shows that all coefficients of the mean production function are positive and significant. For farms in the Oroel and Samara regions, labor and capital have the highest proportional contribution to the production, whereas in Krasnodar, fertilizer and other production costs exhibit high output elasticities as well. According to the estimation results, the production technology in Krasnodar differs from that in Oroel and Samara with regard to labor elasticity. Lower Labor elasticity suggests a higher elasticity of the Land in Krasnodar.

![Place Table 1 here](image)

The estimates for technical change reveal that only one region (Samara) had increasing production possibilities. The other two regions were experiencing declining productivity. Possible reasons for this are insufficient replication of capital input or limited provision with material inputs due to liquidity problems. However, the estimate for technical change in the Samara region is rather high in the period considered. Consequently, it makes estimation results for this region less plausible. On the other hand, considering the initial situation in agriculture of this region in the first part of the 1990s, as well as efforts of farms in Samara to

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7 $\gamma_j = 0$ means that a factor is neutral with regard to technical inefficiency.

8 All variables with the insignificant parameter estimates were excluded estimating the model.
introduce modern production technologies in the later 1990s may support such estimation results.

In the following three hypotheses are discussed:

1. Production risk is a significant factor in Russian agriculture
2. Production risk includes a regional systemic component.
3. Technical inefficiency (TI) in production enhances the production uncertainty of Russian agriculture.

(1) Parameter estimates of the risk function are highly significant. Results of the likelihood-ratio test of the JP with SPR model against the general specification for all three regions support this model formulation. This implies that production uncertainty is an important source of variability of agricultural production. In addition, according to the estimates, production variability is very high and many of the input coefficients in the risk function have relatively high values, first of all in case of such fixed production factors as labor and capital in Krasnodar. This suggests that farms with a higher fixed factor endowment face a higher degree of production uncertainty.

More insight can be gained if the size of enterprises is considered. Large farms cannot be as flexible as their small counterparts in regard to factor endowment, primarily in the case of fixed factors, because once made, these kinds of production decisions (fixed factor acquisition) have a long-term effect. This applies especially to Russia, where most farms still use equipment and production practices from the past. Moreover, with regard to labor input, most farms in Russia have retained a protective employment policy that obstructs serious changes in their production patterns (Osborn and Trueblood, 2002). Accordingly, model estimates can serve as a basis for an empirically-relevant conclusion: current factor endowment of the farms analyzed in this study is still not adjusted to production conditions and must be fitted to them in the future.

One important advantage of the JP-approach is the possibility of distinguishing between an input effect on mean output and its impact on output variability, i.e., risk. In this study, large differences among the sign and the magnitude of the parameter estimates in the mean and risk function could not be found, except for the input “Suppl”: its coefficients are positive and significant in the mean production function and negative and also significant in the production risk function of farms and in the Kumbhakar with SPR specification for farms in Samara. This indicates that mean production output is increased and production risk is reduced with increased use of this input. Such results provide some confirmation to the view that pesticides
are not a factor for increasing, but for stabilizing agricultural production (Quiggin and Chambers, 2003).

(2) The parameter estimates of systemic risk for all three regions are highly significant. This suggests the presence of systemic risk in these regions. In addition, the values of systemic risk are rather large. These results imply that a considerable part of output variation explained by systemic risk in the selected regions.

The relatively low values of systemic risk in 2000 and 2001, compared to its seven-years-average value for all three regions, confirm compliance of the model estimates with the actual climatic conditions in the period considered (Gaidar, 2002). However, there may be a serious identification problem in the paper's estimates: the magnitude of systemic risk in Krasnodar and Oroel has declined mirroring the recovery of the Russian economy since 1999. This may suggest that the dummy variables in the production risk function capture not only systemic risk but also the effects of an improvement of the macro-economic environment. However, improved economic conditions should reveal their impact on the decision variables like factor input. Thus, the study assumes that they should be captured in the idiosyncratic component of the risk function but not in the systemic risk component. Moreover, the macroeconomic influence cannot be observed for the farms in Samara. This leads to the conclusion that the dummy variable coefficients reflect mainly climatic conditions.

(3) The likelihood-ratio tests show that the specification of the model including technical inefficiency is more appropriate for two regions: Krasnodar and Samara, i.e., technical inefficiency enhances the variability of agricultural production in these regions. The hypothesis \( H_0: \text{No Inefficiency} \) \( (q(x) = \text{const.}, \sigma_u^2 = 0) \) was not rejected for the farms in the Oroel-region. Thus, the presence of technical inefficiency for this region cannot be statistically proven.

The variance of output defined in the model with TI as \( \sigma^2 = \{\exp(\beta_t D_t)g(x)\}^2 + q(x)^2\sigma_u^2 \) is explained mostly by variance due to production risk - \( \exp(\beta_t D_t)g(x)^2 \): for almost all farms in the Krasnodar and Samara regions \( q(x)^2\sigma_u^2 < \exp(\beta_t D_t)g(x)^2 \), i.e., according to model estimates, high agricultural production variability arises first of all from production risk (Figures 1 and 2).

**Place Figures 1 and 2 here**

In the Samara region technical inefficiency is explained by capital input and farm size, while in Krasnodar only farm size has a strong significant effect on technical inefficiency. Farm size has a negative effect on TI, which suggests that the large farms in these two regions have been
more efficient. However, capital input increases technical inefficiency of the selected farms in Samara. This result is surprising at first glance because Samara was characterized as a dynamic region with a relatively high rate of technical change (Table 1). However, the estimation results may be explained by looking at the theoretical impact of machinery on factor input and the development of inputs. As mechanical innovation, new machines belong to labor saving technologies (Hayami and Ruttan 1985). Thus, they allow a substitution of labor by capital without affecting output significantly. Their adoption is, in general, a response to an increase in labor cost. Higher capital intensity calls for a decrease in labor intensity. However, as mentioned above, the farms in Russian agriculture pursue a protective employment policy and avoid significant labor releases. Thus, the decrease of technical efficiency results from the insufficient adjustment of factor endowment to the economic requirements.

As represented in Figures 3 and 4, technical inefficiency is rather moderate and the average rate does not significantly change along the considered time in both regions, where its presence was proven statistically. Additionally, most parts of the farms in both regions have rather low technical inefficiency scores (about 84 per cent of the farms in Krasnodar have technical inefficiency lower than 0.2, while in Samara 94 per cent of the selected farms do not exceed this value, i.e., there were not any serious differences in the efficiency of most farms in the period considered.

**Place Figures 4 and 5 here**

The concept of technical efficiency is based on comparing the enterprises within the sample taken into consideration. This rather restricts the expressiveness of this concept in the case of a rather homogeneous sample, as was the case in this study\(^9\). From this point of view,

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\(^9\) In this study, we compared farms which had to satisfy to following criteria: a crop area of more than 200 ha, revenue from crop production more than 50 % of the whole farm revenue, grain area more than 40 % of total crop area and production of grain for sale more than 50 % of the whole grain production.
applying the methodology employed to a group of rather heterogeneous farms\textsuperscript{10} may allow more insight into how technical inefficiency influences the development of agricultural production in Russia.

5. Conclusions

This study has focused on the estimation of the magnitudes of technical inefficiency and production risk faced by agricultural producers in Russia. The study used Just and Pope model (1978) to estimate a production function considering production risk, and its extension, by incorporating technical inefficiency as specified by Kumbhakar (2002) in the framework of cross-sectional data. The models were extended by introducing a term to account for a systemic part of production risk and by applying it to panel data.

By means of the panel data analysis of 447 farms in different parts of Russia, results were obtained which support the hypothesis that production risk is a major source of production variability in Russian agriculture. Concurrently, the analysis demonstrates that there is only a weak response of the farms to production risk: most production factors enhance farms' production volatility.

The study results do not support the hypothesis that the recent growth of Russian agricultural production was induced by an increase of farms’ technical efficiency. The farms selected for the study did not remarkably improve their efficiency during the considered period. On the other hand, it was found that the systemic component of risk substantially influences the farms’ production development. Its low estimated values for two successive years, 2000 and 2001, suggest that the production increase in this period was related to the favourable weather conditions. However, the possibility exists that it may comprise an effect of stabilisation in the Russian economy to some degree.

Even though technical efficiency does not seriously exaggerate agricultural production according to the study results, there is a potential to increase it. Furthermore, it is assumed

\textsuperscript{10} For example, to draw a sample of farms from different regions.
that there was no farm in the samples which has succeeded in shifting the respective regional production frontier to the Western benchmark. Correspondingly, actual technical inefficiencies of the farms may be higher. However, as production risk plays a major role in the development of agricultural production at this stage, Russian farms have to search for options to improve their responses to natural hazards to which they are exposed, first of all with respect to the introduction of innovative production technologies and practices that can provide increased factor flexibility.

**References**


Table 1: Parameter estimates

<table>
<thead>
<tr>
<th>Variable</th>
<th>Krasnodar</th>
<th>Oroel</th>
<th>Samara</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>JP with SPR</td>
<td>Kumbhakar with SPR</td>
<td>JP with SPR</td>
</tr>
<tr>
<td>$\alpha_0$</td>
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<td>6.45***</td>
<td>6.04***</td>
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<td>$\alpha_{\text{Labor}}$</td>
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<td>0.07***</td>
<td>0.10**</td>
</tr>
<tr>
<td>$\alpha_{\text{Fertiliz}}$</td>
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<td>0.10***</td>
<td>0.07***</td>
</tr>
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<td>$\alpha_{\text{Seed}}$</td>
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<td>---</td>
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<td>---</td>
<td>---</td>
</tr>
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<td>$\alpha_{t}$</td>
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<td>-0.02***</td>
<td>-0.02*</td>
</tr>
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<td>$\beta_{\text{Labor}}$</td>
<td>0.23***</td>
<td>0.30***</td>
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<td>0.11***</td>
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</tr>
<tr>
<td>$\beta_{\text{Fertiliz}}$</td>
<td>0.04**</td>
<td>0.05**</td>
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</tr>
<tr>
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<td>0.18***</td>
<td>0.21***</td>
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<tr>
<td>$\beta_{\text{Suppl}}$</td>
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<tr>
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<td>5.29***</td>
<td>5.28***</td>
<td>5.38***</td>
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<td>1.00***</td>
<td>0.94***</td>
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<td>0.91***</td>
<td>0.91***</td>
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<tr>
<td>$\gamma_{\text{Labor}}$</td>
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<td>$\gamma_{\text{Seed}}$</td>
<td>---</td>
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<td>---</td>
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<tr>
<td>$\gamma_{\text{Suppl}}$</td>
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<tr>
<td>$\gamma_{\text{Size}}$</td>
<td>-0.53***</td>
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<td>$\sigma_u^{1/2}$</td>
<td>81.89***</td>
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<td>7.32*</td>
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</table>

Value of test statistics (LR) 35.76 4.06 19.22

*** - significant at the 1% level, ** - significant at the 5% level, * - significant at the 10% level
1 Suppl - other costs
2 $\sigma_u' = \gamma_0 \sigma_u$
Figure 1: Ratio of the variance induced by TI to the total variance of selected farms in Krasnodar (average for the farms over 1995-2001)

Figure 2: Ratio of the variance induced by TI to the total variance of selected farms in Samara (average for the farms over 1995-2001)
Figure 3: Technical inefficiency of selected farms in Krasnodar (1995-2001) (0.00 = 100 per cent efficiency)

Figure 4: Technical inefficiency of selected farms in Samara (1995-2001) (0.00 = 100 per cent efficiency)
Appendix

Figure 1: Grain Production in Russia, 1985-2003

Table 1: Yield and Yield Variability of Main Russian Agricultural Products in 1985-2003

<table>
<thead>
<tr>
<th>Product</th>
<th>Average yield, 0.1t/ha</th>
<th>Standard deviation</th>
<th>Coefficient of variation, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cereals, total</td>
<td>16.1</td>
<td>2.2</td>
<td>13.9</td>
</tr>
<tr>
<td>Wheat*</td>
<td>16.6</td>
<td>3.6</td>
<td>21.6</td>
</tr>
<tr>
<td>Sugar Beet</td>
<td>195.3</td>
<td>27.2</td>
<td>13.9</td>
</tr>
<tr>
<td>Sunflower Seed</td>
<td>10.1</td>
<td>2.1</td>
<td>20.3</td>
</tr>
</tbody>
</table>

* - yield per ha of crop area