Long-term efficiency of the Moscow region corporate farms during transition (evidence from dynamic DEA)

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Abstract

This paper the approaches developed in the context of dynamic DEA: In particular, we consider free disposablitiy, economies of scale and input congestions. The methods are applied to agricultural corporate farms in Moscow Oblast for the period 1996-2004. The main findings are (1) suboptimal output structure is dominant source of inefficiency, technical efficiency is less severe expect for farms with input congestion (2) farms are less constrained regarding variable inputs (or malfunctioning input markets) but, particularly in recent year by the availability of labour, and, (3) that farm do not suffer from scale inefficiency. However, we found indication that larger farms have less problems to cope with technical change.

Keywords: dynamic DEA, agriculture, Russia

JEL Classifications: D24, Q12

1 Introduction

Even several years after introducing market-oriented reforms Russian agriculture is still characterized by an unbalanced institutional development with the following characteristics:

- information asymmetry (Serova and Khramova, 2002);
- oligopoly (Serova et al., 2003, p.140; Svetlov, 2005);
- corruption (Gylfason, 2000; Serova et al., 2003, p.158);
- high transaction costs (Wehrheim et al., 2000; Csaki et al., 2000);
- low demand for factors of agricultural production: for land and land shares (Shagaida, 2005; Il'ina and Svetlov, 2006), for machinery (Serova et al., 2003, p.107);
- lack of collateral (Yastrebova and Subbotin, 2005; Csaki et al., 2000);
- very high opportunity cost of capital (Gataulin and Svetlov, 2005, p.224).

These characteristics are assumed to negatively influence ability of farms to fully use their technical capabilities and efficiently allocate their resources and production. Surprisingly, studies of Grazhdaninova and Lerman (2005) and Svetlov and Hockmann (2005) suggest that many Russian corporate farms appropriately react to market signals in short run. However, little is known about the long run impacts of the poor institutional environment in Russian agriculture. Even because of the impact of institutional factors on investment decisions, the consequences biased decisions can be severe since they influence factor allocation and remuneration as well as competitiveness of the sector over a long period.

This paper resents a first step in closing the gap of knowledge. It is aimed at measuring efficiency of agricultural corporate farms[3] in a long run framework. A special reference is made to impact of quasi-fixed inputs allocation on farms efficiency. We confine our study to the Moscow region using farm data spanning the period 1995 to 2004. Three hypotheses will be investigated:

1) Allocative inefficiency dominates technical inefficiency.
2) Farms evolved from mainly costs-constrained to labour-constrained.
3) Farm size is smaller than optimal.

The first two hypotheses are related to Svetlov and Hockmann (2005) who analysed allocative and technical efficiency in a static setting. The third hypothesis is justified by Yastrebova and Subbotin (2005) and Il'ina and Svetlov (2006).

We use the methodology of dynamic data envelopment analysis (DDEA) developed by Nemoto and Goto (1999) and (2003). We extend their structural analysis of overall efficiency scores initiated by Nemoto and Goto (2003) regarding two aspects:

- decomposing overall efficiency scores obtained from DDEA into technical and allocative components, and
- estimating the share of congestion effects within both technical and allocative inefficiencies.

The rest of this paper is organized as follows. Section 2 discusses the methodology used in study. Section 3 describes data. In Section 4 different empirical models are specified, whose results are discussed in Section 5. Section 6 compares our results to other studies and Section 7 concludes the paper.

2 Methodology

The methodology is based on two pioneering studies of Nemoto and Goto (1999, 2003) and their decomposing of overall efficiency scores obtained from DDEA into static and dynamic components. We extend this decomposition by developing another decomposition in dynamic technical and dynamic allocative efficiency scores. Dynamic technical efficiency is completely independent on value measures, including opportunity costs of capital, which are commonly used as discount factors in DDEA models.

2.1 Overall dynamic efficiency and its structure

The analysis of an intertemporal frontier is based on the assumption of a production possibility set Φ_t such that (Nemoto and Goto, 2003)

$$\Phi_t = \{(\mathbf{x}_t, \mathbf{k}_{t-1}, \mathbf{k}_t, \mathbf{y}_t) \in \mathbb{R}_+^{l+m} \times \mathbb{R}_+^{m+n} \mid (\mathbf{k}_t, \mathbf{y}_t) \in Y(\mathbf{x}_t, \mathbf{k}_{t-1})\}, \quad (1)$$

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[3] Refer to Osborne and Trueblood (2002) for definition.

with variable inputs (x_{it}, i = 1,..,l), quasi-fixed inputs (k_{it}, i = 1,..,m) and outputs (y_{it}, i = 1,..,n). $t \in \{t_0, t_1, \ldots, T\}$ represents time.

Overall dynamic (output oriented) efficiency[4], can be defined as

$$\mathrm{ODE} = \frac{R(\overline{\mathbf{k}_0})}{\overline{R}},$$

where $\overline{R}$ are cumulative revenues of a DMU in the period from t_0 to T (discounted to t_0) and

$$R(\overline{\mathbf{k}_0}) = 1\Big/\max_{\{\mathbf{y}_t,\mathbf{k}_t\}_{t=1}^T}\left\{\sum_{t=1}^{T}\gamma_t(\mathbf{w}_t{}'\mathbf{y}_t)\,|\,(\mathbf{x}_t,\mathbf{k}_{t-1},\mathbf{k}_t,\mathbf{y}_t)_{t=1}^T \in \times_{t=1}^T\Phi_t, \mathbf{k}_0 = \overline{\mathbf{k}_0}\right\}. \quad (2)$$

Here dashed symbols refer to exogenous values, γ_t reflects intertemporal preferences (or opportunity cost of capital), $\mathbf{w}$ is a $n\times 1$ output prices vector.

For addressing the first research hypothesis (see Section 1), we decompose ODE into *overall static efficiency* (OSE) and *overall efficiency of the dynamic allocation*[5] (OEDA). OSE will be further separated into ASE (*allocative static efficiency*) and TSE (*technical static efficiency*). Particularly,

$\mathrm{OSE} = R(\overline{\mathbf{k}_t})_{t=1}^T / \overline{R}$, where

$$R(\overline{\mathbf{k}_t})_{t=1}^T = 1\Big/\max_{\{\mathbf{y}_t\}_{t=1}^T}\left\{\sum_{t=1}^{T}\gamma_t(\mathbf{w}_t\mathbf{y}_t)\,|\,(\mathbf{x}_t,\overline{\mathbf{k}_{t-1}},\overline{\mathbf{k}_t},\mathbf{y}_t)_{t=1}^T \in \times_{t=1}^T\Phi_t\right\}. \quad (3)$$

$$\mathrm{OEDA} = \frac{\mathrm{ODE}}{\mathrm{OSE}}$$

$\mathrm{TSE} = \delta(\overline{\mathbf{k}_t},\overline{\mathbf{y}_t})_{t=1}^T$ with and

$$\delta(\overline{\mathbf{k}_t},\overline{\mathbf{y}_t})_{t=1}^T = 1\Big/\max_{\delta}\left\{\delta\,|\,(\mathbf{x}_t,\overline{\mathbf{k}_{t-1}},\overline{\mathbf{k}_t},\delta\overline{\mathbf{y}_t})_{t=1}^T \in \times_{t=1}^T\Phi_t\right\} \quad (bubble) \quad (4)$$

or, alternatively,

$$\delta(\overline{\mathbf{k}_t},\overline{\mathbf{y}_t})_{t=1}^T = 1\Big/\max_{\delta,\{\mathbf{y}_t\}_{t=1}^{T-1}}\left\{\delta\,|\,(\mathbf{y}_t = \overline{\mathbf{y}_t})_{t=1}^{T-1}, \mathbf{y}_T = \delta\overline{\mathbf{y}_T}, (\mathbf{x}_t,\overline{\mathbf{k}_{t-1}},\overline{\mathbf{k}_t},\mathbf{y}_t)_{t=1}^T \in \times_{t=1}^T\Phi_t\right\} \quad (pooling) \quad (5)$$

$$\mathrm{ASE} = \frac{\mathrm{OSE}}{\mathrm{TSE}}$$

The specification of TSE that we use differs from Nemoto and Goto (2003). The idea here is to completely avoid monetary terms in TSE specification and to preserve its original meaning specified in Charnes et al. (1978). This idea can be implemented in two ways, which we call 'bubble' and 'pooling' models. The choice among them depends on whether the researcher is interested in attaching uniform importance to each year or concentrates on the period T. Both

4 We prefer the term *overall dynamic efficiency* to *overall efficiency* used in Nemoto and Goto (2003) because the former underlines the dynamic nature of this indicator.

5 Nemoto and Goto (2003) call this *dynamic efficiency*.

specifications have disadvantages. In the 'bubble model' the technological possibilities of only one year is likely to determine the solution, namely that of the year when the inefficiency is the lowest. In the 'pooling model' the result is equivalent to a common static DEA analysis for period T: data of other periods do not affect $\delta(\overline{\mathbf{k}_t},\overline{\mathbf{y}_t})_{t=1}^T$. Further decomposition of TSE is performed in the conventional way (e.g. Grosskopf, 1986; Färe and Grosskopf, 1983).

When ASE is estimated from with constant return to scale imposed (Φ_t^{CRS})it can be decomposed into *allocative pure static efficiency* (APSE) and *allocative static scale efficiency* (ASSE) in the following way:

$$\mathrm{ASE} = \frac{R^{CRS}(\overline{\mathbf{k}_t})_{t=1}^T}{\overline{R}\cdot\delta^{CRS}(\overline{\mathbf{k}_t},\overline{\mathbf{y}_t})_{t=1}^T},$$

$$\mathrm{APSE} = \frac{R^{VRS}(\overline{\mathbf{k}_t})_{t=1}^T}{\overline{R}\cdot\delta^{VRS}(\overline{\mathbf{k}_t},\overline{\mathbf{y}_t})_{t=1}^T},$$

$$\mathrm{ASSE} = \frac{\mathrm{ASE}}{\mathrm{APSE}}$$

Here $R^{CRS}(\overline{\mathbf{k}_t})_{t=1}^T$ and $\delta^{CRS}(\overline{\mathbf{k}_t},\overline{\mathbf{y}_t})_{t=1}^T$ are defined according to (3) to (5) with $\Phi_t = \Phi_t^{CRS}$. where the latter follows (1) with imposed CRS property and free disposability (FD). $R^{VRS}(\overline{\mathbf{k}_t})_{t=1}^T$ and $\delta^{VRS}(\overline{\mathbf{k}_t},\overline{\mathbf{y}_t})_{t=1}^T$ are defined similarly but with $\Phi_t = \Phi_t^{FD}$, i. e., the omission of the constant return to scale restriction.

In the production possibility set Φ_t^{NFD} neither constant returns nor free disposability is imposed. The corresponding indicators ($R^{NFD}(\overline{\mathbf{k}_t})_{t=1}^T$ and $\delta^{NFD}(\overline{\mathbf{k}_t},\overline{\mathbf{y}_t})_{t=1}^T$ allow to decompose APSE into *allocative pure static efficiency under non-free disposability* (ASPEN):

$$\mathrm{ASPEN} = \frac{R^{NFD}(\overline{\mathbf{k}_t})_{t=1}^T}{\overline{R}\cdot\delta^{NFD}(\overline{\mathbf{k}_t},\overline{\mathbf{y}_t})_{t=1}^T}$$

and *allocative static congestion efficiency* (ASCE):

$$\mathrm{ASCE} = \frac{\mathrm{APSE}}{\mathrm{APSEN}}.$$

The restrictions required to impose the different properties to Φ_t can be found in Grosskopf (1986) with respect to return to scale and in Färe and Grosskopf (1983) with respect to congestion.

The decomposition of ODE can be oriented not only with regard to static sources and dynamic sources, but also with respect to allocative and technical sources. The latter is often of higher interest than the similar decomposition of OSE. Moreover, the results of this decomposition can differ from the traditional static view. It addresses efficiency of the intertemporal input structure and efficiency of output allocation over both commodities and time[6].

We define *technical dynamic efficiency* as $\mathrm{TDE} = \delta(\overline{\mathbf{k}_0},\overline{\mathbf{y}_t})_{t=1}^T$, where the right hand side is:

6 This interpretation of allocation conforms to the strict definition of a commodity given by Debreu (1959).

$$\delta(\overline{\mathbf{k}_0},\overline{\mathbf{y}_t})_{t=1}^{T} = 1 \Big/ \max_{\delta,\{\mathbf{k}_t\}_{t=1}^{T}} \left\{\delta \mid (\mathbf{x}_t,\mathbf{k}_{t-1},\mathbf{k}_t,\delta\overline{\mathbf{y}_t})_{t=1}^{T} \in \times_{t=1}^{T}\Phi_t, \mathbf{k}_0=\overline{\mathbf{k}_0}\right\} \qquad (bubble) \qquad (6)$$

or

$$\delta(\overline{\mathbf{k}_0},\overline{\mathbf{y}_t})_{t=1}^{T} = 1 \Big/ \max_{\delta,\{\mathbf{y}_t,k_t\}_{t=1}^{T-1}} \Big\{\delta \mid (\mathbf{y}_t=\overline{\mathbf{y}_t})_{t=1}^{T-1}, \mathbf{y}_T=\delta\overline{\mathbf{y}_T}, \\ \mathbf{k}_0=\overline{\mathbf{k}}_0, (\mathbf{x}_t,\overline{\mathbf{k}_{t-1}},\overline{\mathbf{k}_t},\mathbf{y}_t)_{t=1}^{T} \in \times_{t=1}^{T}\Phi_t\Big\} \qquad (pooling) \qquad (7)$$

Differently from (4) or (5) in these specifications the technologies of each year matter, because the quasi-fixed input paths of each decision maker is directly considered in the optimisation. Again, both specifications are independent of monetary measures. The former assumes uniform importance of periods while the latter biases TDE to the achievable performance increase in the latest period.

Allocative dynamic efficiency (ADE) can then be defined as ODE/TDE. Further decompositions of both ADE and TDE are possible following the same path as in the case of ASE. This provides the following efficiency measures:

- *allocative pure dynamic efficiency* (APDE);
- *allocative dynamic scale efficiency* (ADSE);
- *allocative pure dynamic efficiency under non-free disposability* (APDEN);
- *allocative dynamic congestion efficiency* (ADCE);
- *technical pure dynamic efficiency* (TPDE);
- *technical dynamic scale efficiency* (TDSE);
- *technical pure dynamic efficiency under non-free disposability* (TPDEN);
- *technical dynamic congestion efficiency* (TDCE).

These efficiency measures are jointly linked as follows: ADE = APDE×ADSE; APDE = APDEN×ADCE; TDE = TPDE×TDSE; TPDE = TPDEN×TDCE.

The purpose of these decompositions is to figure out how the scale and congestion effects influence:

- performance of producing a defined output-and-time mix;
- optimality of output-and-time allocation

from Debrew's (1959) point of view of a commodity.

2.2 Sources of inefficiency

In order to evaluate the second research hypothesis, it is necessary to identify the factors that affect the various lower efficiency indicators. The available literature suggests two different ways to do this. One approach is incorporating constraints in DEA reflecting the possible sources of inefficiency. The example of such study is Svetlov and Hockmann (2005). However, the applicability of this approach is restricted to factors that may be represented as a constraint in DEA and to the limitations in number of constraints to the number of variables. However, the most common is a two-stage procedure: first, estimating efficiency scores by DEA, and, second, regressing the efficiency score on explanatory variables using Tobit regression (e.g. Kirjavainen and Loikkanen, 1998) or truncated regression (e.g. Bezlepkina, 2004).

Considering the aims of the study and the set of hypotheses to be tested, we apply two-stage analysis. However, Simar and Wilson (2000) argue that most of the second-stage analyses yield results that can be hardly reliably interpreted. Because of this problem, we do ot use regression but instead calculate the Spearman's rank correlations between efficiency scores and explanatory variables at the second stage.

The justification for this choice is the following. The presence of noise in the source data negatively biases the estimates of DEA efficiency scores. In addition, attaching efficiency scores of 1 to the farms on the revealed frontier is just a convention. Rather, it is quite reasonable to suppose that fully efficient farms do not exist. This suggests that it is more reasonable to rely on the ordering of the scores rather than on their magnitude. This diminishes the importance of data error problems and makes common informal procedures of data validity tests sufficient for obtaining scores order. Using non-parametric approaches on both stages increases robustness of the results and softens the requirements to analyzed data. In particular, this methodology allows us to use shadow prices obtained from DDEA models as explanatory variables in efficiency analysis. The necessary assumption to secure conclusiveness of Spearman's rank correlations is monotonicity of a factor to an efficiency score indicator. It needs to be tested before interpreting rank correlations.

2.3 Accessing return to scale

To address the third research hypothesis, two approaches are available. First, Färe and Grosskopf (1985) define three different production frontiers under different restrictions with respect to return to scale (RTS). A second originates from Banker (1984), Banker, Charnes and Cooper (1984). They propose:

- the value **i'λ**, where **i** is a unit vector and **λ** is a vector of weights estimated by DEA, and
- the dual value of the constraint **i'λ** = 1

as indicators of returns to scale attributed to a particular farm. Relative computational simplicity, which is important because of large size of the DDEA programming matrix, made us to decide in favour of the second approach.[7]

The dual value p_t^{VRS} of the VRS constraint has a clear economic interpretation. In the output oriented setup its meaning follows from (2):

$$p_{VRS} = \lim_{\varepsilon\to 1}\left\{ \max_{\{\mathbf{y}_t,\mathbf{k}_t\}_{t=1}^{T}} \left\{\sum_{t=1}^{T}\gamma_t(\mathbf{w}_t\mathbf{y}_t) \mid (\varepsilon\mathbf{x}_t,\varepsilon\mathbf{k}_{t-1},\mathbf{k}_t,\mathbf{y}_t)_{t=1}^{T} \in \times_{t=1}^{T}\Phi_t^{VRS}, \mathbf{k}_0=\overline{\mathbf{k}_0}\right\} - \\ -\varepsilon \max_{\{\mathbf{y}_t,\mathbf{k}_t\}_{t=1}^{T}} \left\{\sum_{t=1}^{T}\gamma_t(\mathbf{w}_t\mathbf{y}_t) \mid (\mathbf{x}_t,\mathbf{k}_{t-1},\mathbf{k}_t,\mathbf{y}_t)_{t=1}^{T} \in \times_{t=1}^{T}\Phi_t^{VRS}, \mathbf{k}_0=\overline{\mathbf{k}_0}\right\}\right\} \qquad (8)$$

Positive p_t^{VRS} indicates that a marginal proportional increase of variable and fixed inputs leads to a higher increase of an objective function ($R(\overline{\mathbf{k}_0})$)than the same proportional increase of objective function itself. Consequently, a negative dual value attached to **i'λ** = 1 suggests

[7] The latter is extended by Banker and Thrall (1992) in order to make allowance for the case of alternative solutions of DEA problems. However, this situation is of actual importance only for efficient farms (Førsund and Hjalmarsson, 2002). On this reason, we did not special efforts to address this problem.

that the DMU operates at increasing return to scale and vice versa. In case of constant return to scale this constraint is not binding (the corresponding dual value is zero).

The assumption of convexity of production possibility set is crucial for the RTS measures. If the technology does not possess this property the RTS analysis can be meaningless. However, it is possible to control for its validity at the stage of interpretation. Particularly, p_t^{VRS} should be positively correlated with ranks to DMU's size indicators.

3 Data

The source of data is a registry of corporate farms of Moscow region for the period 1995 to 2004 provided by Rosstat[8]. The information for some farms are incomplete and appear unreliable. These farms are excluded from the empirical analysis. One criterion for excluding an observation in a given year is more than ten times growth of either production costs or depreciation in comparison to the previous year. Additionally, we excluded observations that show unitary dynamic efficiency due to changes in fixed or quasi-fixed inputs that could not be explained given the available data. The example is a large herd population suddenly emerging in a particular year at an unknown expense. Table 1 specifies the number of observations available and used in each year.

Table 1: Number of observations available from the Moscow region corporate farms registry.

Year	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
# of observations	381	402	377	377	367	363	353	343	232
- excluded	3	15	–	27	38	21	4	5	1
- used	378	387	377	350	329	342	349	338	231

Source: authors' calculations.

For composing DDEA problems, the use of quasi-fixed inputs in 1995 are also required. These were available for 175 farms. These farms are subjected to farm-specific dynamic efficiency analysis. The reference technologies for each year are defined using the data of all farms (but excluded).

For each farm, the following data on fixed (non-reproducible) inputs (**x**) are available:

- Number of poultry, 000 heads;
- Number of employers;
- Arable land, ha[9];
- Meadows and pastures, ha;
- Long-term credit, thousand Roubles;
- Short-term credit, thousand Roubles;

The data on quasi-fixed (reproducible but not available at the market) inputs (**k**):

- Number of cows;

[8] Rosstat is a federal statistical agency of Russian Federation.

[9] Usage of the arable land is represented by a sown area. The availability is represented by the area of arable land owned or rented by a farm as for November 1st of the corresponding year.

- Number of pigs;
- Depreciation, thousand Roubles (proxy for the service of fixed assests);
- Costs, thousand Roubles;

The data on marketable outputs (**y**) are:

- Grain, tons;
- Revenue from grain sales, thousand Roubles;
- Revenue from sales of other crops, thousand Roubles;
- Milk, tons;
- Revenue from milk sales, thousand Roubles;
- Other animal production, thousand Roubles.

Farm-specific milk and grain prices that are calculated from the source data vary too widely. Such variation hardly can be explained by transaction costs and quality differences. The cause is an imperfect accounting, leading to inexact meaning of the 'revenue from sales' variables. The subject of an accounted contract is often grain (or milk) plus a set of services from either side of contractors. The contracts are likely to provide the options to delay payments, to pay in advance, to pay in kind (fuel against grain), prescribe specific transportation conditions, different terms of risks coverage, all these being accounted as revenue from grain or milk sales.

Another cause of large price variation is hold-up problems: the terms of some contracts might be fulfilled incompletely. This biases average prices calculated from actual revenues. In order to reduce the influence of above mentioned factors, for the purpose of this study we calculate average (for the Moscow region) prices of both milk and grain using the registry data as a source.

The discount factors, or annual opportunity costs, in the DDEA specifications are approximated average interest rates on short-term (one year and shorter) credits for the period 1996…2004 provided by the Central Bank of Russian Federation. The credits under consideration are credits in Roubles that are issued in the given year by credit organizations to juridical persons.

4 Empirical specification

The empirical DDEA models used in this study are output-oriented. Although it is possible under monetary criteria to optimize both inputs and outputs, the micro-economic data on physical amounts of inputs are not available.

Optimization problem (2) can be transferred into a linear programming problem:

$$
\begin{aligned}
&\max_{\{\mathbf{y}_{nt},\mathbf{k}_{nt},\boldsymbol{\lambda}_{nt}\}_{t=1996}^{2004}} \sum_{t=1996}^{2004} \gamma_t(\mathbf{w}_t\mathbf{y}_{nt})\\
s.t.\quad &\overline{\mathbf{x}_{nt}} - \mathbf{X}_t\boldsymbol{\lambda}_{nt} \geq \mathbf{0},\ t=1996,\ 1997,\dots,2004;\\
&\overline{\mathbf{k}_{n,1995}} - \mathbf{K}_{1995}\boldsymbol{\lambda}_{n,1996} \geq \mathbf{0};\\
&\mathbf{k}_{n,t-1} - \mathbf{K}_{t-1}\boldsymbol{\lambda}_{nt} \geq \mathbf{0},\ t=1997,\ 1998,\dots,2004;\\
&\mathbf{K}_t\boldsymbol{\lambda}_{nt} - \mathbf{k}_{nt} \geq \mathbf{0},\ t=1996,\ 1997,\dots,2003;\\
&\mathbf{K}_{2004}\boldsymbol{\lambda}_{n,2004} - \overline{\mathbf{k}_{n,2004}} \geq \mathbf{0};\\
&\mathbf{Y}_t\boldsymbol{\lambda}_{nt} - \mathbf{y}_{nt} \geq \mathbf{0},\ t=1996,\ 1997,\dots,2004;\\
&\boldsymbol{\lambda}_{nt} \geq \mathbf{0},\ \mathbf{y}_{nt} \geq \mathbf{0},\ \mathbf{k}_{nt} \geq 0,\ t=1996,\ 1997,\dots,2004,
\end{aligned}
\tag{9}
$$

where a dash over a symbol indicates that the parameter is bound to the actual date. $\mathbf{Y}_t$, $\mathbf{X}_t$, and $\mathbf{K}_t$ denote matrices containing the corresponding variables of all firms. *Overall dynamic efficiency* is then defined as an optimal value of objective function of (9) divided by actual return (Nemoto and Goto, 2003). For analytical purposes 16 different specifications of problem (9) are used (Table 2).

Table 2: Empirical model specifications used in this study (numbers refer to the corresponding formulae)

	Constant return to scale (CRS)				Variable return to scale (VRS)			
	Overall efficiency (OE)		Technical efficiency (TE)		Overall efficiency (OE)		Technical efficiency (TE)	
	Dynamic	Static	Dynamic	Static	Dynamic	Static	Dynamic	Static
Free disposability (FD)	(9)	(10)	(11)	(12)	(9), (13)	(10), (13)	(11), (13)	(12), (13)
Congestion model (CM)	(14)	(15)	(16)	(17)	(14), (13)	(15), (13)	(16), (13)	(17), (13)

Overall static efficiency is defined using:

$$
\begin{aligned}
&\max_{\{\mathbf{y}_{nt},\mathbf{k}_{nt},\boldsymbol{\lambda}_{nt}\}_{t=1996}^{2004}} \sum_{t=1996}^{2004} \gamma_t(\mathbf{w}_{nt}\mathbf{y}_{nt})\\
s.t.\quad &\overline{\mathbf{x}_{nt}} - \mathbf{X}_t\boldsymbol{\lambda}_{nt} \geq \mathbf{0},\quad t=1996,1997,\dots,2004;\\
&\overline{\mathbf{k}_{n,1995}} - \mathbf{K}_{1995}\boldsymbol{\lambda}_{n,1996} \geq \mathbf{0};\\
&\overline{\mathbf{k}_{n,t-1}} - \mathbf{K}_{t-1}\boldsymbol{\lambda}_{nt} \geq \mathbf{0},\quad t=1997,1998,\dots,2004;\\
&\mathbf{K}_t\boldsymbol{\lambda}_{nt} - \overline{\mathbf{k}_{nt}} \geq \mathbf{0},\quad t=1996,1997,\dots,2004;\\
&\mathbf{Y}_t\boldsymbol{\lambda}_{nt} - \mathbf{y}_{nt} \geq \mathbf{0},\quad t=1996,1997,\dots,2004;\\
&\boldsymbol{\lambda}_{nt} \geq \mathbf{0},\ \mathbf{y}_{nt} \geq \mathbf{0},\quad t=1996,1997,\dots,2004,
\end{aligned}
\tag{10}
$$

The efficiency indicator is given by the ratio (10) and actual return.

Specification (11) is used for (*pooled*) *technical efficiency* analysis. Comparison of solutions of (9) and (11) allows analysing the contribution of technical and allocative components to ODE.

$$
\begin{aligned}
&\max_{\{\delta_t,\mathbf{k}_{nt},\boldsymbol{\lambda}_{nt}\}_{t=1996}^{2004}} \delta_{2004}\\
s.t.\quad &\overline{\mathbf{x}_{nt}} - \mathbf{X}_t\boldsymbol{\lambda}_{nt} \geq \mathbf{0},\quad t=1996,1997,\dots,2004;\\
&\overline{\mathbf{k}_{n,1995}} - \mathbf{K}_{1995}\boldsymbol{\lambda}_{n,1996} \geq \mathbf{0};\\
&\mathbf{k}_{n,t-1} - \mathbf{K}_{t-1}\boldsymbol{\lambda}_{nt} \geq \mathbf{0},\quad t=1997,1998,\dots,2004;\\
&\mathbf{K}_t\boldsymbol{\lambda}_{nt} - \mathbf{k}_{nt} \geq \mathbf{0},\quad t=1996,1997,\dots,2003;\\
&\mathbf{K}_{2004}\boldsymbol{\lambda}_{n,2004} - \overline{\mathbf{k}_{n,2004}} \geq \mathbf{0};\\
&\mathbf{Y}_t\boldsymbol{\lambda}_{nt} - \delta_t\overline{\mathbf{y}_{nt}} \geq \mathbf{0},\quad t=1996,1997,\dots,2004;\\
&\boldsymbol{\lambda}_{nt} \geq \mathbf{0},\ \mathbf{y}_{nt} \geq \mathbf{0},\ \mathbf{k}_{nt} \geq 0,\quad t=1996,1997,\dots,2004,
\end{aligned}
\tag{11}
$$

A *dynamic technical efficiency* score is defined as $1/\delta_{2004}$, where δ_{2004} is a maximal possible increase of outputs in the last period with given amounts of fixed and *initial* amounts of quasi-fixed inputs.

Static technical efficiency is obtained from the following problem:

$$
\begin{aligned}
&\max_{\{\delta_t,\mathbf{k}_{nt},\boldsymbol{\lambda}_{nt}\}_{t=1996}^{2004}} \delta_{2004}\\
s.t.\quad &\overline{\mathbf{x}_{nt}} - \mathbf{X}_t\boldsymbol{\lambda}_{nt} \geq \mathbf{0},\quad t=1996,1997,\dots,2004;\\
&\overline{\mathbf{k}_{n,1995}} - \mathbf{K}_{1995}\boldsymbol{\lambda}_{n,1996} \geq \mathbf{0};\\
&\overline{\mathbf{k}_{n,t-1}} - \mathbf{K}_{t-1}\boldsymbol{\lambda}_{nt} \geq \mathbf{0},\quad t=1997,1998,\dots,2004;\\
&\mathbf{K}_t\boldsymbol{\lambda}_{nt} - \overline{\mathbf{k}_{nt}} \geq \mathbf{0},\quad t=1996,1997,\dots,2004;\\
&\mathbf{Y}_t\boldsymbol{\lambda}_{nt} - \delta_t\overline{\mathbf{y}_{nt}} \geq \mathbf{0},\quad t=1996,1997,\dots,2004;\\
&\boldsymbol{\lambda}_{nt} \geq \mathbf{0},\ \mathbf{y}_{nt} \geq \mathbf{0},\quad t=1996,1997,\dots,2004.
\end{aligned}
\tag{12}
$$

It is calculated similarly to *dynamic technical efficienc*.

The VRS efficiency scores are obtained by adding the constraints

$$\mathbf{i}\boldsymbol{\lambda}_{nt} = 1,\ t = 1996,\ 1997,\ \dots,\ 2004 \tag{13}$$

to any of specifications.

The assumption of freely disposable resources does not always hold. Relaxing it allows simulating a situation when farms only can dispose excess resources by using the production experience of other resource-excessive farms. The corresponding efficiency scores allow for a level of congestion in a particular farm (Färe and Grosskopf, 1983). To provide this in the empirical models, all the inequalities on fixed and quasi-fixed inputs, excluding the terminating condition $\mathbf{K}_{2004}\boldsymbol{\lambda}_{n,2004} - \overline{\mathbf{k}_{n,2004}} \geq \mathbf{0}$, are replaced with either equalities or two-sided constraints (see formulae (14) to (17) in Appendix 1). Two-sided constraints are used in the cases when some amount of a resource is known from the available data as disposable. In our particular case, this feature is only used for the case of arable land, on which we have data on both availability and usage. The data indicate that the latter is often less than the former. The data on outputs do not present total production but only sold amounts. Such data are not applicable for measuring outputs congestion. On this reason, in specifications (14) to (17) outputs remain freely disposable.

5 Results

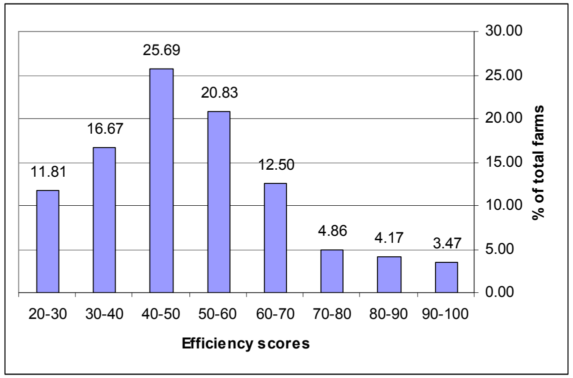
5.1 Composition of inefficiencies

The analysis presented below is based on the results of modeling 144 farms that conform to following requirements:

- their data have not been excluded from the model in either year on any reason;
- specification (9) resulted in an optimal solution[10].

The overall dynamic efficiency scores vary from 0.241 to 1. Figure 1 provides the distribution of the efficiency scores.

Figure 1: Distribution of overall dynamic efficiency scores



Source: own calculations

For the analytical purposes, we split all the 144 observations into sextiles with respect to overall dynamic efficiency score. The boundaries between the sextiles are 0.640, 0.550, 0.475, 0.415 and 0.330. Table 3 displays the structure of inefficiencies in terms of static and dynamic sources.

[10] Formally, the composition of all DDEA problems is such that infeasible solutions are not possible. However, since the simplex table of DDEA problem is very large, unavoidable computation errors sometimes prevent the simplex algorithm to converge to a feasible solution, although existing. As extensive testing suggests, this mostly relates to static and especially non-free disposability specifications and often happens to the farms that are located at the corresponding frontier or close to it.

Table 3: Efficiency scores associated with static and dynamic sources of overall dynamic inefficiency, %.

Sextile	ODE	Static sources			Overall efficiency of dynamic allocation (OEDA)
		OSE	ASE	TSE	
All	50.34	61.02	63.37	94.89	81.26
1	79.51	87.68	87.68	100.00	90.87
2	59.94	72.27	72.86	99.65	83.47
3	51.70	64.55	66.57	97.29	80.54
4	44.70	56.72	58.95	96.36	79.34
5	37.90	49.51	52.51	93.77	77.11
6	28.31	36.98	45.21	83.51	76.72
Spearman's rank correlation to ODE		*0.961*	*0.931*	*0.582*	*0.610*

Rank correlations are significant at α=0.01.
Source: own calculations.

In contrast to theoretical expectations[11], static inefficiency sources dominate over OEDA. Among the static inefficiency indicators, TSE plays a minor role. The loss of TSE is caused, as deeper analysis (17) and (13) suggests, almost wholly by the congestion problems (TSCE=86.83% in sextile 6 and 95.28% in sextile 5). The results suggest that the farms in the set are nearly technically efficient in the static sense throughout the modelled period.

The problem of allocative static efficiency is addressed in more details in Table 4. Scale inefficiency is about uniform throughout the sextiles and it contributes rather marginally to allocative static inefficiency. The congestion inefficiency sources dominate in all sextiles except sextile 6. In contrast to technical inefficiencies, allocative inefficiencies ones cannot be almost totally explained by congestion. However, in most cases the allocation of inputs is not perfectly guided by prices.

Table 4: Efficiency scores associated with sources of allocative static inefficiencies, %.

Sextile	ASE	Allocative pure SE (APSE)			ASSE
		Total	APSEN	ASCE	
All	63.37	64.81	84.60	76.91	95.78
1	87.55	88.37	97.27	92.83	96.18
2	72.86	74.20	93.00	82.29	95.76
3	66.57	68.08	91.78	76.70	94.86
4	58.95	61.39	81.42	76.31	95.63
5	52.51	54.11	80.57	69.10	95.89
6	45.21	46.07	66.93	67.30	96.50
RC	*0.931*	*0.879*	*0.631*	*0.581*	*insignificant*

[11] The reasons for these expectations are unstable economic processes and legislation changes which are expected to hamper efficient dynamic resource allocation during the period analysed.

Rank correlations are significant at α=0.01.
RC is Spearman's rank correlation to ODE. Refer to Section 2.1 for the rest of abbreviations.
Source: authors' calculations.

This suggests that the uncertainty in short-term decision making that farms are facing cannot be overcome by existing management practices. However, it does not necessarily imply low quality of management, especially because the same farms are highly efficient in a technical sense. This reasoning, although not rigorous, suggests addressing the issue of *underdeveloped markets* which cause that farm managers have to allocate inputs and outputs in the absence of reliable process and price relations. If this explanation holds, large variation of market prices are expected. This is exactly what is supported by the data. Table 11 in Appendix 2 provides evidence of very high price volatility on the grain and, to the lesser extent, on the milk markets. While milk prices volatility was reduced since 1996, the opposite holds for the grain market. This suggests the *absence of progress in development of a functioning grain market*.

Farms suffer from unfavourable external conditions unevenly. Positive rank correlations between ODE and specific efficiency scores associated with different sources of inefficiency (see Tables 3 and 4, also Tables 5 and 6 below) indicate that the different impacts are not random. This can be caused by the similar reaction of different inefficiency sources on the same factor or by the fact of market disintegration: different farms might access different markets that are characterised by various prices and price volatilities. The lower the correlation between efficiency scores and their factors, the more probable the second reason is.

The ASCE column of Table 4 provides that the congestion problems are urgent even in the most advanced farms in terms of performance. This confirms the results of Shagaida (2005), Il'ina and Svetlov (2006) about missing land market and of Csaki et al. (2000) and Serova and Khramova (2002) about high transaction costs.

Another approach is to split overall dynamic efficiency into allocative and technical components, each including static and dynamic sources. Tables 5 and 6 suggest that allocative inefficiencies dominate. Technical inefficiencies are also considerable. Since TSE is high, this is mostly due to dynamic technical inefficiencies suggesting that accumulation processes are not perfectly adjusted to changing technologies.

Scale inefficiencies are relatively small and uniform throughout the sextiles (Table 5). Congestion inefficiencies are the smallest in the first sextile and relatively similar in the rest of the groups. As it can be seen from comparisons with the static analysis, congestion problems have greater impact on static efficiency than on dynamic efficiency. APDE is a dominant source of ADE, covering static allocation problems and imperfections in the dynamic allocation. The latter, although of less importance than the former, are still high, as a consequence of unpredictable "economic future" during transition. Both APDE and APDEN monotonously decrease from top to bottom sextile, indicating that their contribution in ADE in "worse" sextiles is larger than in "better" ones.

Table 5: Efficiency scores associated with sources of allocative dynamic inefficiencies, %.

Sextile	ADE	Allocative pure DE (APDE)			ADSE
		Total	APDEN*	ADCE*	
All	58.20	59.49	63.86	86.90	96.47
1	80.00	82.22	89.76	92.40	95.68
2	62.43	63.52	72.80	87.39	95.90
3	57.19	57.98	69.00	81.92	96.20
4	52.01	53.23	58.67	85.90	96.32
5	50.63	50.90	52.98	85.75	97.94
6	49.99	50.06	46.43	86.54	97.04
RC	*0.692*	*0.726*	*0.791*	*insignificant*	*insignificant*

*) Because in many cases the solutions of (16) the software could find due to convergence problems were clearly lower than a priori known lower boundary of actual optimum, these values are likely to be biased.
RC is Spearman's rank correlation to ODE.
Rank correlations are significant at α=0.01.
Source: authors' calculations.

The conclusions about the structure of TDE (Table 6) are in general the same as that about allocative dynamic inefficiency, with two reservations. First, unlike TSE, TDE plays an important (although not dominating) role in ODE, except for two upper sextiles. Second, although congestion, just as in static case, yields the most of the problems with TDE, TPDEN is quite recognizable in three lowest sextiles, especially in the 6th. Compared to "almost-perfect" outcome of (17), (13) (all the 144 farms are found to be efficient in this specification), this signals that the management of technical change is not that efficient as the management of existing technologies. The problems with congestion again points to the insufficiently developed input markets and low level of labour mobility.

Table 6: Efficiency scores associated with sources of technical dynamic inefficiencies, %.

Sextile	TDE	Technical pure DE (TPDE)			TDSE
		Total	TPDEN	TDCE	
All	84.73	86.67	95.97	89.67	97.65
1	99.88	99.91	100.00	99.89	99.97
2	96.27	97.45	99.97	97.48	98.77
3	91.23	94.43	99.09	94.87	96.61
4	87.65	89.12	95.78	92.71	98.19
5	77.04	79.00	95.31	83.34	97.50
6	59.16	62.69	87.27	73.63	95.21
RC	*0.733*	*0.715*	*0.391*	*0.648*	*0.505*

RC is Spearman's rank correlation to ODE.
Rank correlations are significant at α=0.01. Refer to Section 2.1 for the rest of abbreviations.
Source: authors' calculations.

5.2 Factors of inefficiencies

Table 7 makes it evident that the larger farms in terms of fixed input use have, on average, larger ODE indicated by model (9)[12]. With several exclusions, this holds also for ADE and TDE. The ADE signals that larger farms have advantages in efficient resource allocation, which provides evidence of *high transaction costs*. Evidently, in such a situation the effect of costs on ADE should be greater compared to depreciation and cows population, just as the data show.

Table 7: Spearman's rank correlations between dynamic efficiency scores and input amounts.

Year	1996	1997	1998	1999	2000	2001	2002	2003	2004
ODE									
Costs	0.480	0.515	0.570	0.337	0.707	0.734	0.748	0.756	0.745
Depreciation*	0.257	0.257	0.218	0.183	0.364	0.471	0.514	0.586	0.536
Cows	0.191	0.257	0.329	0.201	0.457	0.506	0.537	0.596	0.612
ADE									
Costs	0.353	0.375	0.402	0.179	0.471	0.514	0.542	0.538	0.515
Depreciation	0.277	0.255	0.234	0.162	0.368	0.428	0.404	0.459	0.417
Cows	0.153	0.196	0.268	0.159	0.350	0.381	0.414	0.453	0.461
TDE									
Costs	0.319	0.352	0.411	0.256	0.545	0.546	0.535	0.549	0.568
Depreciation	0.119	0.140	0.085	0.073	0.171	0.280	0.338	0.380	0.344
Cows	0.135	0.181	0.225	0.122	0.331	0.368	0.384	0.427	0.446

Rank correlations that are insignificant at α=0.05 are presented in a smaller font.
Source: authors' calculations.

The significant rank correlation between costs and TDE indicated the importance of working (turnover) capital for avoiding dynamic technical inefficiencies. In other words, it is essential for accessing innovations and performing technical adjustments timely. Cows population has a smaller impact on TDE, which can be explained with lower liquidity. Fixed assets can scarcely facilitate financing of technical adjustments and weakly correlate with TDE rather with production costs. The impact of input amounts on the ODE is increasing during time. We explain this by the growth of production. Since in 2004 farms use factors in a larger scale than in 1996, the impact of any factor on efficiency scores in 2004 is likely to be higher than in 1996. Sows population do not display any statistically significant impact on the efficiency scores, mostly due to their rare presence among farms' inputs.

Explaining inefficiency by the shortage of a fixed factor is rarely used in the literature. However, corresponding shortages may display low ability of farm management to timely recognize necessary adjustments. It may also signal either infrastructural problems in procuring resources or external hindrances regarding their efficient allocation. For this reason, we analyze the rank correlation of ODE to (quasi)-fixed inputs shadow prices (abbreviated infra to SP). In some cases the number of non-zero shadow prices is small, which restricts the analytical capability of this approach. In 1997 long-term loans constraint was effective in neither farm, in

[12] Partially this effect can be attached to a dial of inverse causality: the large farms are often former smaller but efficient farms, which, due to high efficiency, have accumulated resources for growth.

1998 the same happened to short-term loans. However, Table 8 still contains some significant rank correlations for conclusions.

Table 8: Spearman's rank correlations between ODE and input shadow prices.

Year	1996	1997	1998	1999	2000	2001	2002	2003	2004
Cows	-0.179	-0.101	-0.081	-0.230	0.242	0.169	0.238	0.179	0.306
Depreciation[a)]	0.206	0.118	-0.157	-0.146	0.254	0.221	0.409	0.168	0.134
Costs	-0.254	-0.194	0.006	-0.080	0.036	0.112	0.122	0.177	0.148
Employment	0.276	0.022	-0.055	0.051	0.158	-0.213	-0.260	-0.265	-0.051
Arable land	0.287	0.462	-0.093	-0.100	0.305	0.254	0.447	0.573	0.194
Grassland	-0.140	-0.083	0.355	0.186	0.121	0.075	-0.209	0.291	0.294
Long-term loans	1.000	–	-0.142	0.773	-1.000	0.655	-0.125	-0.231	0.211
Short-term loans	-0.511	-0.272	–	-0.706	0.053	0.164	-0.512	-0.010	-0.416

Non-zero shadow prices obtained from (9) are used to compute this table.
Rank correlations that are insignificant at α=0.05 are typed using a smaller font.
Source: authors' calculations.

First, all significant rank correlations of SP's of monetary inputs, namely costs and loans, are *negative*. The interpretation is that the lack of monetary inputs negatively influences ODE[13]. The significant Spearman values are concentrated before the financial crisis in 1998. This supports the findings in Gataulin and Svetlov (2005) and Bezlepkina et al. (2005). Before 1998 rather artificial disequilibrium at the financial markets exists. Very attractive State short-term obligations' interest rates swept liquid turnover assets away from agriculture (both in direct and indirect ways), making farms heavily expenses-constrained.

Before 2000 farms had a very limited access to bank loans, which implied a weak evidence of their scarcities' impact on ODE. But since 2002 we observe definite negative relation between opportunity costs of borrowed capital and performance. This does not suggest a real negative impact of credit inaccessibility on the performance (otherwise we would observe a significantly negative rank correlations between cost SP's and ODE in the same years). More likely, the efficient farms have easier access to credits and experience less problems caused by their scarcity.

Second, all significant rank correlations of SP's of inputs in kind, namely cows, fixed capital proxy, land, are *positive*: The farms that extract more revenues from an additional input unit are more efficient. In this context, it is important to distinguish between farms that *have to* experience high input shadow process and those that *are able* to exploit the resources and make their SP high. Since DDEA assumes the same access of any farm to the same set of technological processes, the ability of farms to raise input shadow price is imposed to be equal. Thus, it is correct to conclude that *operating under the conditions of a scarce "input in kind" pushes farm's performance to raise*.

The remaining constraint on employment produces relatively many significant rank correlation values. They display a clear trend from 1996 to 2003, suggesting that insignificance in

[13] The reservation should be made here for an inverse influence of poor performance on monetary inputs. However, commonly poor performance leads to lower amount of monetary inputs rather than to their larger impact on revenues. On this reason the possibility of inverse causality unlikely distorts this interpretation.

1997-1999 is not due to the lack of data (indeed, we obtained 115 to 145 nonzero SP's for these three years) but due to an actual absence of influences.

After fast discharge of workers during transition, the majority of farms turned from labour-abundant (that is suggested by the positive relation of ODE to labour SP in 1997) into labour-lacking, as the negative rank correlations of 2001-2003 suggest. By 2004 the farms seem to react to the emergence of this problem in the proper way. These results could finally end discussions about labour-abundance of farms in the Moscow region. However, the analysis of different model specifications provides that the situation is more complex. In general, the only robust signal of Table 8 with respect to labour is that in optimal long-term outlook the scarcity of labour can be expected to hamper ODE rather than to contribute to it.

In Appendix 3 similar correlations are computed for the outcome of three more model specifications, namely (10); (9) & (13); (14) & (13). The purpose of this appendix is to give a wider impression about the robustness of rank correlations in case of varying model specifications. From behavioural point of view, which is essential to think about SPs as of something comparable with market prices, specification (10) is the most adequate, following by (9), which was used in the rank correlations analysis above. Specification (9) & (13) occupies the third position. Besides the theoretical considerations, this follows from Table 12 in Appendix 4. Some comments are necessary with respect to differences in the correlations of the corresponding ranks under different model specifications. However, first, the impact of input amounts is robust throughout the four specifications.

In Table 13 provides the results of the OSE computation. The costs shadow price has a negative rank correlation with OSE in the later years. While (9) tends to smoothen production growth, (10) considers a decline before 1998 and growth later on. Hence, it solves the problem of financial lacks in the earlier period of reforms by the corresponding decrease in other quasi-fixed inputs but production costs financing. Contrarily, faster than optimal with respect to (9) growth in recent years predetermines an opposite situation. Having to choose technologies facilitating fast growth, farms face stronger short-term budget constraints. The impact of labour scarcity on OSE remains positive in all cases when it is significant and, unlike the case of ODE, does not display any trend. This suggests *presence of labour abundance*.

Allowing for variable return to scale (Table 14) makes costs scarcity virtually ineffective on pure ODE. This suggest that the scale effects revealed by Table 7 are of a considerable extent caused by the scarcity of production costs financing. The contribution of the nature of the technology in these effects is secondary which may arise from high transaction costs on the input markets.

Table 15 provides some outstanding results in comparison to the previous. This is because in specification (14) & (13) the non-zero shadow process of inputs are more frequent and not constrained in sign. So, the corresponding rank correlations are affected not only by the scarcity, but also by abundance of the resources. Arable land is a abundant factor in the Moscow region. The shadow prices are theoretically expected to positively correlate to ODCE. Indeed, during 1996-2004 rank correlations between ODCE and SPs of arable land from (14) & (13) are significant at α=0.001 and vary from 0.350 (1996) to 0.675 (2000). Consequently, the positive influence of land scarcity on efficiency is largely determined by congestion in the farms where the arable land scarcity is low. It is noticeable that the rank correlations of cost SPs to pure ODE under non-disposability in 2001 and 2003 are positive. In case of costs, unlike arable lands, there is no positive rank correlations between their SPs from (14) & (13) and ODCE. Three times (in 1997, 2001 and 2003) even negative correlation is observed (Table 17). *A higher scarcity of resources for covering costs implies a lower scarcity of other inputs, which, in turn, results in decreasing congestion effects*. Indeed, the significant negative

correlations to ODCE are accompanied by the significantly positive correlations to pure ODE under non-disposability (years 2001 and 2003).

Under the assumption of free disposability, like in (9), shadow price correlations are determined by the farms where the abundance of financing is not the case. These correlations indicate what happens to farm performance due to hardness of budget constraints *in farms where the budget constraints are hard* (HBC cases). Non-free disposability specification enlightens also the cases where *the budget constraints are soft*[14] (SBC cases), attaching negative SP to financing sources when appropriate. This makes the average impact of costs SPs on ODE uncertain (Table 17).

In order to deeper investigate this situation, we consider the following:

1. Almost all SPs of cost constraints are *positive,* expect in 1996 (Table 16),
2. Six of nine rank correlations of SPs of short-term loans constraint to pure ODE under non-disposability are significantly *negative*,
3. Rank correlations between loan *amounts* and ODE are *not significant* (at α=0.05), except for the cases of long-term loans in 2002-2004, and
4. on average, 60% of SP's on loans are *negative*.

The negative correlations for short-term loans' SPs (point 2) can be explained with presence of inverse causality: farms displaying higher performance have easier access to loans, which diminishes the SPs. However, point 3 contradicts to this. So, these correlations can be interpreted so that, despite a lot of cases of excess loans (point 4), the cases of high shadow price of short-term loans associate with lower productivity, which indicates presence of the opportunities to improve their performance by accessing more bank loans, which are also revealed by costs constraints (point 1). These opportunities dominate over the existing negative effects of SBCs.

Concluding, with respect to financing this model specification suggests:

- The *presence of both soft and hard budget constraints effects on Moscow region corporate farms* so that the farms' performance suffers from either.
- The soft budget constraints is mostly due to loans.
- Negative effect of the hard budget constraints on ODE is due to the congestion of other resources that occurs when financing is scarce.
- Overall effect of costs scarcity on ODE (Table 8) is uncertain due to its different orientation in farms operating under different types of budget constraints, except for 1996 and 1997 when this effect was significantly negative.

These conclusions do not cause doubts in the role of hard budget constraints in regression of Russian agriculture before 1998, which was discovered by Epstein (2006), Gataulin and Svetlov (2005), Svetlov and Hockmann (2005) and Bezlepkina et al. (2005). Contrarily, it ex-

[14] A typical cause for SBCs is credit allocation distortions because of political pressure and "grey economy" operations. [0]In Russia during 1996-1998 it also was having another specific reason, namely shrinkage of output market shares of many farms. The farms who lost markets but were not able to sweep turnover assets out of agriculture timely could have relatively abundant sources of financing in the following production cycles. Earlier this could not be the case because of extreme inflation. This can explain a deal of negative SPs on costs (in addition to usual negative SPs on credits) in 1996 and absence of such later on.

plains that two additional forces, namely the hard and soft budget constraints, affected the farms during transition period.

5.3 Changes in inputs scarcity during transition

In the following only findings that display reasonable robustness are presented. The discussions is based on Table 9 and 18 in Appendix 4. In the latter the resources are ordered according to the frequency of non-zero shadow prices. Table 9 bases on the outcome of (10)[15]. The persistently high position of labour in Table 9 (above 70% during 7 years) suggests that the farms are able to efficiently reduce labour force and keep it in reasonable proportion to other resources. They adequately react to changes in outputs and to technological changes. Comparison to other resources suggests that the farms rather suffer from low capacity of labour market to provide them skilled employees[16].

Table 9: Percentage of farms experiencing scarcity of a resource in problem (10).

Rank	1996	1997	1998	1999	2000	2001	2002	2003	2004
1	costs 83.0	costs 82.3	empl 89.8	empl 93.2	Empl 94.6	costs 89.8	costs 90.5	costs 91.2	cows 92.5
2	empl 69.4	fixed-cap 75.5	costs 83.7	fixed-cap 80.3	Cows 59.2	cows 75.5	empl 76.9	fixed-cap 79.6	fixed-cap 84.4
3	fixed-cap 59.2	empl 56.5	cows 62.6	grass 80.3	fixed-cap 51.7	fixed-cap 45.6	arable 39.5	empl 74.8	costs 80.3
4	grass 25.2	cows 52.4	fixed-cap 45.6	costs 40.8	costs 39.5	arable 42.2	fixed-cap 35.4	grass 72.1	empl 72.1
5	arable 23.8	shcred 33.3	grass 29.3	cows 24.5	grass 38.1	grass 36.7	cows 32.7	arable 44.9	grass 57.8
6	cows 21.8	pigs 21.8	pigs 17.0	pigs 16.3	arable 34.7	empl 34.0	long-cred 23.8	cows 40.8	arable 41.5
7	pigs 5.4	grass 15.0	arable 9.5	arable 15.0	shcred 25.2	pigs 14.3	grass 14.3	long-cred 34.7	shcred 28.6
8	shcred 2.0	arable 11.6	long-cred 9.5	shcred 2.7	pigs 14.3	shcred 10.2	pigs 13.6	shcred 25.2	long-cred 14.3
9	long-cred 0.7	long-cred 3.4	shcred 0.0	long-cred 2.0	long-cred 1.4	long-cred 2.7	shcred 12.2	pigs 13.6	pigs 10.9

Abbreviations: fixedcap = depreciation (acting as a proxy for fixed assets); empl = employment; arable = arable land; grass = grassland; longcred = long-term loans; shcred = short-term loans.
Source: authors' calculations.

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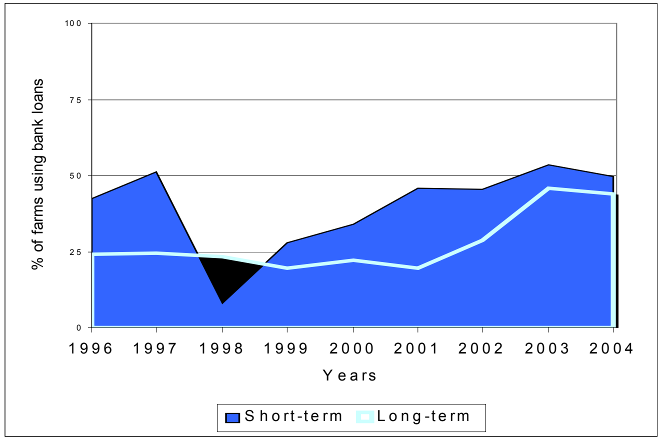
[15] Scarcity ranks based on specification (9), which are presented in Appendix 5, are affected by optimal allocation of quasi-fixed inputs over time imposed. Specification (11) imposes a structure of outputs, which is likely to be influenced by true resources scarcities. This likely biases scarcity ranks.

[16] Hockmann and Kopsidis (2005) suggest that this conclusion unlikely relates to parts of Russia outside the Moscow region. A high payable demand of labour in Moscow and relatively developed public transit systems in the region prevent congestion problems of labour in rural areas nearby Moscow city. In other regions of Russia these factors rarely have an impact on rural employment.

The contribution of the discussion about the importance of lack of either fixed or turnover capital in Russia (Epstein, 2006 and Zeldner, 2005) is that both are indeed ranked high (taking together two of the four topmost positions annually). In 6 of 9 years the latter is ranked higher. The share of farms with non-zero loan shadow prices is extremely low in the majority of years. A straightforward explanation is that transitional farms, due to a lack of collateral and high opportunity cost of capital, seldom use bank loans. However, Figure 2 shows that this occurs too often to explain the share of non-zero shadow prices. Thus, it is more likely that the farms do not feel themselves constrained in loans when they pursue higher performance. There are several causes for this situation:

- presence of alternative sources of financing (debt on payments instead of short-term loans, leasing instead of long-term loans, credit co-operatives, futures market etc.);
- availability of managerial practices that avoid the demand of bank loans. These practices are efficient given the existing state of financial infrastructure and available terms of loans;
- bank credits are not always allocated to the farms displaying higher performance (see above about credits as sources of SBCs).

Figure 2: Bank loan usage by corporate farms in Moscow Region



Source: own calculations

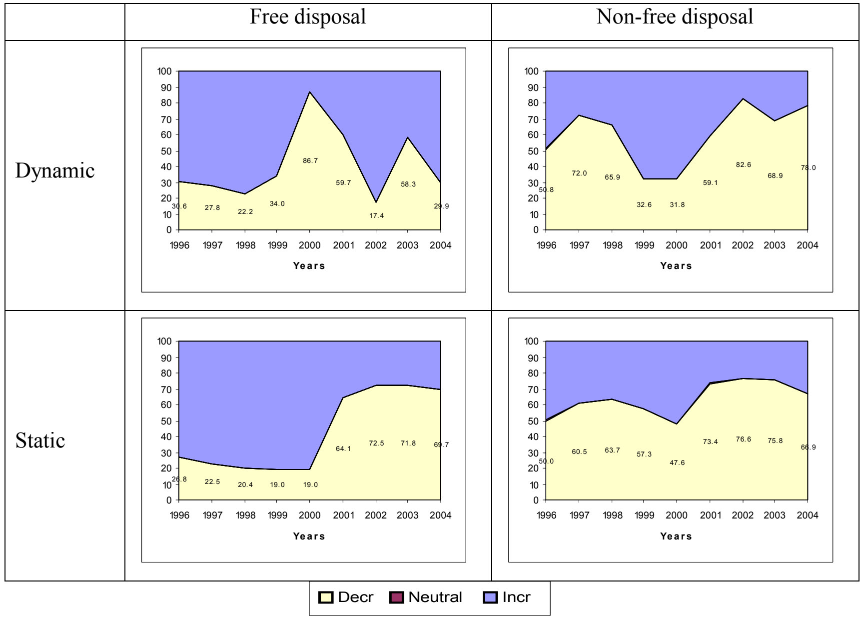
5.4 Farm size and return to scale

Subsection 5.2 suggests that farms using larger amount of resources perform better. However, the reason for this could be an inverse causality, since farms with higher performance might have resources for growth. Second, this correspondence might not be homogenous, increasing size of a *particular* farm is not always among the means of improving its performance. Third, the estimated scale efficiency scores are high (Subsection 5.1), in contrast to stable positive rank correlations between resource quantities and efficiency scores.

In this subsection we analyze the scale effects in order to explain the above formulated observations. Figure 3 presents returns to scale accessed by the sign of the dual variable of the VRS constraint provided by the following specifications: northwest – (9) & (13); northeast – (14) & (13); southwest – (10) & (13); southeast – (15) & (13).

The conclusions about the dominating return to scale regime are not robust within the various of specifications. Thus, a closer look at the meaning of each RTS indicator is required. The dynamic specification actually assumes a single technology but distinguishes same outputs differing in time as if they were different commodities. The static specification assumes a separate technology for each year. Thus, scale effects from dynamic specifications suggest how a farm can improve capacity utilisation of a single meta - technology by changing its size in a particular year. Size changes are (formally) utilized by production changes *at, before and after* the moment of change. Scale effects from static specifications are subjected to the moment when the change takes place and depend only on a year-specific technology. Furthermore, in the dynamic specification the dependence of capability to invest in growth on farm size is accounted by scale effects, while in static specification it is not.

Figure 3: Annual structure of farms with respect to return to scale in the sense of overall efficiency



Source: own calculations

Omitting free disposability subjects the scale effects to the congestion problem. It affects the scale effects neutrally if there is no correlation between RTS and congestion. One observation from of Figure 3 (dynamic, free disposal) is that the majority of farms operate at increasing RTS. As scale efficiencies suggest, the size actually does not matter too much in terms of performance. However, in 2000, 2001 and 2003 some of the farms that in other years are smaller than optimal got being larger than optimal, although none of these years is characterized with extreme average farm size changes. Noticeably, year-specific weather or policy conditions

can explain this change only to a limited extent because of intertemporal nature of dynamic frontier. Rather, the reason is short-term changes in proportions of fixed inputs (labour, land, loans), which could provide temporary benefits to smaller farms. The southwestern part of the chart suggests a technology that since 2001, which changed from increasing to decreasing RTS. So, in the recent years many farms (39,8% in 2004) have the opportunities to exploit increasing RTS only in long run, while short-run decision making faces decreasing RTS.

Considering congestion in a dynamic setup suggests widespread existence of decreasing RTS, except for 2000. Smaller farms easier avoid congestion in transition, as it is expected theoretically. The same holds for the static setup, but only before 2000. Later congestion plays a minor role in defining the composition of farms set with respect to RTS.

In a technical sense, as Figure 4 suggests (see Appendix 5), the majority of farms operate at constant return to scale. In a dynamic setup their share is continuously increasing, except for 2004; in static setup it is decreasing. Both can be explained by increasing number of cases of technology updates. This makes the existing scale sub-optimal in short run while bringing the scale closer to optimum in the long run.

A comparison of Figures 3 and 4 provides that for the majority of farms RTS effects can be utilized by *shifts in output allocation*. Hence, it is reasonable to hypothesise that *the major outputs of the studied farms are characterized, as a rule, by opposite scale effects*. It also explains the breakpoint in 2000, when dairy profitability showed a sharp growth, switching the reproduction mode in this branch from shrinking to expanded. Sharp peaks in northwestern part of Figure 3 and the lack of correspondence between the results of different model specifications make doubts in robustness of RTS estimates. For this reason we provide the data on them by sextiles in Appendix 5 (Figures 5 to 8). They suggest that the farms in all the sextiles are affected by the same factors of changes in RTS indicators that is hardly probable to happen at random.

Table 10: Spearman's rank correlations between dual value of VRS constraint and factors.

Year	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
Dynamic setup: model (9) & (13)									
ODE	-0.009	0.151	0.084	0.246	-0.127	0.298	0.161	0.266	0.422
Production costs	0.405	0.503	0.494	0.401	0.145	0.575	0.353	0.470	0.526
Depreciation[a)]	0.353	0.325	0.364	0.254	0.219	0.371	0.230	0.363	0.356
# of cows	0.287	0.124	0.175	0.242	0.157	0.499	0.365	0.360	0.645
Static setup: model (10) & (13)									
ODE	-0.059	-0.028	0.094	0.230	0.009	0.351	0.420	0.234	0.440
Production costs	0.233	0.300	0.368	0.247	0.304	0.612	0.626	0.483	0.559
Depreciation[a)]	0.156	0.198	0.325	0.206	0.089	0.214	0.308	0.322	0.308
# of cows	0.293	0.221	0.439	0.360	0.158	0.552	0.463	0.532	0.641

Rank correlations that are insignificant at α=0.05 are typed using small font.
Source: authors' calculations.

Table 10 shows how RTS depends on inputs. All significant rank correlations here are positive: the larger the size is the more it is likely to operate with decreasing return to scale. This fits the theoretical expectations and supports convexity of the revealed technology. Negative RTS is more likely to be the case of higher efficient farms because of (a) positive correlation of the dual value of VRS constraint and size indicators; (b) positive correlation of efficiency and size indicators.

6 Conclusions, discussion and outlook of extensions

In this paper we investigate dynamic efficiency of Moscow region corporate farms for the period 1996-2004. The sample allows analyzing the impact of progress in market transition on technical and allocative efficiency and on factors that determine this. The unavailability of data on investment sources allows large annual increments in animal population, depreciation and costs without explicit reason. Under such circumstances, we have to analyze ODEs that are estimated under very demanding presumption. For simplicity, we presume that the options the best-practice farms used to accumulate the liabilities for fast growth are available to every farm in the set. Even with this limitation, we are able to draw some conclusions regarding the hypotheses developed in the introduction:

1) In accordance to the first hypothesis, the dominating source of inefficiency is suboptimal output allocation. In a technical perspective the farms are almost efficient, unless congestion problems are taken into acount.
2) The second hypothesis is not rejected by the data. During 1996 and 2004 the number of costs-constrained farms declined while the number of labour-constrained farms increased.
3) The third hypothesis concerning suboptimal farm size got only limited support, since the scale inefficiencies found are low. A positive relation between technical dynamic efficiency and farm size suggests that larger farms are likely to be more capable to introduce innovations. However, this also can result from the fact that the more efficient the farm is the slower it collapses in an unfavourable economic environment.

The study suggests that increasing input scarcity can be an effective method of improving performance. In addition to the dramatically destructive impact of the swept-out of turnower assets in mid 1990th, the abundance of land during the transitional period was a factor affecting farm performance negatively. Moreover, the shadow price of land was a strongly influential factor of overall dynamic efficiency. Thus, policies directly aimed at increasing the value of agricultural land are expected to have a positive indirect impact on farm performance.

Congestion is a considerable source of inefficiencies and, specially, almost the only source of existing technical inefficiencies. This signals underdeveloped markets on the inputs side. There is an urgent need for lowering fixed inputs transaction costs in order to turn disposing extra resources from a costly problem into a profitable business.

With respect to farm size and scale effects our study suggests that the latter does not effect farm performance to a large extent. Attaining optimal size with respect to a reference technologies does not provide substantial benefits, since CRS and VRS frontiers differ only slightly. In this respect, the evident positive rank correlation between ODE and size (in terms of costs, machinery and dairy cows population) originates in the field of institutional rather than neo-classical economics. If underutilizing technological capacities due to non-optimal size is scarcely the reason for the mentioned correlation, then the cause could be sought among other source than scale inefficiency, like opportunities to innovate, access to specific markets and services, ability to pay reasonable wages to skilled managers etc.

We found farms in the Moscow region to be efficient in a technical sense. This supports Grazhdaninova and Lerman (2005) and Svetlov and Hockmann (2005). In contrast to findings of Serova et al. (2003) and Bezlepkina et al. (2005) we found that labour abundance is not typical at least for Moscow region corporate farms. Labour persistently belong to the resources with scarcity. This finding is also supported by Epstein (2006).

Serova and Shick (2006), Bezlepkina (2004) Sedik et al. (1999) highlight that soft budget constraints hinder agricultural development in Rusia. However, Epstein (2006), Gataulin and

Svetlov (2005), pp. 217-222, Svetlov and Hockmann (2005) came to opposite results. Our findings suggest that Moscow region corporate farms suffer from both problems. In 1996 and 1997, when the share of farms constrained in production costs was above 75%, the effect of hard budget constraints: higher scarcity of costs imposed lower ODE with rank correlation –0.254 and –0.194, correspondingly. However, the presence of significant and increase of farms zero shadow price of costs of costs signals the simultaneous existence of soft budget constraints.

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Appendix

1. Specifications of (9)…(12) with omitted free disposability of inputs

Below-dashed symbols indicate the non-disposable amount of a resource.

$$
\begin{aligned}
&\max_{\{\mathbf{y}_{nt},\mathbf{k}_{nt},\boldsymbol{\lambda}_{nt}\}_{t=1996}^{2004}} \sum_{t=1996}^{2004} \gamma_t(\mathbf{w}_{nt}\mathbf{y}_{nt})\\
s.t.\quad &\overline{\mathbf{x}_{nt}} - \mathbf{X}_t\boldsymbol{\lambda}_{nt} \ge \mathbf{0},\quad \mathbf{X}_t\boldsymbol{\lambda}_{nt} - \underline{\mathbf{x}_{nt}} \ge \mathbf{0},\quad t=1996,1997,\dots,2004;\\
&t=1996,1997,\dots,2004;\\
&\overline{\mathbf{k}_{n,1995}} - \mathbf{K}_{1995}\boldsymbol{\lambda}_{n,1996} = \mathbf{0};\\
&\mathbf{k}_{n,t-1} - \mathbf{K}_{t-1}\boldsymbol{\lambda}_{nt} = \mathbf{0},\quad t=1997,1998,\dots,2004;\\
&\mathbf{K}_t\boldsymbol{\lambda}_{nt} - \mathbf{k}_{nt} \ge \mathbf{0},\quad t=1996,1997,\dots,2003;\\
&\mathbf{K}_{2004}\boldsymbol{\lambda}_{n,2004} - \overline{\mathbf{k}_{n,2004}} \ge \mathbf{0};\\
&\mathbf{Y}_t\boldsymbol{\lambda}_{nt} - \mathbf{y}_{nt} \ge \mathbf{0},\quad t=1996,1997,\dots,2004;\\
&\boldsymbol{\lambda}_{nt} \ge \mathbf{0}, \mathbf{y}_{nt} \ge \mathbf{0}, \mathbf{k}_{nt} \ge 0,\quad t=1996,1997,\dots,2004.
\end{aligned}
\tag{14}
$$

$$
\begin{aligned}
&\max_{\{\mathbf{y}_{nt},\mathbf{k}_{nt},\boldsymbol{\lambda}_{nt}\}_{t=1996}^{2004}} \sum_{t=1996}^{2004} \gamma_t(\mathbf{w}_{nt}\mathbf{y}_{nt})\\
s.t.\quad &\overline{\mathbf{x}_{nt}} - \mathbf{X}_t\boldsymbol{\lambda}_{nt} \ge \mathbf{0},\quad \mathbf{X}_t\boldsymbol{\lambda}_{nt} - \underline{\mathbf{x}_{nt}} \ge \mathbf{0},\quad t=1996,1997,\dots,2004;\\
&\overline{\mathbf{k}_{n,1995}} - \mathbf{K}_{1995}\boldsymbol{\lambda}_{n,1996} = \mathbf{0};\\
&\overline{\mathbf{k}_{n,t-1}} - \mathbf{K}_{t-1}\boldsymbol{\lambda}_{nt} = \mathbf{0},\quad t=1997,1998,\dots,2004;\\
&\mathbf{K}_t\boldsymbol{\lambda}_{nt} - \overline{\mathbf{k}_{nt}} \ge \mathbf{0},\quad t=1996,1997,\dots,2004;\\
&\mathbf{Y}_t\boldsymbol{\lambda}_{nt} - \mathbf{y}_{nt} \ge \mathbf{0},\quad t=1996,1997,\dots,2004;\\
&\boldsymbol{\lambda}_{nt} \ge \mathbf{0}, \mathbf{y}_{nt} \ge \mathbf{0},\quad t=1996,1997,\dots,2004.
\end{aligned}
\tag{15}
$$

$$
\begin{aligned}
&\max_{\{\delta_t,\mathbf{k}_{nt},\boldsymbol{\lambda}_{nt}\}_{t=1996}^{2004}} \delta_{2004}\\
s.t.\quad &\overline{\mathbf{x}_{nt}} - \mathbf{X}_t\boldsymbol{\lambda}_{nt} \ge \mathbf{0},\quad \mathbf{X}_t\boldsymbol{\lambda}_{nt} - \underline{\mathbf{x}_{nt}} \ge \mathbf{0},\quad t=1996,1997,\dots,2004;\\
&\overline{\mathbf{k}_{n,1995}} - \mathbf{K}_{1995}\boldsymbol{\lambda}_{n,1996} = \mathbf{0};\\
&\mathbf{k}_{n,t-1} - \mathbf{K}_{t-1}\boldsymbol{\lambda}_{nt} = \mathbf{0},\quad t=1997,1998,\dots,2004;\\
&\mathbf{K}_t\boldsymbol{\lambda}_{nt} - \mathbf{k}_{nt} \ge \mathbf{0},\quad t=1996,1997,\dots,2003;\\
&\mathbf{K}_{2004}\boldsymbol{\lambda}_{n,2004} - \overline{\mathbf{k}_{n,2004}} \ge \mathbf{0};\\
&\mathbf{Y}_t\boldsymbol{\lambda}_{nt} - \delta_t\overline{\mathbf{y}_{nt}} \ge \mathbf{0},\quad t=1996,1997,\dots,2004;\\
&\boldsymbol{\lambda}_{nt} \ge \mathbf{0}, \mathbf{y}_{nt} \ge \mathbf{0}, \mathbf{k}_{nt} \ge 0,\quad t=1996,1997,\dots,2004.
\end{aligned}
\tag{16}
$$

$$\max_{\{\delta_t,\mathbf{k}_{nt},\boldsymbol{\lambda}_{nt}\}_{t=1996}^{2004}} \delta_{2004}$$

$$\begin{aligned}
s.t.\quad & \overline{\mathbf{x}_{nt}} - \mathbf{X}_t\boldsymbol{\lambda}_{nt} \geq \mathbf{0}, \quad \mathbf{X}_t\boldsymbol{\lambda}_{nt} - \underline{\mathbf{x}_{nt}} \geq \mathbf{0}, \quad t = 1996, 1997, \ldots, 2004; \\
& \overline{\mathbf{k}_{n,1995}} - \mathbf{K}_{1995}\boldsymbol{\lambda}_{n,1996} = \mathbf{0}; \\
& \overline{\mathbf{k}_{n,t-1}} - \mathbf{K}_{t-1}\boldsymbol{\lambda}_{nt} = \mathbf{0}, \quad t = 1997, 1998, \ldots, 2004; \\
& \mathbf{K}_t\boldsymbol{\lambda}_{nt} - \overline{\mathbf{k}_{nt}} \geq \mathbf{0}, \quad t = 1996, 1997, \ldots, 2004; \\
& \mathbf{Y}_t\boldsymbol{\lambda}_{nt} - \delta_t\overline{\mathbf{y}_{nt}} \geq \mathbf{0}, \quad t = 1996, 1997, \ldots, 2004; \\
& \boldsymbol{\lambda}_{nt} \geq \mathbf{0}, \mathbf{y}_{nt} \geq \mathbf{0}, \quad t = 1996, 1997, \ldots, 2004.
\end{aligned} \tag{17}$$

2. Price volatility

Table 11: Price variation per average price, %

	1996	1997	1998	1999	2000	2001	2002	2003	2004
Grain	36.7	41.2	78.6	43.7	39.6	51.5	51.8	40.1	51.1
Milk	29.9	24.6	22.0	13.8	17.2	16.6	19.6	18.1	16.7

Source: own calculation

3. Supplementary data for performance analysis

Table 12: Correlations between the modelled and actual revenues in the model specifications used for SP analyses

Specification	(9)	(10)	(9), (13)	(14), (13)
Pearson’s correlation	0.886	0.928	0.865	0.782
Spearman’s rank correlation	0.873	0.898	0.839	0.658

All correlations are significant at α=0.01.
Source: own calculations.

Table 13: Spearman’s rank correlations between OSE and factors

	1996	1997	1998	1999	2000	2001	2002	2003	2004
Input amounts									
Costs	0.419	0.459	0.522	0.268	0.653	0.688	0.717	0.730	0.732
Depreciation[a)]	0.180	0.186	0.165	0.081	0.288	0.405	0.448	0.528	0.493
Cows	0.159	0.221	0.291	0.137	0.415	0.462	0.497	0.562	0.581
Input shadow prices[a)]									
Cows	0.193	0.111	0.274	-0.212	0.222	0.510	0.454	0.368	0.319
Depreciation[a)]	0.259	0.245	0.315	0.023	0.324	0.574	0.330	0.332	0.189
Costs	-0.105	-0.083	-0.081	0.122	0.205	-0.345	-0.281	-0.122	-0.184
Employment	0.284	0.151	0.229	0.323	-0.124	0.595	0.483	0.199	0.052
Arable land	0.515	0.447	0.321	0.345	0.238	0.448	0.505	0.215	0.209
Grassland	0.022	0.115	0.298	0.180	0.266	0.006	0.208	0.287	0.355

[a)] Non-zero shadow prices obtained from (10).
Rank correlations that are insignificant at α=0.05 are typed using small fonts. Factors having one or no significant correlations are not presented.
Source: authors’ calculations.

Table 14: Spearman’s rank correlations between pure ODE and factors.

	1996	1997	1998	1999	2000	2001	2002	2003	2004
Input amounts									
Costs	0.480	0.518	0.576	0.320	0.709	0.738	0.749	0.758	0.747
Depreciation	0.255	0.263	0.224	0.169	0.360	0.475	0.514	0.588	0.539
Cows	0.184	0.241	0.313	0.188	0.444	0.493	0.523	0.584	0.597
Input shadow prices[a)]									
Cows	0.006	-0.069	0.020	0.058	0.223	0.179	0.495	0.281	0.256
Depreciation[a)]	0.310	0.121	0.263	0.007	0.172	0.303	0.364	0.221	0.159
Employment	0.288	-0.054	-0.028	0.073	0.236	-0.300	-0.066	-0.131	0.009
Arable land	0.516	0.405	0.076	0.166	0.406	0.336	0.361	0.581	0.457
Grassland	-0.040	-0.039	0.098	0.048	0.215	0.057	0.008	0.112	0.303

[b)] Non-zero shadow prices obtained from (9) & (13).
Rank correlations that are insignificant at α=0.05 are typed using small font. Factors having one or no significant correlations are not presented.
Source: authors’ calculations.

Table 15: Spearman’s rank correlations between pure ODE under non-free disposability[a)] and factors.

	1996	1997	1998	1999	2000	2001	2002	2003	2004
Input amounts									
Costs	0.552	0.546	0.556	0.292	0.672	0.673	0.661	0.655	0.677
Depreciation[b)]	0.308	0.313	0.338	0.174	0.391	0.447	0.463	0.492	0.466
Cows	0.330	0.347	0.377	0.234	0.482	0.516	0.538	0.584	0.593
Input shadow prices[b)]									
Cows	0.135	0.180	0.251	-0.014	0.309	0.358	0.419	0.348	0.487
Pigs	0.189	0.221	0.228	0.204	-0.211	0.022	-0.022	-0.089	-0.133
Depreciation	0.022	0.317	0.333	0.296	0.179	0.304	0.316	0.149	0.115
Costs	-0.215	0.097	-0.075	-0.012	0.137	0.483	0.228	0.533	0.267
Employment	0.199	0.002	0.021	0.167	0.264	-0.360	0.002	-0.081	-0.019
Arable land	-0.098	-0.200	-0.225	-0.088	-0.195	-0.328	-0.039	-0.174	-0.141
Grassland	0.170	0.158	0.036	0.021	0.152	0.255	0.087	-0.074	-0.081
Long-term loans	-0.647	-0.315	-0.352	-0.379	-0.429	-0.099	-0.334	-0.478	-0.127
Short-term loans	0.105	-0.202	-0.749	-0.343	-0.298	-0.497	-0.289	-0.329	-0.318

[a)] The efficiency score obtained from (14) & (13).
[b)] Non-zero shadow prices obtained from (14) & (13).
Rank correlations that are insignificant at α=0.05 are typed using small font. Factors having one or no significant correlations are not presented.
Source: authors’ calculations.

Table 16: Share of factor's negative shadow prices in non-zero shadow prices in specification (14) & (13), %

	1996	1997	1998	1999	2000	2001	2002	2003	2004
Cows	50.4	1.3	2.4	2.1	1.1	1.2	2.4	1.4	1.0
Pigs	55.8	1.6	2.3	4.6	15.9	12.0	31.4	19.4	40.8
Depreciation[a)]	30.7	2.4	1.3	0.0	1.8	2.0	1.1	1.1	1.1
Costs	23.6	2.7	0.8	3.2	0.0	1.4	1.4	0.0	0.0
Employment	31.2	36.0	12.9	2.2	2.9	10.1	4.3	10.0	10.0
Arable land	59.8	69.4	80.2	78.7	55.8	49.1	71.9	76.2	68.4
Grassland	42.1	59.4	41.6	13.5	27.0	57.5	61.6	52.5	54.0
Long-term loans	77.8	94.1	64.5	85.2	93.1	96.2	27.1	19.2	59.4
Short-term loans	79.7	40.0	87.5	88.2	54.9	65.6	55.7	60.0	50.7

Source: authors' calculations.

Table 17: Rank correlations of non-zero shadow prices of costs in specification (14) & (13) to different efficiency measures

Year	1996	1997	1998	1999	2000	2001	2002	2003	2004
ODE	**-0.227**	-0.073	-0.118	-0.102	0.111	0.149	-0.036	0.202	-0.035
Pure ODE under non-disposability	**-0.215**	0.097	-0.075	-0.012	0.137	**0.483**	0.228	**0.533**	0.267
ODCE	-0.137	-0.316	-0.120	-0.012	-0.021	**-0.266**	-0.202	**-0.269**	-0.165

Rank correlations that are insignificant at α=0.05 are typed using small font.
Source: authors' calculations.

4. Resources scarcity ranking (supplementary data)

Table 18: Percentage of farms experiencing scarcity of a resource in problems (9) and (11)

Rank	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
Problem (9)									
1	costs 83.0	pigs 95.9	pigs 97.3	empl 98.0	empl 99.3	empl 98.6	empl 98.6	empl 99.3	empl 99.3
2	empl 74.1	cows 91.8	empl 95.9	pigs 96.6	pigs 78.2	pigs 76.9	pigs 63.3	fixedcap 89.8	cows 74.1
3	fixedcap 58.5	empl 78.2	costs 74.8	grass 92.5	cows 46.3	fixedcap 69.4	arable 58.5	pigs 86.4	fixedcap 73.5
4	cows 28.6	costs 76.2	cows 59.9	fixedcap 61.9	arable 46.3	cows 49.7	costs 51.0	grass 71.4	grass 67.3
5	grass 28.6	fixedcap 59.2	fixedcap 43.5	cows 28.6	grass 44.9	arable 49.0	fixedcap 36.7	cows 59.9	arable 51.0
6	arable 25.2	shcred 42.2	grass 22.4	costs 26.5	costs 37.4	costs 45.6	longcred 23.8	longcred 50.3	pigs 39.5
7	pigs 15.6	grass 20.4	arable 17.0	arable 17.0	fixedcap 27.9	grass 38.8	shcred 15.6	arable 39.5	costs 36.7
8	shcred 3.4	arable 12.2	longcred 11.6	longcred 2.7	shcred 23.1	shcred 17.7	grass 12.2	shcred 26.5	shcred 31.3
9	longcred 1.4	longcred 0.0	shcred 0.7	shcred 2.7	longcred 0.7	longcred 2.0	cows 10.9	costs 25.2	longcred 28.6
Problem (11)									
1	costs 35.4	pigs 34.0	pigs 20.4	empl 18.4	pigs 10.9	empl 7.5	empl 8.2	empl 8.2	empl 19.0
2	empl 30.6	cows 27.2	empl 16.3	grass 14.3	empl 8.8	pigs 5.4	cows 3.4	pigs 6.8	grass 15.0
3	fixedcap 32.0	empl 26.5	cows 10.9	cows 10.9	grass 5.4	cows 4.1	pigs 3.4	fixedcap 4.8	shcred 8.2
4	cows 21.1	costs 22.4	grass 10.9	pigs 10.9	cows 4.1	fixedcap 4.1	fixedcap 3.4	costs 3.4	arable 6.1
5	arable 17.0	fixedcap 19.7	arable 7.5	arable 8.2	arable 3.4	arable 2.7	grass 3.4	grass 3.4	longcred 3.4
6	grass 15.6	grass 19.7	costs 6.1	costs 5.4	fixedcap 1.4	costs 2.0	arable 2.7	shcred 3.4	cows 2.0
7	pigs 4.1	arable 10.9	fixedcap 4.8	fixedcap 4.1	costs 1.4	grass 2.0	costs 1.4	arable 2.7	pigs 1.4
8	shcred 3.4	shcred 10.9	longcred 1.4	longcred 1.4	shcred 1.4	longcred 0.0	shcred 0.7	longcred 2.7	fixedcap 1.4
9	longcred 0.7	longcred 2.0	shcred 0.0	shcred 0.7	longcred 0.0	shcred 0.0	longcred 0.0	cows 2.0	costs 0.7

Abbreviations are: fixedcap = depreciation (acting as a proxy for fixed assets); empl = employment; arable = arable land; grass = grassland; longcred = long-term credit; shcred = short-term credit.
Source: authors' calculations.

5. Return to scale (supplementary data)

Figure 4: Annual structure of farms with respect to return to scale in the sense of technical efficiency

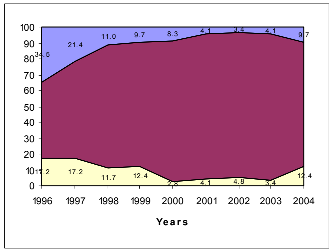
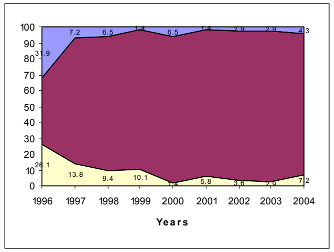
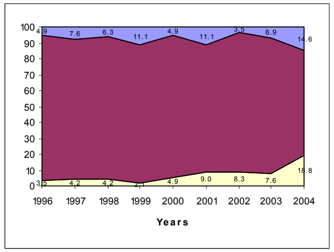
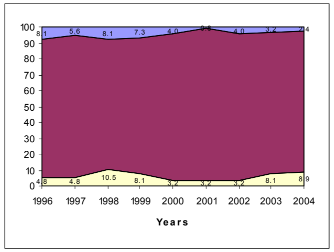
	Free disposal	Non-free disposal
Dynamic		
Static		

Figure 5: Share of farms acting at decreasing return to scale in each sextile of ODE (dynamic setup, free disposability).

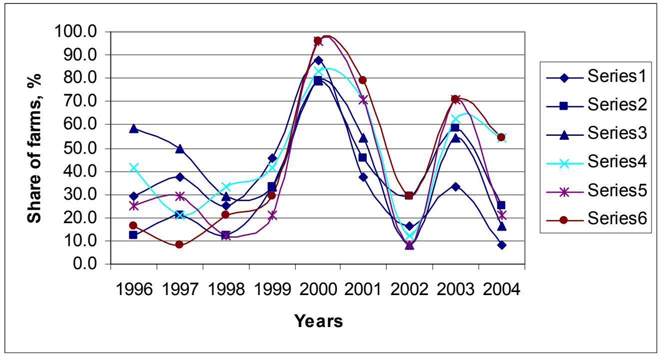


Figure 6: Share of farms acting at decreasing return to scale in each sextile of ODE (dynamic setup, non-free disposability).

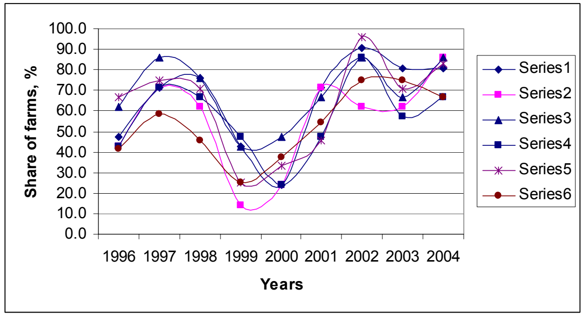


Figure 7: Share of farms acting at decreasing return to scale in each sextile of ODE (static setup, free disposability).

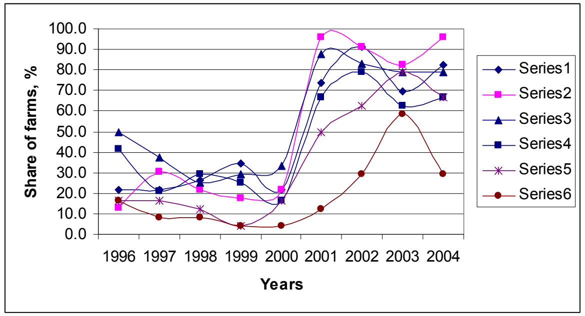


Figure 8: Share of farms acting at decreasing return to scale in each sextile of ODE (static setup, non-free disposability).