Productivity and Efficiency in Russian agriculture
New insights based on risk considerations and efficiency dynamics

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Conventional efficiency analysis

\[ y = f(x) + v + u, \text{ with } v \sim N(0, \sigma_v) \text{ and } u \sim \text{half-normal, exponential} \ldots \]

Stochastic frontier analysis

- Inefficiency
- Risk and efficiency

Example: correlation between inputs and efficiency (dynamic efficiency)

Outlook

Conventional SFA: Shortcomings

Empirical analysis:
- Pure technical application of existing software (Limdep, Frontier)
- Statement that inefficiency is found
- Further analysis of efficiency score (by region, by firms, development over time)

Shortcomings:
- No thorough consideration of (neoclassical) production economics: measuring factor input (homogeneity), theoretical consistency
- No conceptual analysis of efficiency ⇒ completeness
- Risk considerations
- Correlation of x and u
- Adjustment costs

Risk and efficiency

1. Objectives and Model
2. Estimation
3. Data and empirical implementation
4. Estimation results
   a. Significance of risk
   b. Technical change and efficiency
5. Conclusions

Grain production, sown area and yield development in Russia, 1980-2003
Source: Goscomstat
Risk and efficiency

Objectives:
to analyze factors influencing production variability
to explain the pattern of development of agricultural production:
- to what extent production risk influences the output development?
- what are the consequences for efficiency?

Model:
\[ y_i = f(x_i; a) + \exp(D_i) \gamma(x_i; b) \rho_i - \varphi(x_i; \gamma) \nu_i \]

- risk function
- systematic
- idiosyncratic

Estimation: ML (Kumbhakar 2002)
\[ v_i \sim N(0, I) \]
\[ w_i \sim N(N[0, a_i^2]) \]

Risk and efficiency: Data

Source:
farm data from Rosstat (Russian Statistical Agency) for 1996-2001
Krasnodar (South Russia), Oroel (Central Russia), Samara (Volga Russia)
443 enterprises — 3 samples (180, 70 and 193, respectively)
large farms with a crop area of more than 200 ha (22 – 45% of total crop area in the region)

Definitions:
- Output: annual farm revenue from crop production
- Labor: number of employed in crop production
- Capital: construction and machine maintenance costs
- Fertilizer: cost of fertilizers
- Seed: cost of seed
- Other costs: usually costs of plant protection
- Time: 

Risk and efficiency: Estimation

Maximum likelihood estimation:
\[ y_i = f(x_i; a) + \exp(D_i) \gamma(x_i; b) \rho_i - \varphi(x_i; \gamma) \nu_i \]
\[ f(x_i) = \prod_{i=1}^{n} \phi \left( \frac{x_i - \mu_i}{\sigma_i} \right) \exp \left( - \frac{1}{2} \left( \frac{x_i - \mu_i}{\sigma_i} \right)^2 \right) \]
\[ L = \prod_{i=1}^{n} f(x_i; \theta) \]
Efficiency scores:
\[ \alpha = \sigma_i \left[ \rho_i / \sigma_i + (\phi(\rho_i / \sigma_i)) / (\phi(\rho_i / \sigma_i)) \right] \]
\[ \sigma_i = \beta_i \left[ \phi(\rho_i / \sigma_i) \right] \]

Risk and efficiency: Significance of risk

Technical inefficiency vs. production risk
for most farms in all regions the variance of production output is explained mostly by variance due to production risk:
\[ \sigma^2(\varphi) < \sigma^2(y) \]
high agricultural production variability was caused primarily by production risk in the reference period

Risk and efficiency: Regional aspects

Regional aspects of production risk
negative input effect on output variability could be found only in Samara with respect to labor and capital
however, for two other regions most of the considered factors have a risk-increasing effect on agricultural output

except for farms in Samara there exists only a weak response of the farms to production risk — most production factors enhance farms’ production volatility
Risk and efficiency: Efficiency & Productivity

Technical efficiency development

Krasnodar
Samara
Oroel

Annual technical change

Risk and efficiency: Conclusions

Production risk
production risk presents an important source of variability of agricultural production in Russia.
investigations on agricultural production development in Russia should pay more attention to the presence of production risk and related farmer behavior only a weak response of the farms to production risk - farms have to search for options to improve their responses to production risks further research is needed to analyze the farmers’ responses to production risk. If agricultural producers do not exhibit risk-adjusting behavior, the reasons for this have to be analyzed

Technical efficiency: two development patterns
under constant technology farms learn from past experience and, thus, are on a path towards the best production practice – U-curve effect
if the technological effect prevails, for the enterprises which fail to adopt innovative techniques, the distance to the best domestic practice increases, implying a decline in technical efficiency

Correlation of x and u: Outline

1. Objectives
2. Model and estimation procedure
3. Data and empirical implementation
4. Estimation results
   a. Parameter estimates
   b. Efficiency
   c. Productivity
5. Conclusions

Motivation and objectives

Objectives:
- to analyze development productivity and efficiency in Russian agriculture using an approach imposing weaker assumption on the structure of the error terms and correlation issues
- to investigate factors explaining regional heterogeneity and efficiency
- to assess the developments with regard to the transition progress

Estimation procedure

Stochastic frontier: $\ln(y) = f(x, \alpha) + \epsilon$, with $\epsilon = \eta + \eta + \nu$

Maximum Likelihood Estimation:
- error terms are independently and identically distributed
- no serial correlation in the error terms
- no correlation between explanatory variables and error term (simultaneity problem); converse empirical evidence
Estimation procedure

Stochastic frontier: \( \ln(y_{it}) = f(x_{it}, \alpha) + \beta_0 + \beta_1 \ln x_{it} + \sum \alpha_j x_{ij} + \nu_i + \epsilon_i \) with \( \nu_i = \eta_i - u_i + \psi_i \)

2-Step Procedure:

1st step: Estimation of technology parameters

System Generalized Methods of Moments (SYS-GMM) (Blundell and Bond, 1998)

\[ E(x_{it} \mid \beta_0, \beta_1) = 0, \quad p > 2 \] (initial conditions do not affect \( \beta_0, \beta_1 \))

\[ E(x_{it} \mid \beta_0, \beta_1) = 0 \quad (y \text{ and } x \text{ are stationary}) \Rightarrow \text{heterogeneity, simultaneity} \]

\[ \Rightarrow \text{weak instruments} \quad (\text{consistent estimates when } x \text{ and } y \text{ are almost integrated}) \]

2nd step: Estimation of fixed effects and TE as components of \( \theta_{it} \)

ML – (Fixed Effect) Stochastic frontier model

\[ E(x_{it} \mid \beta_0, \beta_1) = 0, \quad p > 2 \]

\[ \Rightarrow \text{estimates of } \eta_i, \text{ determinants of efficiency (}\delta_u, \delta_v) \]

Empirical implementation

Translog technology:

\[ f(x_{it}, \alpha) = u_i + \alpha_t + \frac{1}{2} \sum \alpha_j x_{ij} \ln x_{ij} + \frac{1}{2} \sum \alpha_j x_{ij} \ln x_{ijk} \]

Total factor productivity \( \ln \left( \frac{\text{TFP}_{it}}{\eta_i} \right) \) Caves, Christensen & Diewert approach

\[ \Rightarrow \text{multilateral consistent comparisons of TFP level and development} \]

Efficiency indicator

\[ E(\nu_i \mid \nu_j) = f(\nu_i - \nu_j, \alpha_i) \]

Jondrow et al. procedure

Data

Source

Rosstat

61 of the 79 Russian regions (north of the arctic circle not considered ) 1994 to 2005.

Variable definitions (production function)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Definition</th>
<th>Effect</th>
<th>Hypothesis: ( \alpha )</th>
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<tbody>
<tr>
<td>TOT</td>
<td>Ratio of input and output prices</td>
<td>&gt; 0</td>
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<td>ANI</td>
<td>Number of cattle</td>
<td>Restructuring of production</td>
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<td>INC</td>
<td>Per capita income</td>
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<td>Time</td>
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<td>MLR</td>
<td>Man land ratio</td>
<td>Total function of farms</td>
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Results: Parameter estimates

Parameters of the production function (selected)

<table>
<thead>
<tr>
<th>Variable</th>
<th>ML-SF</th>
<th>SYS-GMM and ML</th>
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<tbody>
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<td>Time</td>
<td>0.002</td>
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<tr>
<td>Time²</td>
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Results: Efficiency

Development of technical efficiency (by region and annual average)

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<th>Year</th>
<th>0.70</th>
<th>0.75</th>
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Determinants of efficiency

| Variable | Parameter estimate | Average effect of $E[v|u]$ | Parameter estimate | Average effect of $E[v|u]$ | Total effect on $E[u|v-u]$ |
|----------|-------------------|-----------------------------|-------------------|-----------------------------|----------------------------|
| AFA      | -12.695***        | >0                          | 9.621***          | >0                          | > 0                        |
| INV      | -0.917*           | < 0                         | 1.698***          | > 0                         | > 0                        |
| TOT      | -1.165**          | >0                          | 4.356***          | > 0                         | > 0                        |
| ANI      | -1.839***         | >0                          | 2.448***          | > 0                         | > 0                        |
| INC      | -1.256*           | >0                          | 1.869***          | > 0                         | > 0                        |
| MLR      | -0.813***         | >0                          | 0.741             | > 0                         | > 0                        |
| V        | -0.111***         | >0                          | 0.076**           | <0                          | < 0                        |
| TT       | 0.076**           | <0                          | 0.076**           | <0                          | < 0                        |

2000

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Results: Productivity

TFP development (by region and annual average)

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Conclusions

Estimation:
SYS – GMM is an appropriate alternative to ML in stochastic frontier analysis

Empirical results:
Efficiency is affected by quality of input and adjustment cost ⇒ specification errors
Indication that technical change and efficiency are correlated
Reforms had a positive impact on productivity and efficiency
Limited evidence for regional convergence

Thank you!