Factors of technical and economic efficiency of corporate farms in Moscow region

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1. Introduction

After more than a decade of transition to market system the objective nature of transitional problems in Russian agriculture has been at last widely acknowledged. Consequently, the researchers' attention is drawn now mostly by the economic causes of existing problems rather than by political ones, as it took place recently.

The mainstream of econometric studies of Russian agriculture has shifted from just understanding the situation to its regular monitoring for the purpose of providing systematic appropriate advices to politicians. These advices should be based on regular and easily understood methodological approaches. The methodologies should be powerful enough to address a wide range of practical questions of agricultural policy.

Russian agriculture experiences a bundle of long-term problems that probably require politicians' attention in future with no regard to the completion of transitional process. This bundle includes difficult natural conditions, low land price (*Gataulin et al.*, 2003), hard competition with other branches of economy for capital and labour force (*Svetlov*, 2003), the burden of social problems (*Uzun et al.*, 1999), insufficient quality of labour resources, lack of managerial and technological skills (*Serova*, 2000), unstable political and legal environment (*ibid.*). However, there are tactical problems that should be watched on a regular base to react appropriately in short run. Among them there are lacks of short-term capital (*Svetlov*, 2003; *Epstein & Tillack*, 1999), machinery (*Zinchenko*, 2001), labour (in terms of quantity), livestock and so on. These problems arise due to frictions in resource flows resulting from underdevelopment of specific institutions or insufficient infrastructure.

The aim of this paper is to develop and test a systematic approach applicable for monitoring the restricting factors of agricultural production efficiency at the regional level.

The theoretical contribution of the paper is a microeconomic framework that allows identifying, classifying and measuring the constraining factors of economic and technical efficiency, allowing levels of aggregation as low as data permit. The empirical contribution is finding that since

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2002 short-term capital no longer occupies the position of the most important factor constraining efficiency of agricultural corporate farms in Moscow region. It is replaced with a set of constraints including lacks of machinery, labour and even land, which indicates very important changes: many resources have become scarce, hence, market resource allocation can now be expected to become effective indeed.

The set of research questions is:

a) what is an econometric technique that facilitates the above formulated aim of this paper in the best way?

b) how to identify and measure the constraining factors of production efficiency in its different aspects?

c) what are the key constraining factors of production efficiency on Moscow region corporate farms and how do they change within time?

2. Theoretical framework

Many researchers underline the advantages of non-parametric estimation techniques over traditional regression models in econometric studies. Among the non-parametric approaches, the data envelopment analysis (DEA), which is based on linear programming (LP) representation of production frontier suggested by *Fare et al.* (1994), has occupied the leading position. However, the potential of LP represented production frontiers seems to be far from being fully utilized. Here we bring to light just two problems related to DEA in many recent studies.

♦ First, it is well recognized that efficiency measures obtained from DEA analyses are just relative indicators, which are comparable only given the same empirical model. Hence, they have to be compared very carefully between different studies. However, there is still a lack of understanding among economists what is a ‘great’ inefficiency and what is not. Clear and reliable rules of interpretation of DEA outcome are still missed.

♦ Second, in addition to efficiency measures, the DEA models produce (or, to be precise, can produce when properly designed) a plenty of analytical information like shadow prices, scenario analyses, sensitivity tests outcome etc.

In this respect, hereafter we use the approach based on two origins:

♦ the neo-classic microeconomic model of a firm;

♦ the LP representation of production frontier like in DEA.

The basic assumption of this approach is that the technological set of a homogenous sample of firms is sufficiently represented by a linear combination of the observed technologies within the given set of firms. The key idea of the DEA is that a location of a firm outside a production frontier indicates that the firm experiences a specific problem that does not hamper the activities of firms located on the frontier. This allows identifying the problem.

Following the above formulated assumption, a firm (a farm in our case) can be represented in a following way:

$$P^* = \min_{\boldsymbol{\lambda},\mathbf{x},\mathbf{y}}(P \mid P = \mathbf{vy} - \mathbf{wx},\ \mathbf{y} \le \mathbf{B}\boldsymbol{\lambda},\ \mathbf{A}\boldsymbol{\lambda} \le \mathbf{x} \le \mathbf{a}), \qquad (1)$$

which is a specification of the general model

$$\max_{\mathbf{y},\mathbf{x}}(P \mid P = \mathbf{vy} - \mathbf{wx},\ \mathbf{y} \in Y(\mathbf{x})). \qquad (2)$$

The notations are: P^* is an optimal profit; $\mathbf{w}$ and $\mathbf{v}$ are vectors of average input and output prices respectively; $\mathbf{x}$ and $\mathbf{y}$ are optimal vectors of inputs and outputs respectively; $\boldsymbol{\lambda}$ is an optimal vector of intensities of the technologies; $\mathbf{A} = (a_{mi})$ is an input matrix consisting of all available farms' input vectors; $\mathbf{B} = (b_{ni})$ is a corresponding output matrix consisting of all available farms' output vectors; $Y(\mathbf{x})$ is a set of outputs that are possible when inputs $\mathbf{x}$ are given; $\mathbf{a}$ is a 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 considering an ad hoc defined time horizon, i.e. for fixed inputs;
- infinitely large values for other (variable) inputs.

The foremost outcome of the model is P^*. It is always greater or equal to an actual profit from sales value observed in the prototype farm. Closeness of P^* to the actual profit indicates that the farm uses the resources reflected by the model in an efficient way, that means it perfectly utilizes the technological knowledge reflected by the model and does not have any hidden constraints hampering its business. Otherwise the case is poor utilization of technological knowledge (i.e. managerial failures) or presence of constraints that the researcher has to bring to light as problems. These problems may appear as actual problems of the farm or as misspecifications of the model: likely some scarce fixed inputs, maybe hardly observable, are missed. An instructive example is liquidity constraints, which are seldom taken into consideration within the framework of neoclassical approach.

With respect to the aim of our study, this model can also be used as a source of shadow prices of fixed inputs. Under perfectly functioning market and good management the shadow prices are expected to be close to market prices. However, the closeness implies both good market and management only when continues over time, because it also can appear at random. Considerable difference between shadow prices and **w** can be conditioned by insufficient resource management. If this is not the case then:

♦ A shadow price below market price indicates, commonly, that in the given time horizon market fails to sweep out the excess amount of the input or that the market is overheated[2].

♦ Opposite relation between market and shadow prices means a failure of market to deliver necessary quantity of the resource within an available time frame.

Analytical significance of shadow prices is widely known; nevertheless, they characterize only local situation in the surrounding of optimal technology. Deeper analysis requires addressing the question about the amount of existing shortages of a particular resource with respect to other available resources. For this purpose, a component of vector **a** corresponding to a scarce fixed input is replaced with an infinitely large value simulating an abundant resource. Incremental profit indicates the opportunity of profitability growth (therefore, of increasing efficiency of other fixed inputs) by means of increasing the amount of given fixed input. The model also yields the necessary increment of this fixed input.

Problem (1) is very capable in terms of performance analysis. If the solution is outside the frontier then, in order to identify the reason for this situation, it is possible to decompose the observed lack of performance into its components by means of imposing additional restrictions to (1). For instance, the following restrictions can be consequently imposed:

a) all inputs are fixed at their actual values;
b) the structure of outputs is fixed as actually observed;
c) $\boldsymbol{\lambda}\mathbf{1}$, where $\mathbf{1}$ is a vector of ones, is set to 1.

Step (a) allows a researcher to measure the profitability loss due to nonoptimal input structure caused by either managerial or market failures. Step (b) collapses in a classical output-oriented DEA problem that is used for the purpose of technical efficiency analysis, as the solution no longer depends on prices. Compared to (a), it identifies profitability losses due to nonoptimal output allocation. Step (c) captures scale effects.

At step (b) and below shadow prices are scarcely useful for analytical purposes. However, the opportunities of efficiency growth can be identified and measured in the above described manner, i.e. by releasing fixed input constraints.

The important methodological issue we deal with in this paper is that if a farm is in some sense ineffective then *there is a hidden constraint*, due to which the actual technology differs from the modeled one resulting in lower efficiency. This issue directly relates to the first problem of DEA identified at the top of this section. It focuses researcher's attention at seeking for misspecifications instead of immediate claiming a business being improperly run. In this respect, the presence of a large body of ineffective farms (in other words, low ability of an empirical model to predict actual efficiency of the farms) suggests that the research value of a DEA model can be significantly improved by:

- identifying problems that make many farms relatively inefficient;
- mathematical formulation of these problems;
- explicit representation of them in the succeeding version of the model.

3. Empirical model

The empirical model originates at the theoretical model (1) from Section 2 with an actually observed input structure (restriction (a) from Section 2 is imposed). It consists of five linear problems described below. The first is

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

It should be solved for each farm in the data set. The notations are: R_i^* is an optimal amount of sales in the farm i; $\mathbf{v}_i$ is a vector of average output prices for the farm I; $\mathbf{y}$ is an optimal vector of outputs; $\boldsymbol{\lambda}$ is an optimal vector of intensities of the technologies, which are known from all the farms in the data set; $\mathbf{A} = (a_{mi})$ is an input matrix; $\mathbf{B} = (b_{ni})$ is a corresponding output matrix; $\mathbf{a}_i$ is a vector of actual inputs in farm i (that is the i-th column of $\mathbf{A}$); i is a farm index; m is an input index; n is an output index.

To address the question about the attainable level of profit from sales in case of free (for example, from farm's own storage) availability of input j and fixed availability of other inputs, 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. It results from the theoretical model (1) with the imposed restriction (a) and omitted constraint on the input m. In (4) $\mathbf{A}^m$ is the matrix that is similar to $\mathbf{A}$ but has the line m struck out; $\mathbf{a}_i^m$ is a vector resulted from $\mathbf{a}_i$ in the same way. In the case of the input ‘sources of financing of

[2] Overheat of a market can be distinguished by widespread, large and relatively uniform gap between shadow and market price throughout the analysed sample of farms.

production costs', in order to allow for increased costs in case of increased sources of their financing, the problem (4) is replaced by the following one:

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

where $\mathbf{a}_m = (a_{mi})$, c is incremental production costs (excluding depreciation costs), R_i^* is an incremental profit from sales plus depreciation costs.

Having overall losses caused by inefficiency approached by the instrumentality of problem (3) and denoting $(b_{ni}) = \mathbf{b}_i$, an output growth ratio as k, the problem

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

facilitates splitting these losses into two parts. The first part is losses caused by technological inefficiency: $R_i^{**} - R_i$. The second is losses caused by inadequate market adaptation: $R_i^* - R_i^{**}$, where R_i is an actual profit from sales of farm i. This problem follows from (1) with imposed restrictions (a) and (b).

Finally, the problem

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

has the similar purpose as (4) regarding to the technical efficiency. It captures an impact of a particular input on the technical efficiency level of a farm and results from (1) with restrictions (a) and (b), where, in addition, one input constraint is unset.

4. Data

This study has benefited from the data of the registry of Moscow region corporate agricultural farms provided by the State Statistical Committee of Russian Federation (Goskomstat). The registry includes data from annual statistical reports of those entities that are classified by Goskomstat (relying on organization charters) as corporate agricultural firms. The data cover farm profitability, gross and net inputs and outputs in kind (except aggregated inputs and outputs) and in a monetary measure, detailed data about subsidies, total amount of bank credits, overdue credits, accounts payable and receivable (total and overdue). We used the data of years 2002 and, for the purpose of comparison, of year 1999. Using this source, an unbalanced panel data set was formed. Year 1999 has been chosen as a base for comparison on two reasons:

a) this is a first year after the financial crisis of 1998, opening the period of relatively stable 'rules of game' at agricultural and financial markets, hence, the results of the analysis are expected not to be significantly affected by changes in economic and political environment;

b) it gives us an extra option to jointly verify the conclusions of this study to those of *Svetlov* (2001) addressing the research question (c) by the instrumentality of a different methodology.

Russian transitional agriculture is in the course of adjusting production to the changing price system under a pressure of great lack of capital. To ensure consistency of our study with the basic assumption of DEA, which is formulated in Section 2, 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. For, the farms were grouped (separately in each year) by their production patterns. Thereafter we call a *production pattern* a set of non-zero outputs of a farm. Each *group* defines a specific technological set and is analyzed independently on other groups. A group is characterized by a production pattern and a year, that is denoted in the following way: III/1999 means the group of year 1999 farms with production pattern III. An unbalanced *sub-panel* consists of two groups having the same production pattern in different years. Sub-panels are indexed by the number of corresponding production pattern.

The analysis covers only those production patterns that correspond to groups including at least 10 farms both in 1999 and 2001, as too small samples cannot yield a representative definition of a production set. There are 6 production patterns satisfying this condition, which define 6 sub-panels. They are characterized in Table A1 (see Appendix). Some descriptive statistics of these data are presented in Table A2.

In the empirical model (3)…(7) inputs and outputs are specified with maximal particularity that is attainable given the data. The list of outputs can be found in Table A1 in Appendix. There are the following 10 inputs in this specification: sown area; haylands and pastures; agricultural workers; sources of production costs financing[3]; fodder; cows; sows; sheep and goats; fixed assets used in agricultural production; spare parts.

Treatment of sown area as an input instead of arable land requires special reasoning. In Russia, where zero shadow price of land is very common, even most efficient farms often underexploit arable land. In DEA specification the amount of arable land available to a farm is assumed to be a technologically justified demand, but it is nowhere near true in a very specific Russian case (see e.g. Table A2 for the reference). Hence, it is reasonable to reflect arable land use by the actu-

[3] Following short-run profit optimization assumption, depreciation is not considered as a part of costs.

ally sown area. In turn, sown area constraint may capture the effect of other constraints, because the decision about sown areas is made with respect to other constraining factors. If there are few farms where the sown area constraint is bound, it can be ignored; otherwise data envelopment may appear to be an insufficient technique.

Spare parts are used here just as a proxy for machinery variable, which is not available from the data set. However, a lack of spare parts may indicate the lack of financing rather than the lack of machinery. To watch for that, the attention to the constraint on sources of production costs financing is necessary: if this constraint is unbound then the mentioned problem does not exist. Otherwise a conclusion about its presence is not possible. This should be taken into consideration when interpreting results.

5. Results

Ten years having passed after the origination of market reforms the process of agricultural production restructuring is still far from being completed. The relatively favourable for farming sector price system that had been set up after the financial crisis in August 1998 has already been sunk in the past. As a result, the need for adjustment of the production to the market challenges, which was quite significant in 1999, grew even greater by 2002 in all sub-panels except for I and V, where it has barely changed (Table 1). The farms are lacking time to make investments in the required structural adjustments under the conditions of persistently changing market conjuncture. The

1. The opportunities of increasing efficiency on Moscow region corporate farms

	Production patterns					
	I	II	III	IV	V	VI
Year 2002						
Profit*) to sales, %: 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
of that: due to a lack of technical efficiency	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 inadequate adaptation to market	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						
Profit*) to sales, %: 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
of that: due to a lack of technical efficiency	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 inadequate adaptation to market	23.5 (69.7%)	14.5 (60.0%)	13.1 (75.6%)	11.6 (96.3%)	7.1 (75.7%)	5.1 (82.7%)

The table presents weighted averages across the patterns. The weights are the sales values.
*) Short-term profit from sales (depreciation is not included in costs).

2. Share of the farms facing a lack of the given input, % to the number of farms in a group

Inputs	Production patterns					
	I	II	III	IV	V	VI
Sown area	**21.67** 7.14	**20.37** 33.33	**89.66*** 28.13	**—** 10.00	**25.00** 28.57	**50.00** —
Haylands and pastures	**23.33** 9.52	**7.41** 7.02	**20.69** 31.25	**33.33** —	**58.33** 50.00	**50.00** 64.71
Agricultural workers	**40.00** 7.14	**1.85** 29.82	**13.79** 6.25	**33.33** 10.00	**58.33** 64.29*	**—** 17.65
Sources of production costs (but depreciation) financing	**20.00** 88.10*	**72.22*** 84.21*	**48.28** 71.88*	**41.67*** 40.00	**16.67** 21.43	**—** 17.65
Fodder	**46.67** 45.24	**7.41** 45.61	**—** 21.88	**16.67** 40.00	**—** —	**30.00** 70.59*
Cows	**20.00** 19.05	**3.70** 24.56	**13.79** 28.13	**—** 30.00	**33.33** 7.14	**30.00** 52.94
Sows	**—** —	**—** —	**—** —	**8.33** 30.00	**—** 7.14	**10.00** 35.29
Sheep and goats	**—**	**—**	**—**	**8.33**	**—**	**50.00**
Fixed assets used in agricultural production	**56.67** 26.19	**1.85** 42.11	**48.28** 34.38	**16.67** 60.00*	**66.67*** 50.00	**80.00*** 58.82
Spare parts (a proxy for machinery)	**60.00***	**46.30**	**62.07**	**41.67***	**58.33**	**10.00**

An upper figure relates to 2002, the lower one relates to 1999.
In 1999 there are no farms lacking sheep and goats.
In 1999 the model misses the constraint on spare parts because of absence of the data.
Asterisk marks an input that is lacked most often in the corresponding group.

farms that are worst adapted to the market belong to sub-panels I and II, the most numerous. It is noticeable that these farms do not produce pork and vegetables, that are beneficial in the suburban areas like Moscow region.

Technical efficiency of the farms of all sub-panels but VI has been improved during this period, in contrast to worsening (but scanty sub-panels V and VI) adaptation to market. The farms utilize existing technological opportunities quite satisfactory: hidden constraints are not very hampering for technical efficiency.

As for 1999, the resource that farms are the most commonly short in was the source of financing of production costs (groups I-III/1999, the most numerous). This result coming from the data of Table 2 complements with *Svetlov* (2001). However, in 2002 the situation is different. In present the source of production costs financing appear to be the most widespread constraint in group II/2002 and (conjointly with spare parts approximating machinery) in group IV/2002, providing that the share of farms lacking this input decreased. In group VI/2002 and especially in group III/2002 the lack of sown area is noticeable, that previously was observed very seldom, because it was very problematic for farms to finance sowing. To conclude, corporate farms and rural financial system are step by step overcoming the most difficult problem of the previous ten years, which was the shortage of short-term capital. Since that, the demand for raising production intensity by means of investing in fixed production assets is a characteristic feature of present situation in the region, although the lack of short-term capital is still evident.

3. Expected incremental profit from sales[a] per hectare of agricultural land in case of free access to the given input, roubles×1000

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

Upper (bold) figures relate to 2002, lower relate to 1999.
In 1999 there are no farms lacking sheep and goats.
In 1999 the model misses the constraint on spare parts because of absence of the data.
Asterisk marks an input characterised by the highest incremental profit in the corresponding group.
[a]) Short-term profit from sales (depreciation is excluded from costs)

Shortage of different resources differently influences the economic efficiency. Lacks of production costs financing and of fodder, which both are caused by the shortage of turnover assets, were the most noticeable in 1999. Yet, the amount of inefficiency caused by them commonly was not found among the greatest (Table 3). They dominated only in group III/1999, while in other groups fixed assets, sown area and especially sows population availability were found to be more restrictive constraints. It is noticeable that the lack of sows has been largely reduced during the three years, that indicates proper reaction of farm managers to market signals.

As it follows from the empirical specification, the indicators of lacks of sources of production costs financing are not directly comparable to those of lacks of other resources. However, this does not hinder us from observing the general tendency, displayed by both Table 3 and Table 2. Particularly, the inefficiencies caused by the lack of finance are being reduced and replaced by those resulting from the lacks of fixed assets, land and labour force. The greatest inefficiencies in groups I/2002, II/2002 and V/2002 should be attached to machinery, since the profit appears to be very sensitive to spare parts expenses rather than to total production expenses.

However, to recover such large reserves of profit, the spare parts expenses should be 9.5, 1.9 and 2.1 times correspondingly as large as at present (refer to Table A4 in Appendix). Actually this indicates existing differences in the technologies applied in the farms of the same production pattern. The practical conclusion is that step-by-step expansion of the machinery and corresponding technological improvements are a promising path of long-term development of agricultural corporate farms economy. Shadow prices in the problem (1) also justify this conclusion: an incremental rouble of spare parts expenses (caused by additional machinery) is repaid by 15.0, 12.8 and 17.3 roubles of incremental sales, correspondingly (Table A3 in Appendix).

Farms in groups III/2002 and VI/2002 can benefit from expansion of sowings (2.8 and 1.6 times, correspondingly), farms in group IV/2002 – from wider labour use (by 34%). But, as Table A3 suggests, shadow prices of sown area in groups III/2002 and VI/2002 are small (5.16 and 3.12 thousand roubles per hectare). Since that, even a small variation of yields or costs can turn these figures into zero. The shadow price of incremental worker in group IV/2002 is 194 thousand roubles: the margin of the wages is 16 thousand roubles per month. So, the farms that are short in labour force can benefit from attracting workers by means of increased wages, as this figure is much higher than the actual average wages, which amount to 4.5 thousand roubles per month. Alternatively, this margin can be used as a tool of stimulating labour discipline and qualification growth in order to intensify the use of existing labour resources.

Due to a lack of information about resource prices, the analysis of input shadow prices cannot be complete. However, shadow price of dairy cows display noticeable changes in 2002 in comparison to 1999: first, they grew (excluding sub-patterns IV and VI, amounting to less than 30 farms both), second, their variation, still large, became smaller suggesting that market forces continuously shift cows allocation among farms to an equilibrium point, which is characterised (assuming similar productivity) with equal shadow prices of the same resource in different farms. Increased shadow price of agricultural workers in five sub-panels and not very large difference between sub-patterns suggest that the level of underdevelopment of agricultural labour market is decreasing.

Shadow prices of sources of production costs financing are, excepting sub-pattern VI, larger than average credit rate in Russian economy, which was 0.393 in 1999 and 0.179 in 2001 (the data of 2002 is not yet available). Large gap is expected due to high risks and low solvency of corporate farms (see e.g. *Uzun*, 1999, *Epstein & Tillack*, 1999). The situation is opposite with fixed assets as a whole: shadow prices suggest apparent overinvestments in this resource in most of groups. However, the actual reason is the gap between book and fair market value of fixed assets mentioned by many researchers (see e.g. *Uzun* (1999)). So, the level of fixed assets shadow prices is hardly informative, unlike their change, which shows definite growth of their efficiency despite lack of capital needed to adjust their structure and their extremely low liquidity.

4. Possible incremental technical efficiency in case of free input[a)] in Moscow region corporate farms in 2002, %.

Free input	Production patterns					
	I	II	III	IV	V	VI
Sown area	0.40 (0.40)	0.21 (-0.79)	2.25* (2.25)	— (—)	— (—)	— (—)
Hayland and pastures	0.51 (-2.08)	1.33 (0.81)	1.44 (1.24)	— (—)	— (—)	— (-0.82)
Agricultural workers	0.77 (0.77)	— (-0.28)	— (-0.02)	— (—)	— (—)	— (—)
Sources of financing of production costs	1.88 (-12.63*)	1.22 (-2.49*)	0.97 (-2.34*)	— (-2.72*)	— (-0.44)	— (-0.20)
Fodder	1.89* (1.89)	1.46* (-1.53)	0.75 (-1.72)	— (—)	0.60 (-0.26*)	— (-0.04)
Cows	1.74 (0.88)	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 (-5.14)	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)

[a)] Mean value without weighting (mathematical expectation of technical efficiency measure for a random farm chosen from the corresponding data set).

The figures in brackets are the changes to 1999 in points. Dash means no influence (no change).

In 1999 the model misses the constraint on spare parts because of absence of the data.

Asterisk marks the positions that correspond to greatest incremental inputs (for instance, asterisk at -0.26 means that the year 1999 increment of 0.6-(-0.26)=0.86 was the greatest in group V/1999.

We are not able to analyse the spare parts shadow prices in the same way (by comparison against credit rate), because the spare parts are just a proxy. A unitary growth of spare parts expenses in our model is assumed to be conjoined with corresponding growth of machinery value, so, per unit of machinery the shadow prices would be times lower. The certain rate cannot be approached by means of available data.

Shadow prices of haylands and pastures are mostly higher than that of sown area because of large production expenses on arable lands. However, as it has been mentioned in *Svetlov* (2003), excess costs are often caused by delayed financing leading to technological failures. Better financing is expected to shorten losses and to allow loading arable land at its full capacity resulting in higher opportunity costs of arable land. Our results show that the growth of shadow prices of sown area from 1999 to 2002 is quite common, in support to these expectations.

Though technical inefficiency plays a minor role in the problems of farm business, it still of both scientific and practical interest. It is quite expected that the less numerous the group the higher its the efficiency score. The scores presented in Table 4 (except last line) are the differences between average k_i^* obtained from problems (7) and (6). The last line contains average efficiency scores resulting from (6). It is clearly seen that in 1999 the technical efficiency suffered first of all from the lack of short-term finance (groups I/1999 through IV/1999) or from the deficit of fodder, which originates in the same problem of shortage of short-term assets (group V/1999). This view of causes of technical inefficiency is very different from that of *Sedik et al.* (1999) and *Oude Lansink et al.* (2003). In 2002 new factors emerged: in groups I/2002 and II/2002 fodder took leading position (still a component of turnover assets; short-term finance lost leading position but remained influential close to fodder) but in group III/2002 we observe a novel situation: the topmost constraint to technical efficiency is now the sown area. Remarkably, the same factor strongly limits profitability in this group (Tables 2 and 3). Group IV/2002 lacks cows in terms of technical efficiency, while its profitability is mostly affected by short-term finance. Remaining groups lack machinery to improve technical efficiency.

6. Conclusions and discussion

The presented study has demonstrated the capability of LP representation of production frontier and DEA as a problem identification tool for the purpose of adjusting agrarian policies that addresses the first research question formulated in Section 1.

With respect to the second research question it provides the means of identifying constraining factors of both production and technical efficiency and measures widespread and severity of these factors.

Answering the third one, the most important constraining factors are the lacks of machinery and of turnover assets, particularly of sources of production costs financing (whose influence and widespread are decreasing). The shortages of land area and of workers are also noticeable.

Our study scarcely supports the results of *Oude Lansink et al.* (2003), *Sedik et al.* (1999) stressing at managerial failures and conservative policies. The essential source of ineffective resource allocation, according to the above presented analysis, is unstable market. The management operates, as a rule, in an appropriate way, being however constrained with scarce finance and with natural restrictions following from long-term nature of agricultural production. In institutional sense, our study has identified the insufficiency of agricultural financial system to the requirements and specificity of agricultural production, despite many positive changes in this sphere.

The methodological framework applied to this study, which is specified in Section 2, suggests that it is not wholly correct to attach estimated technical inefficiency to scale and allocation problems only, which in turn relate to either management or institutional failures. Sometimes, and very often, the reason is that the technological set appears to be more complex than it is represented by the model. Hence, the farms may appear in unequal positions with respect to the omitted particularities of the technology. Our study gains from explicit accounting for sources of production costs financing as a specific resource. This explains a large part of inefficiency brought to light by other DEA applications to Russian corporate farms.

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

- stabilisation of market conjuncture;
- support for restructuring production;
- stimulating growth of wages of agricultural workers.

The demand for the programs supporting accumulation of own turnover assets by corporate farms, which is noticed in *Svetlov* (2003), still remains. However, the focus of attention should be moved to increasing technological level of production by means of accessing more machinery.

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

The required improvements to the methodology that are the subject for future efforts are depicted below.

Comparison of 2002 to 1999 is not completely convincing, because the specification of year 1999 and year 2002 models is different on data availability and group composition reasons. In particular, in 2002 the effect of sources of production costs financing might be partially captured by the spare parts constraint, while in 1999 the situation might be inverse. The comprehensive data could yield conclusions that differ in some details from presented above; yet the conclusions drawn here relate to the best knowledge that is currently available from the existing data.

The reliability of the conclusions also suffers from the increased amount of bound sown area constraints in 2002. With respect to the discussion in Section 4 on usage of sown area instead of arable land area in the applied model it should be noted that these constraints are bound in 90% of farms in group III/2002 and in 50% of those in group VI/2002. That might cause (although not for sure) biased estimations: overestimated effect of arable land; underestimated effect of other resources, machinery and sources of production costs financing.

The analysis of expected incremental profit from sales is valid only under the assumption that a farm appears having some ‘unused storage’ of the analysed resource and thus does not pay any cost for obtaining it. The exclusion is the sources of production costs financing, for which such an assumption is fully meaningless and, on this reason, is not made. This is reflected by relation (5) of empirical model specification. Hence, the amount of inefficiency caused by the sources of financing is not comparable to other inefficiency amounts unless the latter are allowed for probable costs of their obtaining. This has not been done in our study because of difficulties in approaching these costs. In other words, the inefficiency amount attached to financing sources, which is given in Table 3, is underestimated compared to the inefficiency amount attached to other inputs.

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Appendix

A1. Subpanels of Moscow region corporate farms

Number of sub-panel (production pattern)	Farms sell:									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

*) Animal production excluding meat, poultry, dairy milk, wool and eggs.
The farms of the six sub-panels do not produce wool or eggs.

A2. Descriptive statistics of sub-panels

(minimal, average, maximal values and variance coefficient)

Variables	1999						2002					
	I	II	III	IV	V	VI	I	II	III	IV	V	VI
Sown area	0 2547.6 9136 63.2	333 2526.3 5982 45.2	612 2341.9 4404 42.5	575 2216.0 5464 61.3	5 1297.1 3753 89.1	1758 2906.8 4628 30.8	0 2595.6 5242 42.8	640 2770.6 9257 54.8	644 2331.9 4651 42.9	589 3009.8 4636 41.8	70 1150.8 2888 71.5	0 2346.9 4574 50.8
Hayland and pastures	0 847.4 2593 76.8	0 637.4 2205 77.2	0 610.0 1769 64.6	281 923.9 2197 76.8	0 991.3 3267 98.4	0 604.3 1761 66.9	0 598.3 1761 73.5	0 792.5 4611 95.4	0 759.3 2296 65.4	272 1232.9 3211 77.8	77 984.5 3305 104.5	94 716.5 1388 46.7
Agricultural workers	45 206.6 677 55.7	41 170.0 677 63.1	42 318.2 880 56.3	42 266.4 585 57.5	43 309.4 910 82.3	63 270.9 415 34.3	29 148.2 508 53.6	42 183.8 700 62.4	25 233.0 513 47.0	52 360.2 707 60.7	41 310.7 1041 100.2	63 182.6 288 43.1
Sources of financing of production costs	1523 13602.6 74632 86.7	2566 11144.5 72283 109.5	1995 20283.8 62042 64.7	1395 16492.0 41013 74.9	1514 20049.5 70250 108.3	4662 19117.4 50755 60.2	3137 22406.8 93902 70.2	3244 32968.7 226103 104.0	3736 39218.3 110437 56.5	6097 66662.3 138160 63.0	8546 47732.1 145760 94.1	5553 31126.4 96192 86.1
Fodder	565 5261.4 31625 96.2	510 4183.3 26853 105.9	633 5714.9 14323 66.2	168 4120.4 9171 68.8	503 5803.3 24364 105.9	1283 8537.4 27240 81.1	727 8300.8 25686 70.1	1359 11585.5 89351 119.9	712 10868.0 26333 56.3	1704 18429.3 46995 67.9	1847 12840.3 52923 110.9	1463 11769.8 47090 114.1
Cows	85 712.4 2861 68.1	80 517.3 1262 52.0	93 683.9 1520 56.8	11 665.4 1000 54.8	93 620.3 2131 86.1	52 771.6 1689 57.7	74 568.2 1233 50.7	84 660.2 3200 80.9	66 594.3 1458 50.0	164 839.6 1850 57.6	60 553.3 2476 121.0	196 539.5 1134 61.8
Sows		0 1.2 50 648.1		0 10.7 55 157.1	0 0.4 5 374.2	0 335.5 2087 153.2				0 50.5 260 147.7		0 170.0 1002 185.3
Fixed assets used in agricultural production	1144 63722.6 247115 74.8	11734 47216.5 101102 50.4	5167 79211.5 266566 62.7	27378 87139.1 228905 83.8	4263 50279.9 149990 87.1	36496 84530.2 272089 69.6	0 55500.5 147305 59.9	9220 65488.2 310167 96.2	4145 86768.4 255185 68.9	23543 121019.9 246937 56.7	17347 94722.7 271903 85.2	25778 78687.1 180853 60.9
Spare parts (a proxy for machinery)	…	…	…	…	…	…	0 1492.3 6388 96.1	50 2487.1 31318 180.8	38 2661.4 9171 86.6	140 4284.7 15419 103.5	296 2764.4 12803 131.3	197 1997.9 5198 81.6
Cereals	2 3183.1 40559 215.9	3 1132.0 9011 166.9	4 1770.3 15522 171.3	37 1005.5 2820 100.8		42 3088.5 14806 132.0	2 5128.1 56711 210.4	3 9075.8 52988 147.5	18 5044.9 19385 114.3	5 5222.4 27164 172.3		565 10037.8 35968 131.7
Potatoes	5 2784.9 45109 239.9		72 6191.8 39067 150.1	729 5893.2 28815 147.2	158 4890.0 37241 194.0	9 3842.6 20419 144.1		7 4557.4 43968 206.1	18 7844.1 59980 193.0	297 16757.3 51629 107.4	16 3394.3 20373 168.1	185 2715.1 8106 96.5
Vegetables			19 21383.5 137345 147.7	87 11372.0 88643 242.4	53 34513.1 201373 175.0				25 28607.2 151195 149.9	65 40356.6 201831 179.5	10 30646.7 147976 156.8	
Other crop production	1 222.1 2457 193.7	1 1300.5 50934 603.3	2 1385.8 13525 229.1	5 863.1 3764 168.2	1 710.1 5141 197.9	2 179.7 524 88.4	1 935.3 42022 583.6	1 426.1 4590 206.1	5 2857.7 34036 278.2	2 1387.6 10743 215.3	1 10503.3 87036 233.0	5 219.2 889 127.9
Beef	16 689.2 3655 102.7	17 1183.5 26299 338.8	6 376.0 1450 98.1	32 588.4 2245 114.6	7 571.6 2515 144.6	70 875.8 3480 102.4	4 837.9 4320 84.0	4 962.7 7421 121.1	88 797.9 2756 74.7	2 786.7 3246 119.9	14 944.4 5684 162.8	170 998.1 2555 75.3
Pork				1 19.5 36 65.3		1 1451.2 9527 165.2				1 61.6 490 220.5		4 1150.7 9712 263.3
Milk	1015 21272.5 148346 108.6	755 13563.4 52076 78.5	208 19023.6 56801 80.8	58 14730.5 38104 81.3	124 23610.9 118773 125.9	1198 25297.7 77249 80.2	609 20575.7 60324 69.8	89 27613.7 196287 115.1	855 23608.1 71933 69.9	340 27688.7 62419 77.0	79 23718.8 148989 179.0	4491 18637.9 44349 80.3
Other animal production*)	5 480.7 2409 108.5	14 1562.2 22176 299.8	3 2046.2 24308 233.4	64 1773.5 7431 131.0	14 796.1 3782 144.7	26 1315.7 10091 186.7	17 1527.8 27017 284.3	3 1366.8 17271 234.4	13 1247.8 10347 155.8	156 9636.8 38595 127.1	121 2531.3 17517 194.9	127 3940.5 21056 181.3
Non-agricultural production	13 726.7 12122 228.2	11 418.7 2828 132.2	2 1985.4 8386 110.0	138 1825.8 6083 133.8	18 1710.2 11042 178.6	9 649.2 4538 173.1	2 714.6 3472 117.9	2 1726.7 24372 234.2	36 2848.8 23698 176.7	14 7879.3 23379 95.8	123 3373.3 20191 162.7	23 1402.6 6238 128.9
Sales	0 3691.1 10405 48.0	0 3736.1 8487 48.9	0 3309.5 6176 42.8	872 3446.4 7698 54.4	22 2489.4 5507 67.9	2074 4012.4 7022 36.1	724 17276.9 74415 84.8	1601 25770.4 210074 125.3	5651 37644.1 120899 81.6	2453 64543.0 194899 89.8	3669 45439.8 173888 116.4	4644 25388.8 93351 103.4
Arable land area	0 2843.7 9131 54.8	0 3098.7 6282 47.4	0 2699.5 5693 46.4	591 2522.5 5501 51.8	22 1498.1 4028 80.7	1806 3408.1 5696 34.1	0 3095.0 6082 44.7	0 2983.8 9570 55.0	912 2629.7 5693 43.0	600 3442.4 5501 40.7	655 1510.3 3058 55.5	1980 3069.9 5194 33.3

*) Animal production excluding meat, poultry, dairy milk, wool and eggs.
Missed data are displayed as ellipses.

A3. Average shadow prices*) **of inputs in problem (3),** roubles×1000

Inputs	Production patterns					
	I	II	III	IV	V	VI
Sown area, per hectare	**2.51** 2.94	**13.58** 2.51	**5.16** 4.72	**—** 1.74	**21.39** 3.19	**3.12** —
Haylands and pastures, per hectare	**25.75** 25.78	**5.31** 54.62	**18.68** 29.39	**5.60** —	**13.65** 13.32	**23.74** 3.49
Agricultural workers, per person	**65.71** 21.63	**54.68** 33.33	**38.88** 26.66	**193.97** 97.83	**86.62** 48.29	**—** 2.97
Sources of production costs (but depreciation) financing, per thousand roubles	**0.68** 0.91	**1.04** 0.92	**1.07** 1.41	**1.10** 1.17	**0.72** 0.94	**—** 0.50
Fodder, per thousand roubles	**2.15** 2.90	**3.20** 0.52	**—** 1.35	**1.13** 1.46	**—** —	**1.84** 1.35
Cows, per animal	**24.61** 12.70	**74.38** 2.72	**18.23** 18.10	**—** 16.31	**14.80** 48.67	**11.34** 13.35
Sows, per animal**)	**—** —	**—** —	**—** —	**>0** >0	**—** >0	**>0** 38.65
Sheep and goats, per productive animal**)	**—**	**—**	**—**	**>0**	**—**	**13.37**
Fixed assets used in agricultural production, per thousand roubles	**0.25** 0.33	**0.18** 0.04	**0.62** 0.23	**0.45** 0.09	**0.08** 0.40	**0.04** 0.08
Spare parts, per thousand roubles	**14.99**	**12.79**	**7.06**	**8.15**	**17.25**	**3.95**

Upper (bold) figures relate to 2002, lower relate to 1999.
In 1999 there are no farms lacking sheep and goats.
In 1999 the model misses the constraint on spare parts because of absence of the data.

*) Mean value without weighting (mathematical expectation of technical efficiency measure for a random farm chosen from the corresponding data set).

**) Notation '>0' replaces very large values that are justified with only one farm having very few animals (for instance, the farm in group IV/2002 that has non-zero shadow price has only one saw).

A4. Average lack of resources at a farm, %

Inputs	Production patterns					
	I	II	III	IV	V	VI
Sown area, per hectare	28.19 13.70	37.32 13.70	**277.29** —	— —	**532.41** 44.76	60.73 74.72
Haylands and pastures, per hectare	161.88 99.92	**700.15** 26.77	238.89 114.87	— —	273.26 **280.77**	— 20.91
Agricultural workers, per person	31.64 14.08	— 24.60	5.26 5.54	33.78 12.26	297.71 71.86	— 1.48
Sources of production costs (but depreciation) financing, per thousand roubles	17.39 10.85	29.64 35.98	27.87 35.56	26.21 20.60	— 9.17	— —
Fodder, per thousand roubles	23.98 19.81	13.60 26.68	— 46.63	27.70 62.06	— —	— 28.45
Cows, per animal	15.85 **107.51**	51.98 27.81	5.19 24.62	— 120.61	— 25.42	26.16 66.49
Sows, per animal	— —	— —	— —	72.93 **294.22**	— —	**136.35** **821.87**
Sheep and goats, per productive animal	—	—	—	37.45	—	18.19
Fixed assets used in agricultural production, per thousand roubles	106.84 85.85	— **185.18**	107.62 **139.60**	2.57 52.62	— 65.01	9.88 236.83
Spare parts, per thousand roubles	**948.22**	91.23	253.73	**156.99**	210.70	—

Upper figures relate to 2002, lower relate to 1999.
Bold font indicates the largest lack per group.
In 1999 there are no farms lacking sheep and goats.
In 1999 the model misses the constraint on spare parts because of absence of the data.