Factors constraining efficiency of Russian corporate farms: The case of the Moscow region

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Poster paper prepared for presentation at the International Association of Agricultural Economists Conference, Gold Coast, Australia, August 12-18, 2006

ABSTRACT

The research focus of the paper is to distinguish allocative and technical inefficiencies on Moscow region corporate farms. DEA specifications with both monetary and technical objective functions are applied. To decrease heterogeneity and allow for the accessibility to different technologies of a given farm, the farms are grouped with respect to the set of outputs they produce. As a result of an unstable market environment allocative inefficiency was significant. It causes in general more than zwo third of total inefficiency. Moreover, there is indication that it became more severe 2002, compared to 1999. Sensitivity analyses were used to identify fixed inputs constraining either allocative or technical efficiency. As for technical inefficiency, in 1999 its major source was the lack of liquidity and other resources; in 2002 it was the lack of fodder, liquidity and sown area. The role of insufficient management in regional farming inefficiency is evaluated as being much lower than many earlier studies suggest.

JEL: D24, Q12, C14

Keywords: Technical inefficiency, allocative inefficiency, Data Envelopment Analysis, Moscow region, transitional economy.

1 INTRODUCTION

Data Envelopment Analysis (DEA) developed by CHARNES et al. (1978) has become a standard tool in efficiency analysis The basic assumption of this approach is that the production possibilities of a homogenous sample of firms can be represented by a linear combination of actual farm-level technologies observed within this sample. The key idea of the DEA is that the location of a firm outside a production frontier indicates that the firm is experiencing a specific problem that does not hamper the activities of firms located on the frontier.

Efficiency scores are sometimes discussed as being ‘high’ or ‘low’, although a universal scale is not possible and ‘low’ scores might often be more a result of a misspecified model than of actual under-utilization of available technological knowledge. Actually, the large variance of efficiency scores might not only be caused by bad management failures but also be explained by the fact that many 'non-efficient' farms suffer from resource constraints which are not explicitly considered by the DEA model, while in the 'efficient' ones these constraints are not binding. Such a situation is quite expectable in transitional markets which lack certain institutions, infrastructure and motivations. In addition to efficiency measures, DEA models can produce plenty of analytical information such as shadow prices, scenario analyses, sensitivity tests outcome, etc (e.g. VALDMANIS, 1992; SIMAR and WILSON, 1998; KUOSMANEN et al., 2005).

In this paper, we conduct an efficiency analysis of selected farms in Moscow Oblast. Contrary to other DEA applications to Russian agriculture (SEDIK et al., 1999; and OUDE LANSINK et al., 2003), we use both technical and monetary objective functions in order to approach both allocative and technical efficiency. Following the above-formulated idea about the possible reason for low efficiency scores, we include constraints reflecting those resources that are most commonly reported as efficiency-constraining in BEZLEPKINA (2004), EPSTEIN and TILLACK (1999) and ZINCHENKO (2001). Finally, we apply sensitivity analyses to identify the most restrictive resources. Thus, we also contribute to the discussion which of the several determinants are responsible for the poor performance of Russian agriculture.

2 THEORETICAL FRAMEWORK

A profit maximizing firm (a farm in our case) can be represented as a mathematical programme

$$P^* = \max_{\mathbf{x},\mathbf{y}}(P \mid P = \mathbf{vy} - \mathbf{wx}, \mathbf{y} \in Y(\mathbf{x})), \tag{1}$$

where P^* is an optimal profit, $\mathbf{w}$ and $\mathbf{v}$ are non-negative vectors of average input and output prices, and $\mathbf{x}$ and $\mathbf{y}$ are non-negative vectors of inputs and outputs, respectively. $Y(\mathbf{x})$ is the production possibility set.

Assuming free disposability and convexity, $Y(\mathbf{x})$ can be represented by linear combinations of inputs and outputs as follows:

$$P^* = \max_{\boldsymbol{\lambda},\mathbf{x},\mathbf{y}} (P \mid P = \mathbf{vy} - \mathbf{wx},\ \mathbf{y} \le \mathbf{B}\boldsymbol{\lambda},\ \mathbf{A}\boldsymbol{\lambda} \le \mathbf{x} \le \mathbf{a}), \quad (2)$$

In this presentation λ is an optimal vector of intensities of the technologies; **A** = (a_{mi}) is a non-negative input matrix consisting of all available farms input vectors; **B** = (b_{ni}) is a non-negative output matrix consisting of all available farms output vectors; **a** is a non-negative vector of available amounts of inputs. This vector is assumed to consist of limiting values for those inputs that cannot be adjusted to profit-maximising levels in the short run (fixed inputs) infinitely large values for variable inputs.

Problem (2) is very useful for performance analysis. If the solution is outside the frontier, then, in order to identify the reason, it is possible to decompose the observed lack of performance into its components by means of imposing additional restrictions to (2). For instance, the following restrictions can be imposed:

a) All inputs are fixed at their actual values;
b) Outputs are fixed as to the actually-observed structure;
c) λ' 1 = 1, where 1 is a vector of ones.

Version (a), compared to the solution of (2), allows a researcher to measure profitability loss due to suboptimal input structure caused by either managerial or market failures. Version (a+b) collapses in a classical output-oriented DEA problem that is used for technical efficiency analysis, as the solution no longer depends on prices, and, compared to (a), identifies profitability losses due to non-optimal output allocation. Version (a+b+c) captures scale effects. In the two latter versions, shadow prices are scarcely useful for analytical purposes.

With respect to the aim of our study, this model can also be used for analysing the question regarding the amount of existing shortages of a particular resource with respect to other available resources. For this purpose, the sensitivity analysis is applied. An element of vector **a** corresponding to a scarce fixed input is replaced with an infinitely large value simulating an abundant resource. The increase of profit indicates the opportunity of profitability growth (therefore, of increasing efficiency of other fixed inputs) by increasing the amount of that fixed input.

3 Data

This study uses data of the registry of the Moscow region corporate agricultural farms, which was provided by the Federal Service of State Statistics of Russian Federation (ROSSTAT). The registry includes data from the annual statistical reports of those entities classified by ROSSTAT as corporate agricultural firms. The data cover farm profitability, gross and net inputs and outputs in physical and monetary units, detailed data about subsidies, total amount of bank credits, overdue credits, and accounts payable and receivable (total and overdue). Data of 2002 and 1999 were available. Market entry and exit caused that an unbalanced panel data set had to be used in the calculations. The year 1999 has been chosen as a basis since it is the first year after the financial crisis of 1998 after which a period of relatively stable ‘playing-by-the-rules’ on agricultural and financial markets started. Hence, the results of the analysis are expected not to be significantly affected by changes in the economic and political environment.

In order to ensure consistency with one of the basic assumption of DEA, sub-panels were formed that are homogeneous in terms of their output sets. It is assumed that if a farm does not sell e.g. milk, then milk production technologies are absolutely inaccessible to this farm in the time horizon of our study. Each sub-panel defines a specific technological set. The analysis covers only those which include at least 10 farms in each of the two years. The six sub-panels which satisfy this condition are characterized in Table 1. The table provides also information about the outputs considered in the calculation. Ten 10 inputs are included: sown area, meadows and pastures, agricultural workers, sources of production costs financing, fodder, cows, sows, sheep and goats, fixed assets used in agricultural production, spare parts.

Usage of sown area as an input instead of arable land is due to the fact that even efficient farms in the Moscow region often underexploit arable land. In turn, this approach may cause other problems since the decision about sown area is made with respect to availability of other inputs which may be limiting. However, if the sown area constraint is binding only for a few farms this problem may be ignored. Spare parts is used as a proxy for machinery. A lack of spare parts may indicate the lack of financing rather than the lack of machinery. Identifying the reason requires to check the constraint on sources of production costs financing. If this constraint is not binding lack of spare parts indicates lack of machinery. Otherwise, no unambiguous conclusion is possible.

4 EMPIRICAL MODEL

The empirical model originates from the theoretical model from Section 2, with restriction (a) imposed:

$$R_i^* = \max_{\lambda,\mathbf{y}} (R \mid R = \mathbf{v}_i \mathbf{y},\ \mathbf{y} \le \mathbf{B}\boldsymbol{\lambda},\ \mathbf{A}\boldsymbol{\lambda} \le \mathbf{a}_i)\,. \qquad (3)$$

Problem (3) determines farm *i's* optimal revenue (R_i^*) taking the actual amount and structure of inputs as given. Comparison of the modelled indicators of financial efficiency against actual indicators reveals the amount of reserves.

To calculate the attainable level of revenue under the conditions of free availability of input *j* the problem

$$R_{im}^* = \max_{\lambda,\mathbf{y}} (R \mid R = \mathbf{v}_i \mathbf{y},\ \mathbf{y} \le \mathbf{B}\boldsymbol{\lambda},\ \mathbf{A}^m \boldsymbol{\lambda} \le \mathbf{a}_i^m) \qquad (4)$$

should be solved. This is obtained from theoretical model (2) with the imposed restriction (a) and omitted constraint on the input *m*. In (4) $\mathbf{A}^m$ is is similar to $\mathbf{A}$ but has the line *m* omitted; $\mathbf{a}_i^m$ is derived from $\mathbf{a}_i$ in the same way. The specification (4) is used for all inputs except sources of production costs financing.

Omitting a constraint implies that the fixed input is available for free and production costs do not grow because of its increased usage. When dealing with the input 'sources of financing of production costs', the assumption of unchanged production costs implies that the additional sources are not used. This renders the procedure senseless. For this reason, in this specific case we assume that a higher input necessarily result in larger costs (for instance, a farm urgently obtains a resource at a higher price in order to prevent skipping an important technological operation). To formally represent this assumption, problem (4) is replaced by the following one:

$$R_{im}^{*} = \max_{\boldsymbol{\lambda},\mathbf{y},c}(R \mid R = \mathbf{v}_i\mathbf{y} - c,\ \mathbf{y} \le \mathbf{B}\boldsymbol{\lambda},\ \mathbf{A}^{m}\boldsymbol{\lambda} \le \mathbf{a}_i^{m},\ \mathbf{a}_m\boldsymbol{\lambda} \le a_{mi} + c), \quad (5)$$

where m relates only to the input 'sources of production costs financing', $\mathbf{a}_m = (a_{mi})$, and c represents additional production costs (excluding depreciation costs).

The problem

$$k_i^{*} = \max_{k,\boldsymbol{\lambda}}(k \mid \mathbf{a}_i \ge \mathbf{A}\boldsymbol{\lambda},\ k\mathbf{b}_i \le \mathbf{B}\boldsymbol{\lambda}),\ \ R_i^{**} = k_i^{*}\mathbf{v}_i\mathbf{b}_i, \quad (6)$$

where $\mathbf{b}_i = (b_{ni})$ and k is an output growth ratio, facilitates splitting overall inefficiency measured by problem (3) into two parts: Technological inefficiency $R_i^{**} - R_i$ and allocative inefficiency caused by inadequate market adaptation $R_i^{*} - R_i^{**}$, where R_i is are actual returns of farm i. This problem follows from (2) by imposing restrictions (a+b) described in Section 2. That is, it has the form of an ordinary output-oriented DEA model.

Finally, the problem

$$k_{im}^{*} = \max_{k,\boldsymbol{\lambda}}(k \mid \mathbf{a}_i^{m} \ge \mathbf{A}^{m}\boldsymbol{\lambda},\ k\mathbf{b}_i \le \mathbf{B}\boldsymbol{\lambda}),\ \ R_{im}^{**} = k_{im}^{*}\mathbf{v}_i\mathbf{b}_i, \quad (7)$$

has the same purpose as (4) regarding technical efficiency. That is, it captures an impact of a particular input on the technical efficiency level of a farm and is obtained from (6) by releasing one of the input constraints.

5 RESULTS

The data of Table 1 suggests that, despite ten years having passed after the origination of market reforms, agricultural production again calls for restructuring. The relatively favourable farming sector price system that was set up after the financial crisis in August 1998 has already receded into the past. As a result, the need to adjust production to market challenges, which was quite significant in 1999, became even greater by 2002 in all groups. Farms lack time to make investments in the required structural adjustments in a persistently changing market conjuncture. The farms that are worst adapted to the market belong to the most numerous groups, I and II; these farms do not produce pork and vegetables. Technical efficiency of all groups but VI improved during this period. In addition, the farms utilize existing technological opportunities quite satisfactory and hidden constraints appear not to be very hampering. Moreover, the increase of overall inefficiency was mainly caused by a poor adaptation to the market.

Shortages of different resources influence economic efficiency differently (Table 3). In 1999, the number of sows are the most limiting input in groups IV to VI. Interestingly, in the other groups no shortage of this input was observed. Sown area, fixed assests and sources of production financing had the largest impact on returns. In 2002 the situation changed significantly. Animal input was not most restricting factor in neither group. Moreover, releasing those constraints would increase returns per hectoare only to a limited extent. Higher impacts on returns resulted from free access to sown area, sources of production financing and fixed assests. Inefficiencies caused by a lack of financing are being reduced and replaced by those resulting from the lack of fixed assets, land and labour force. In 2002, the greatest inefficiencies in Groups I, II and V are observed for machinery, since returns appear to be sensitive to spare parts expenses rather than to total production expenses.

Although technical inefficiency plays a minor role in the problems of farm businesses in the Moscow region, it is still of both scientific and practical interest. As expected, the less numerous the group, the higher the efficiency score. The scores presented in Table 4 (except the last line) are the differences between average k^*_{in} and k^*_i obtained from problems (7) and (6). The last line contains average efficiency scores obtained from problem (6).

In 1999, technical efficiency, similar to allocative efficiency, suffered primarily from the lack of short-term finance (Groups I through IV). In Group V, the factor that most hampered technical efficiency was the deficit of fodder, which originated in the same problem of shortage of short-term assets (Group V). In the three largest groups, wider liquidity sources can remove 30 % (Group II) to 48 % (Group III) of existing technical inefficiency, which is not large for transitional agriculture, where it is partially caused by successfully operating farms having some resources frozen in projects under construction. Moreover, easier access to fodder can also decrease technical inefficiency in these groups by 8 to 36 %. Increasing the cow population removes 10 to 16 % of technical inefficiency.

The analysis of year 2002 suggests that in Groups I and II, fodder took the leading position, with up to 19 % and 37 %, respectively, of total technical inefficiency. Short-term finance lost its leading position but remained influential at 19 % and 31 %, respectively. In Group III, we observe a novel situation: The topmost constraint to technical efficiency is now sown area, whose lack causes 48 % of technical inefficiency. The reason is that farms of this group can access vegetable growing technologies. However, this interesting finding, when considering Russia's limited market capacity, rather suggests overuse of other resources (in particular, labour and fixed assets other than machinery) with respect to the most efficient technologies. Remarkably, the sown area also strongly limits returns in this group in 2002 (Tables 3). Group IV lacks cows in terms of technical efficiency, while its returns are mostly affected by short-term finance. Technical efficiency in the other groups is constrained by machinery.

6 Conclusions and discussion

The study has demonstrated the capabilities of DEA as a tool for identifying constraints hampering efficiency increases. The results of other studies, which stress managerial failures and conservative agricultural policies in Russia, are supported to a very limited extent. The essential source of ineffective resource allocation, according to our findings, is an unstable market. Management reacts to market changes, as a rule, in an appropriate way, even if constrained with financial difficulties and with natural restrictions following a protracted cycle of agricultural production. In an institutional sense, our study shows the insufficiency of the agricultural financial system regarding the requirements and specificity of agricultural production, despite the many positive changes in this sphere.

The methodological framework applied to this study suggests that it is not wholly correct to attach estimated technical inefficiency only to scale and allocation problems, which in turn relate to either management or institutional failures. Very often the reason is that the technological set appears to be significantly more complex than represented by the model. Hence, the farms may appear in unequal positions with respect to the omitted particularities of the technology that can be brought to light by means of sensitivity analysis. In particular, our study gains from the explicit accounting for sources of production costs financing as a specific resource, whose lack could cause unexplained inefficiency in a data envelopment model omitting any liquidity constraint.

This study shows the importance, among the various options for solving the social and economic problems of rural society, of the following actions:

- Stabilisation of market conjuncture;
- Support for restructuring production;
- Facilitating access to investment resources.

Newly-emerging shortages of sown areas is a positive finding. If this tendency persists, it would allow for the transition from declarations to deeds in the field of establishing a truly functioning agricultural land market.

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Table 1: Groups of the Moscow region's corporate farms

Number of sub-panel (production pattern)	Farms selling:									Number of farms	
	Cereals	Potatoes	Vegetables	Other crop production	Beef	Pork	Milk	Other animal production*)	Non-agricultural production	1999	2002
I	+			+	+		+	+	+	42	60
II	+	+		+	+		+	+	+	57	54
III	+	+	+	+	+		+	+	+	32	29
IV	+	+	+	+	+	+	+	+	+	10	12
V		+	+	+	+		+	+	+	14	12
VI	+	+		+	+	+	+	+	+	17	10

Source: Authors' calculations based on data from ROSSTAT.
Notes: *) Animal production excluding meat, poultry, dairy milk, wool and eggs.
The farms of the six sub-panels do not produce wool or eggs.

Table 2: Opportunities to increase efficiency on Moscow region corporate farms

	Groups (production patterns)					
	I	**II**	**III**	**IV**	**V**	**VI**
Year 2002						
Sales Profitability*, %, actual	-29.7	-27.9	-4.2	-3.3	-5.0	-25.0
modelled	2.3	12.5	19.9	14.2	-0.5	-18.3
Loss due to inefficiency	32.0	40.4	24.1	17.5	4.6	6.7
- Due to technical inefficiency	7.8 (24.4 %)	2.5 (6.2 %)	4.2 (17.5 %)	0.0 (0.0 %)	0.0 (0.0 %)	2.3 (34.8 %)
- Due to allocative inefficiency	24.2 (75.6 %)	37.9 (93.8 %)	19.9 (82.5 %)	17.5 (100.0 %)	4.6 (100.0 %)	4.4 (65.2 %)
Year 1999						
Sales Profitability*, %, actual	-6.4	-7.4	13.5	4.4	24.7	-5.4
modelled	27.2	16.8	30.7	16.4	34.1	0.8
Loss due to inefficiency	33.6	24.1	17.3	12.0	9.4	6.1
- Due to technical inefficiency	10.2 (30.3 %)	9.7 (40.0 %)	4.2 (24.4 %)	0.4 (3.7 %)	2.3 (24.3 %)	1.1 (17.3 %)
- Due to allocative inefficiency	23.5 (69.7 %)	14.5 (60.0 %)	13.1 (75.6 %)	11.6 (96.3 %)	7.1 (75.7 %)	5.1 (82.7 %)

Source: Authors' calculations based on solutions of models (3) and (6).
Notes: The table presents weighted averages across the patterns. The weights are the sales values.
*) Short-term profit per cent of revenue (depreciation is not included in costs).

Table 3: Additional revenues per hectare of agricultural land in the case of free access to the given input, roubles

Inputs	Groups on production patterns					
	I	II	III	IV	V	VI
Sown area	**10.39** 0.57	**51.98** 18.62*	**312.97*** 6.37	**—** —	**3.53** 0.45	**8.41*** —
Meadows and pastures	**20.79** 4.97	**14.78** 2.43	**29.64** 28.35	**—** —	**0.36** 95.74	**—** 2.43
Agricultural workers	**19.90** 0.75	**—** 5.78	**0.69** 0.07	**44.56** 14.76	**97.51** 74.39	**—** —
Sources of production costs financing	**0.93** 2.80	**29.34** 6.85	**22.56** 32.44*	**32.98*** 1.09	**—** 3.72	**—** —
Fodder	**22.24** 12.58	**1.77** 4.52	**—** 2.96	**11.02** 10.08	**—** —	**—** 6.61
Cows	**3.89** 2.80	**16.31** 0.45	**1.06** 9.44	**—** 3.02	**—** 2.80	**5.55** 9.89
Sows	**—** —	**—** —	**—** —	**6.37** 49.12*	**—** 100.76*	**3.91** 24.34*
Sheep and goats	**—**	**—**	**—**	**12.50**	**—**	**2.08**
Fixed assets used in agricultural production	**31.98** 25.38*	**—** 1.66	**150.99** 14.13	**1.38** 40.55	**—** 77.46	**0.71** 9.60
Spare parts (a proxy for machinery)	**50.98***	**69.60***	**188.37**	**5.69**	**116.18***	**—**

Source: Authors' calculations based on solutions of models (5), (4) and (3).

Notes: * Upper (bold) figures relate to 2002, while lower relate to 1999.
In 1999 there were no farms lacking sheep and goats.
In 1999 the model misses the constraint on spare parts due to an absence of source data.
Asterisks mark the highest value in a group for the given year.

[a]) $R^*_{im} - R^*_i$.

Table 4: Influence of inputs on technical efficiency on the Moscow region's corporate farms

Inputs	Increase of technical efficiency in case of free input[a], %, in the group:					
	I	II	III	IV	V	VI
Sown area	0.40 (-0.49)	0.21 (-0.79)	2.25* (2.25)	— (—)	— (—)	— (—)
Meadows and pastures	0.51 (0.51)	1.33 (0.81)	1.44 (1.24)	— (—)	— (—)	— (-0.82)
Agricultural workers	0.77 (0.55)	— (-0.28)	— (-0.02)	— (—)	— (—)	— (—)
Sources of financing of production costs	1.88 (-3.99*)	1.22 (-2.49*)	0.97 (-2.34*)	— (-2.72*)	— (-0.44)	— (-0.20)
Fodder	1.89* (0.57)	1.46* (-1.53)	0.75 (-1.72)	— (—)	0.60 (-0.26*)	— (-0.04)
Cows	1.74 (-0.82)	0.63 (-0.56)	0.28 (-0.56)	1.17* (1.17)	— (—)	— (—)
Sows	0.12 (0.12)	— (—)	— (—)	— (—)	— (-0.38)	— (-1.08)
Fixed assets used in agricultural production	0.60 (-0.27)	0.49 (0.08)	0.30 (0.14)	— (—)	— (-0.75)	— (-2.35*)
Spare parts (a proxy for machinery)	1.78	1.31	1.42	—	0.71*	4.04*
Average technical efficiency measure	**90.27** (6.00)	**96.01** (8.46)	**95.35** (2.29)	**98.66** (0.27)	**100.00** (3.83)	**100.00** (1.48)

Source: Authors' calculations based on solutions of models (7) and (6).

Notes: * The figures in brackets are the changes to 1999, in points. A dash represents no influence (no change). In 1999, the model misses the constraint on spare parts due to an absence of source data.
The asterisks mark the constraint with the highest impact on efficiency (for instance, the asterisk at -0.26 means that the year 1999 the increase of 0.6 - (-0.26) = 0.86 was the greatest in Group V.

[a]) Mean value without weighting.