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Russia's agriculture: eight years in transition - convergence or divergence of regional efficiency

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DISCUSSION PAPER

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RUSSIA'S AGRICULTURE: EIGHT YEARS IN TRANSITION - CONVERGENCE OR DIVERGENCE OF REGIONAL EFFICIENCY

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ABSTRACT

In this paper, we consider how Russian Agriculture has developed since the constitution of the Russian Federation. The analysis is based on Oblast level data of 75 territorial units during the period from 1993 to 1998 and is focusing on technical efficiency (TE), technological change, and (both aggregated as overall index) on Total Factor Productivity (TFP).

Given that the initial natural conditions were approximately constant the consistence of political programs, market reforms and restructuring were essential determinants of regional developments of TE and TFP above or below the common trend. If this assumption is widely true an investigation of responsible circumstances for these divergences seems to be an important task in the actual regional-economic research. This paper should provide a step of such an analysis - discover common trends, make divergences visible and detect Oblasts characterised by diverging trends.

The results have shown that the agricultural TE and the technological change varied dramatically among regions. Beyond it, we have found a growing gap of TE among regions and a relative homogeneous negative trend of technical change resulting, altogether, in a divergence of regional agricultural TFP. Because agriculture is for many regions the fundamental source of income this fact is alarming, especially when the local agriculture becomes non-competitiveness in comparison with other regions, actually or in future.

JEL: O 013, O 047
Keywords: technical efficiency, rural areas, divergence, Russian Federation, agriculture

ZUSAMMENFASSUNG

Gegenstand dieses Papiers ist die Entwicklung der russischen Landwirtschaft seit Gründung der Russischen Föderation. Die Analyse basiert auf regional aggregierten Daten von 75 Oblasts von 1993 bis 1998 und fokussiert auf die jeweilige technische Effizienz (TE), den technologischen Wandel und, als Aggregat, auf die totale Faktorproduktivität (TFP).

Vorausgesetzt die regionalen natürlichen Bedingungen sind etwa gleich geblieben, dann sind die Konsistenz politischer Programme, marktwirtschaftliche Reformen und Restrukturierung die essentiellen Determinanten über- bzw. unterdurchschnittlicher Entwicklungen von TE und TFP. Wenn dies zutrifft, dann erscheint die Untersuchung der für die regionalen Divergenzen verantwortlichen Hintergründe als ein zentrales Ziel der aktuellen regional-ökonomischen Forschung. Dieses Papier soll hierzu einen Beitrag leisten – allgemeine Trends offen legen, Divergenzen aufzeigen und Oblasts mit abweichenden Trends identifizieren.

Die Ergebnisse zeigen erheblich differierende Werte sowohl bei der landwirtschaftlichen TE als auch beim technischen Wandel zwischen den einzelnen Regionen. Darüber hinaus kann man eine wachsende Disparität der TE bei einem relativ einheitlich negativen technischen Wandel feststellen, was insgesamt in eine zunehmende Divergenz der regionalen landwirtschaftlichen TFP mündet. Da die Landwirtschaft für viele Regionen die elementare Einkommensquelle darstellt, scheint dieses Faktum als durchaus alarmierend; insbesondere dann, wenn die lokale Landwirtschaft im regionalen Vergleich droht nicht mehr wettbewerbsfähig zu sein oder zu werden.

JEL: O 013, O 047
Schlüsselwörter: technische Effizienz, rurale Gebiete, Divergenz, Russland, Landwirtschaft

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1 INTRODUCTION

Recently, many research efforts have been focused on the sources of agricultural growth. Especially the transition of the economies in Central and Eastern Europe and the question of the development of agriculture as a whole in these countries are both stimulating analysis of trends in efficiency, productivity and technological change. But there is an additional aspect that should be considered in the present analysis – not only the development of agriculture as a whole in the context of increasing international integration and globalisation is an important field of research, but also the regional (intra-national) differences in competitiveness of agriculture. This is especially true for country like Russia, where still exist a high variability of economic as well as political and agro-ecological imperfections – the former one is even more distorted now than at the beginning of the transition process.

The purpose of this report is to shed light on the reasons for Russia's dismal economic performance in the agricultural sector and to help policy makers setting priorities for reforms. This is done by analysing Russia's output and productivity gaps among regions in agricultural production. Knowledge is sought in order to understand the main constraints to productivity improvements, and to identify concrete actions that the government and entrepreneurs can undertake to raise productivity according to regional specifics.

In our consideration we are going to discuss the following issues:

- The approaches to measure a performance of the agricultural sector;
- The regions' levels of technical efficiency;
- The pattern in the changes in technical efficiency by region as a result of reforms;
- The economic and institutional factors explaining the levels of technical efficiency;
- The conclusions which can be drawn about the extent of producers transformation.

In this paper we attempt to analyse some major aspects of the situation and the common trend of agricultural efficiency as an indicator of quality of external environment and institutional framework in different regions as well as in the whole Russian economy. Throughout the analysis, the development of the Russian agriculture since the constitution of the Russian Federation (January 1992) are considered. The investigation is based on region level data from 75 out of 89 territorial units over the period from 1993 to 1998 and is focusing on technical efficiency (the measure of physical relationship between production factors and output), technological change and on the total factor productivity (the latter two aggregated as overall index). Besides technical efficiency there are others measures of efficiency and productivity (for instance allocative efficiency) but these ones have been often criticised, principally in those cases where prices are distorted, and producers have imperfect knowledge and pursue goals other than profit maximisation.

In this study, first, we measure the absolute and relative technical efficiency of each region. In a second step, those regions which differ from the trend are compared; to give an account of them and to try to explain the various developments. In the third step, we give – based on our empirical results – some proposals for improving the economic environment for a sustainable enhancement of the agriculture performance. Because of the regional focus in the analyses, the recommendations have mostly the character of regional/structural policy implications.

In principle, there are four major reasons[1] to believe that the transition began in 1992 results in significant growth of welfare and enhancement of the regional performance, respectively, due to improvement of efficiency (valid for allocative as well as technical efficiency).

- Improvement of resource allocation – liberalised markets balance supply and demand through the price mechanism and are therefore more flexible and efficient.
- Hard budget constraints and cutbacks of subsidies – stimulate producers to manage production factors more efficiently and force non-competitive producers to leave the market.
- Stronger competitive pressure due to the opening of the economy to international markets – domestic input and output prices are adjusting to international prices, and factor-use patterns are changing according to market demand.
- Privatisation – motivate new owners to improve management practices and allocate the resources more efficiently, it also provides access for foreign investors to the economy.

According to the theory, all these aspects should provide a more technically efficient economy and gives the external environment for producers to realise an input/output-combination at the current production possibility frontier rather than inside the production possibility set. An empirical test of this hypothesis and an analysis which standing is reached to date can support Russian policy makers and give an impression which potential of the analysed sector is under-exploited. Beyond that, the study is also able to detect factors impeding faster improvements of technical efficiency.

Although all of the major sources for potential improvements of efficiency (see above) are going on, there remain a lot of evidences of incomplete institutional reforms in Russia. First of all, among frequently cited causes for low levels of production are macroeconomic instability, incomplete market reforms, corruption, and lacking managerial skills of entrepreneurs due to the planned system's legacy.[2] Moreover, the mechanism of a competitive market is not everywhere completely installed and some necessary institutions are underdeveloped, even eight years after the beginning of transition. Secondly, the protectionist policies of some regional governments are alleviating competition on some markets and lead to geographic market segmentation. For example, the cutback of subsidies and the opening of the economy for international/regional trade and investors are not implemented in the same extend in all regions. High transactions costs also prohibit the exploration of trade opportunities and deeper specialization. Thirdly, incomplete and informal privatization may result in an inadequate supply of managerial effort. Soft budget constraints are not unusual (particularly in agriculture) and the privatization has not reached yet its initial objectives. In general, investments have decreased to a historically low level due to a economic instability, and there is no substantial growth yet in sight.

Many of the mentioned facts above are especially true for agriculture and, hence, prohibit a prospective recovery. This points out the large opportunities for enhancement of the current situation in the Russian agricultural sector. Since agriculture is for many regions the fundamental source of income, this sector should attract major political interest.

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1 See SOTNIKOV (1998), pp. 412-414.
2 MCKINSEY GLOBAL INSTITUTE (1999) – www.mckinsey.ru.

2 REVIEW OF PREVIOUS STUDIES CONCERNING RUSSIA'S AGRICULTURE EFFICIENCY

Previous studies of agricultural enterprise restructuring in Russia have relied on farm-level surveys in a small number of regions (for example, BROOKS and LERMAN, 1994; BROOKS et al., 1996; BROCK, 1997).[3] The conclusions of these studies can be summarised as follows:[4]

- Most farms (95%) have complied formally with the decrees mandating reorganisation into incorporate companies and divestiture of state-owned land;
- Most privatised farms are still internally managed like collective farms, but with more administrative autonomy and less financial security than in the Soviet era;
- Markets for commercial agricultural land have yet to develop. Neither legislators nor farm managers and employees see much usefulness in allowing land markets that might facilitate borrowing (with land as collateral), investing, and modernising.

Other studies used higher aggregated data sets and / or provided estimations regarding production possibility sets and the efficient boundaries (for example, BOUZAHER et al., 1994; KURKALOVA and JENSEN, 1996), that analysed a sample of collective farms in today's Ukraine). The results showed that in the period of down-going communist era in the Soviet Union as a whole (therefore also in the today's Russia) the trend of technical efficiency was negative or at best stable for almost all commodities. Hence, there could have been two opposite trends: an easy enhancing of efficiency through improvement of factor allocation, or one could have nothing changed and the negative trend would continue, respectively.

Some later studies have considered how the Russian agricultural technical efficiency has changed in average over the period of transition (SEDIK et al., 1999), evaluating price- and trade – liberalisation effects on agriculture efficiency and welfare aspects of inefficient production (SOTNIKOV, 1998), respectively. Both studies were based on regional data and provided an impression of which stage of transition has been reached in 1995 (end of the analysed period), which are the major institutional and political disabilities, and what could be the essential measures for improving the agricultural efficiency as a whole.

Particularly, the studies mainly give similar policy implications though they have partly different empirical results and conclusions. SEDIK et al. (1999) pointed out that in nearly all analysed regions the agriculture has become more inefficient over time (1991-1995), and the rate of deterioration has been much smaller in those regions which had been originally relative high efficient. Therefore, the initial conditions played the most important role regarding development of efficiency up to 1995. SOTNIKOV (1998) has given a slightly different picture.[5] He found initially increasing technical efficiency scores during 1991-1993, and afterwards a decreasing trend back to the initial level of efficiency. The author has attributed this fact to initial efficiency gains from improving the resource allocation, followed by decreasing efficiency scores mainly determined by the lack of investments. That was leading to a worsening of fixed capital quality and consequently to a stagnant (or negative) technological progress.

The overall results of both studies are more consistent with an agricultural sector that follows a policy of regional self-sufficiency than with one engaged in actual restructuring. It was the common conclusion of both studies that deep economic reforms rather than partial restructuring are needed to improve production efficiency.

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[3] There are some other studies that concern the pre-transition phase of the situation in Russia's agricultural enterprises (see DANILIN et al., 1985; SKOLD and POPOV, 1992; KOOPMAN, 1989).

[4] See SEDIK et al. (1999).

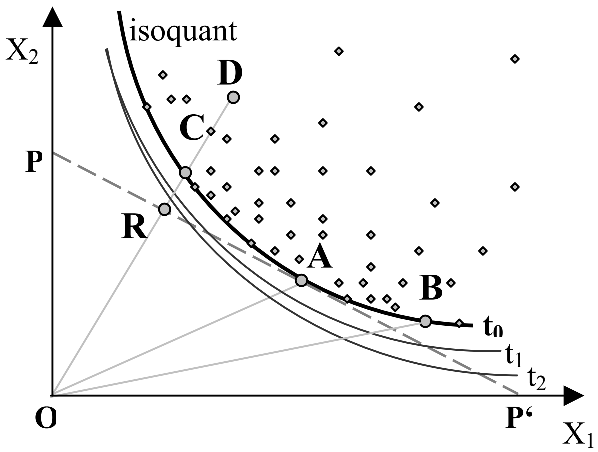
[5] It should be mentioned that SEDIK et al. (1999) excluded the livestock production out of the analysis.

3 METHODOLOGY

The general approach to estimate technical efficiency is described in the seminal work of Farrell (1957). According to the definition, technical efficiency (TE) is the ability to produce a given level output with a minimum quantity of inputs with a certain technology. Allocative efficiency (AE) can be estimated to evaluate the ability of choosing optimal input levels for given factor prices – it concerns the optimal allocation of factors of the production which maximise the producers profits. Economic or total efficiency (EE) is the product of technical and allocative efficiency. It should be evident that technically efficiency refers to the physical characteristics of the production process rather than two others.

The concept of efficiency will be explained with reference to Figure 1.[6] The diagram shows the efficient unit isoquant for a group of regions using inputs X_1 and X_2 at a particular time (t_0).[7] Regions located on this isoquant use the least amounts of these inputs to produce one unit of output. If points A, B, C and D denote regions which are producing a unit of the product, then regions A, B, C, being on the isoquant, are technically efficient but region D would be judged to be technically inefficient. A measure of technical efficiency for region D is given by OC/OD, i.e. region D could reduce both inputs by a proportion OC/OD and still produce the same level of output. Given relative inputs prices, the isocost-line PP' indicates the minimum cost of producing one unit of output and so overall economic efficiency is highest at the point A on the unit isoquant. Noting that the point R has the same level of costs as A but is outside of the production possibility set.

Figure 1: Farrell's Efficiency Indices



Farrell proposed that overall economic efficiency of region D could be measured as OR/OD, with OR/OC representing allocative efficiency, or the divergence between the minimum cost point and the costs incurred at point C. The overall economic efficiency measure can be decomposed as follows OR/OD=OC/OD*OR/OC, i.e. EE=TE*AE.

Given these definitions, region A would be economically efficient, regions B and C would be technically efficient but not allocatively efficient, and region D would be neither technically nor allocatively efficient.

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6 The figure illustrate the input-oriented concept, which shows an Input Distance Function regarding the Input Requirement Set. Also frequently used is the output-oriented concept, which shows an Output Distance Function regarding the Production Possibility Set. Essentially, one should select this orientation according to which quantities (inputs or outputs) the subjects have most control over (see e.g. COELLI et al., 1998, pp. 134 ff.). It should be mentioned, that output- and input-oriented models will estimate exactly the same frontier and there-fore, by definition, identify the same set of subjects as being efficient. It's only the efficiency measure associated with the inefficient subjects that may differ between the two methods. Furthermore, in many instances, the choice of orientation has only a minor influence upon the scores obtained (COELLI et al., 1998, pp. 158-159).

7 An additional aspect to the efficiency considerations is the technological change over time. Whenever the production frontier changes its shape or the position (shift) we speak about technological change. The figure shows three hypothetically isoquants – for the present time (t_0), the time (t_1) and (t_2). The three isoquants (t_0, t_1, t_2) represent a hypothetical neutral (t_0 ò to t_1) and non-neutral (positive) technological progress (t_1 ò t_2), respectively.

3.1 The myth of efficiency

A measure of producer performance in response to economic incentives is often useful for policy purposes. The concept of economic efficiency provides a theoretical foundation for such a measure. The efficiency can only be considered in relative sense, as a deviation from the best practice of a representative peer group of producers. The technical efficiency can be taken to be a universal goal that is applicable in any economic system. On the other hand allocative efficiency and overall economic efficiency presume that the entrepreneurs' objective is profit maximisation. Nevertheless, it should be noted at the outset that the validity of the concept has been questioned by a number of authors. We will therefore try to access its usefulness in the light of some of this criticism.

The controversy about the interpretation of efficiency measure concerns both the validity of the efficiency standards used and the accuracy of the empirical measures obtained. PASOUR (1981) suggests that a level of performance which is achievable only under ideal conditions of perfect knowledge is not an appropriate standard against which to measure real world performance. The performance standards derived on the assumption of profit maximisation should not be used to measure the performance of entrepreneurs whose objective functions include other elements than profit. A third area of controversy raises questions about the accuracy of empirical measures. In particular it is argued that observed inefficiency may be due solely to our inability to measure inputs accurately. For example quality differences in land and labour are often difficult to record, while the problems of measuring capital inputs and management expertise are further complications (we try to avoid these problems more or less).

Another pertinent argument suggests that the notion of efficiency is relevant only within the narrow confines of the perfectly competitive equilibrium and hence irrelevant to real world problems. Specifically, allocative efficiency assumes that market prices are a true measure of relative scarcity but when prices are distorted by governments or monopolies or where goods remain outside the market system, the role of prices in resource allocation is greatly impaired.

As a final criticism we can add the difficulty of interpreting a static efficiency measure in the dynamic setting of agricultural decision making. Since the producer's resource allocation decisions are based on expectations over several production periods, any performance standard over a single period may be misleading. When confronted with this lengthy catalogue of criticism, a number of authors (e.g. RIZZO, 1979) have concluded that the concept should be abandoned. Finally, care has to be taken, when reviewing empirical work on the subject. However, on a more positive note, we should accept the proposition that it is valid to try to estimate producers' performance in terms of technical efficiency, since to a larger extent the latter approach avoid many of the criticism levied upon more general efficiency concepts. In particular, measures of technical efficiency rely less heavily on the assumptions of perfect knowledge, perfectly competitive markets and the profit maximisation objective.

Despite these disabilities, we will employ the basic concept of efficiency measurement. There remain many reasons for excluding the allocative efficiency out of the empirical analysis. First, the methodical disabilities are especially important for a country in transition – like Russia. And secondly, there is no suitable access to disaggregated and qualified price data for all regions. Therefore, we only consider technical efficiency – the ability of regions (aggregated producers) to transform inputs to outputs efficiently.

3.2 The methodological framework

Empirical studies using frontier production function methodologies to measure productive efficiency can be differentiated on the basis of two criteria. The first of these relates to the use of parametric methods versus non-parametric methods. Parametric methods involve specification of a particular functional form, while non-parametric methods do not have this requirement.

Production efficiency studies may also be differentiated on the basis of whether they utilise deterministic or stochastic methods (i.e., the second criterion). Deterministic methods assume that all deviations from the frontier function result from inefficiency. Stochastic methods allow for some deviation to be attributable to statistical noise.

The vast majority of empirical studies have utilised parametric approaches to measure production efficiency.[8] Deterministic frontier functions can be estimated using two alternative approaches: programming models and statistical models (i.e., econometric analysis). Stochastic frontier functions are estimated through the use of statistical models. Both deterministic and stochastic modelling approaches have experienced widespread use in the analysis of production efficiency for developing countries.

Given the alternative empirical tools available, the choice as to the "best" method is unclear. Little rigorous analysis has been done in assessing the sensitivity of efficiency measures to the choice of methodology. BRAVO-URETA and RIEGER (1990) compare the results of deterministic (both programming and econometric analyses) and stochastic parametric efficiency models for a sample of U.S. dairy farms. While the estimates from each approach differ quantitatively, the ordinal efficiency rankings of farms obtained from the different models appear to be quite similar. This would suggest that, to a certain degree, the choice between deterministic and stochastic methods is somewhat arbitrary.

3.3 Selection of the suitable method

There are two common methods to measure technical efficiency. These are data envelopment analysis (DEA) and stochastic frontier analysis (SFA). Both methodologies are relatively established and straightforward ways of obtaining a static measure of technical efficiency. The econometric approach (SFA) has the virtue of being stochastic, and so attempts to distinguish the effects of statistical noise from those of productive inefficiency. However, the econometric approach is parametric, and so can confound the effects of misspecification of (even flexible) functional forms (of both technology and inefficiency). A main attraction of the econometric approach is the possibility it offers for a specification in the case of panel data. It also allows for a formal statistical testing of hypotheses and the construction of confidence intervals. COELLI (1995a) concludes that the stochastic frontier method is recommended for use in agricultural applications, because measurement error, missing variables and weather, etc. are likely to play a significant role in agriculture.

For the technical efficiency analysis one can use one of both Stochastic Frontier Analysis (SFA) & Data Envelopment Analysis (DEA). Here, we engage a SFA solely because it seems to be the most appropriate methodology for this analysis. The strengths and limitations of this methods are discussed in the next chapter of in this paper.

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[8] BATTESE (1992) provides a review of parametric efficiency models, both deterministic and stochastic.

3.4 Features of the Stochastic Frontier Analysis

Our goal is not only to define the best method to measure technical efficiency, but also attempt to explain technical efficiency. This leads to more complex methodological issues. With both SFA and DEA methodologies, earlier studies engaged in two steps approaches, which was later found to be a theoretical problem.[9] The first stage involves the measuring of the technical inefficiency effects under the assumption that these inefficiency effects are identically distributed. The second stage involves the specification of a regression model for the predicted technical inefficiency effects, which contradicts the assumption of identically distributed inefficiency effects in the stochastic frontier.

This has led to a few alternative formulations for simultaneous estimation which employ the one-stage approach[10]. In this case, we can use, for example, the BATTESE and COELLI (1995) formulation in which the following system of equations is simultaneously estimated using maximum likelihood procedures[11]:

$$Y = g(X_a, \beta) + v - u \qquad (1)$$

$$u_i = Z_i\delta + w_i \qquad i = 1,..., n \qquad (2)$$

where Y is output, X_a denotes the actual matrix of inputs, β is the parameter-vector of a production function, v is a random error term with zero mean, u is a nonnegative one-sided error term, Z_i is a vector of exogenous explanatory variables, δ is a vector of parameters to be estimated, and w_i is a random variable. Here, w_i is a truncated normal variable with zero mean and variance σ^2 such that $w_i \geq - Z_i\delta$, which is consistent with $u_i \sim N(-Z_i\delta, \sigma^2)$.

An important feature of this model is the composite nature of the error term. In essence, this model can be considered a special case of violating the standard OLS model assumption of having a spherical error term. When this assumption is violated, the error term is examined further to separate random noise and systematic technical inefficiency.

The frontier production function is represented by $g(X_a, \beta)$, and is a measures the maximum potential output for any particular input vector X_a. Both v and u cause actual production to deviate from this frontier. The random variability in production that cannot be influenced by producers is represented by v; it is identically and independently distributed as $N(0, \sigma_v^2)$. The nonnegative error term u represents deviations from maximum potential output attributable to technical inefficiency; u is identically and independently "half normal" distributed $(i.e., |N(0, \sigma_u^2)|)$. The expression of technical efficiency relies on the value of the unobserv-

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9 With SFA, this problem is best explained in BATTESE and COELLI (1995), pp. 325-326.

10 There are several reasons for estimating all parameters of the model in one stage (see FRIED et al., 1993). First, this procedure provides more efficient estimates than the two-stage procedure, whereby efficiency scores are obtained and then regressed on explanatory variables. Second, in general, it is hard to distinguish between a variable that belongs to the first stage (production function) and the second stage (explanatory variables). Third, in a one-stage model, explanatory variables directly influence the transformation of inputs and efficiency is estimated, controlling for the influence of explanatory variables. Fourth, another problem with the two-stage estimation model is that if Z and X variables are likely correlated, then estimates of ß and the technical efficiency scores are biased (FRIED et al., 1993). The one-stage formulation does not solve the problem of multicollinearity, but it reduces the omitted variable problem of the two-stage estimation.

11 For a detailed derivation of the log-likelihood function see: BATTESE and CORRA (1977); AIGNER, LOVELL and SCHMIDT (1977), p. 28.

able u_i, which must be predicted. These predictions are obtained by deriving the expectation of the appropriate function of u_i conditional on the observed value of v_i - u_i.

Following the method used by BRAVO-URETA and EVENSON (1994) efficiency is empirically measured using adjusted output, as follows $Y^* = g(X_a, \beta) - u$, where u is calculated as:

$$E(u_i / \in_i) = \frac{\sigma\lambda}{1+\lambda^2}\left[\frac{f^*(\in_i \lambda/\sigma)}{1-F^*(\in_i \lambda/\sigma)} - \frac{\in_i \lambda}{\sigma}\right] \quad (3)$$

Here, $f^*(...)$ and $F^*(...)$ are the standard normal density and cumulative distribution functions, respectively, $\lambda = \frac{c_u}{\sigma_v}$, $\in = v - u$, $\sigma^2 = \sigma_v^2 + \sigma_u^2$ and Y^* is the observed output, adjusted for statistical noise. This adjusted output forms the basis for calculating X_t.

Technical efficiency is measured as:

$$TE_i = Y_i / Y_i^* = F(X_i;\beta)\exp(v_i - u_i) / F(X_i;\beta)\exp(v_i) = \exp(-u_i), \quad (4)$$

where Y_i^* is potential output.

The estimation procedure for obtaining the final maximum likelihood estimates of parameters of the stochastic frontier production function follows a grid search. Technically, starting from given initial values, an iterative procedure is employed to find the parameters that provide the maximum value of the log-likelihood function. The initial values are commonly given by previous OLS and COLS estimations, respectively.

In recent studies, the question of the most appropriate distribution for the compound error term has arisen.[12] Three commonly assumed distributions are the truncated half-normal distribution proposed by AIGNER, LOVELL and SCHMIDT (1977), truncated normal distribution proposed by STEVENSON (1980), and the gamma distribution proposed by GREENE (1990)[13].

Important model specification issues are the choice of the functional form and methods of dealing with potential data problems (omitted variables, multicollinearity, heteroscedasticity). Common functional forms used in practice include the Cobb-Douglas functional form and translog functional form[14]. The latter represents the class of more flexible functional forms and may be chosen for modelling frontier agricultural production technology. The specification of translog function is flexible but it often does not yield coefficients of plausible sign and magnitude, possibly due to degrees of freedom or multicollinearity. However, KOPP and SMITH (1980) suggest that functional form has a limited effect on empirical efficiency measurement, i.e. the measurement of technical efficiency is insensitive to the choice of functional form, because this property is more related to the shifts of isoquants, rather than their shapes, according to KURKALOVA and JENSEN (1996).

The Cobb-Douglas functional form also meets the requirement of being self-dual, allowing an examination of economic efficiency. However, the Cobb-Douglas form has been used in many

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12 BRAVO-URETO and PINHEIRO (1993) provide a discussion of this methodological issue.

13 GREENE (1990) proposes a modified frontier model that includes a one-sided error term specified using a Gamma distribution, rather than the half-normal. However, GREENE does not provide a test of this specification. While more flexible distributional assumptions can be made for u, most empirical stochastic frontier production function studies use the half-normal distribution.

14 The transcendental logarithmic function.

empirical studies, particularly those relating to agriculture in developing countries. Yet in this study, this specification is not appropriate due to its restrictions. In recent studies more "flexible" functional forms than the Cobb-Douglas have been used for modelling the frontier of the agricultural production technology (e.g., the translog used by KUMBHAKAR, 1994). In this study also a translog functional form is employed to model production technology. This was done, because the translog functional form meets lower *a priori* requirements than the Cobb-Douglas form on the basic production behaviour. Therefore, the translog form should give a more appropriate replication of the real situation.

4 THE ECONOMETRIC MODEL

It should be mentioned that we employ the basic concept of technical efficiency described above in a modified way – comparable the concept of an aggregated Metaproduction Function (MPF), first introduced by HAYAMI and RUTTAN (1970). We compare every region with the estimated (overall) Production Frontier. But its imaginable that every region has own production frontiers, defined by economic and institutional variables and is not able to reach the overall frontier due to regional specifically circumstances. Therefore, the MPF is defined by the best practise producers as well as the best natural and institutional conditions. To avoid a misspecification and to give also the account of the influence of these variables, we include such institutional variables as explanatory variables (called Z_i – see in the next chapter) in the model. In the result, we could use the basic concept of technical efficiency measurement (as discribed in Figure 1), and the Z_i variables covers differences in the natural and institutional conditions (for example: soil quality, temperature, rainfall), and bridge the potentially gap between real production frontier of the region and the overall frontier. The significance of the Z_i variables will be an indicator for the existence of individually production frontiers among regions. In a further step, we account the influence of these variables on the efficiency, and try to give some policy implications based on this measurements.

We apply maximum likelihood techniques to estimate parameters and predict errors. These have proven to be the most popular approaches to the estimating parameters in the stochastic frontier model. The translog production function was used to describe the first equation from the system. It has the following form

$$\ln Y_{it} = \beta_0 + \sum_{j=1}^{n} \beta_j \ln X_{ijt} + \sum_{j\leq}^{n} \sum_{k=1}^{n} \beta_{jk} \ln X_{ijt} \ln X_{ikt} + \sum_{j=1}^{n} \beta_{jj} \frac{1}{2} (\ln X_{ijt})^2 + \\ + \sum_{j=1}^{n} \beta_{jt}\, t \ln X_{ijt} + \beta_t t + \beta_{tt} t^2 + v_{it} - u_{it} \qquad (5)$$

where the subscript i refers to the region and t to the time period, Y_{it} represents the value of agricultural production, X_{ijt} represents n production inputs for each region, β are parameters of the production function and β_0 is an intercept. The error term is assumed to have two components, with properties as discussed above.

The basic idea was to specify the model flexible over time. Therefore, we have added a linear as well as a quadratic time variable to cover shifts of the isoquant over time[15] (neutral technological progress – means a radial shift of the isoquant in relation to the origin). The t-indices at the variables provide also the possibility to account non-neutral technological prog-

[15] Implicit, we have used a formulation of technological progress following the concept of HOCKMANN (1992), pp. 97-98. He suggests a exponentially functional form for description of technological progress over time.

ress.[16] The technical change index between two points in time can be directly calculated from the estimated parameters by a simple partial derivation of the production function with respect to time (at a particular data point). If technical change is non-neutral then this technical change index may vary for different input vectors. HENCE, COELLI et al. (1998) suggest that a geometric mean should be used to estimate the technical change index between adjacent periods t_0 and t_1.

$$\text{Technical Change} = \left\{\left[1+\frac{\partial f\left(x_{it_0}, t_0, \beta\right)}{\partial t_0}\right] * \left[1+\frac{\partial f\left(x_{it_1}, t_1, \beta\right)}{\partial t_1}\right]\right\}^{0.5} \quad (6)$$

The index of technical efficiency change (= TE_{it_1} / TE_{it_0}) and technical change may then be multiplied together to obtain a Malmquist Total Factor Productivity (TFP) index.[17]

To estimate the coefficients and then to incorporate the effects of explanatory variables on technical efficiency scores a one stage estimation approach was used. As before v_{it} is identically and independently distributed as $N(0,\sigma_v^2)$. The nonnegative error term u represents deviations from maximum potential output attributable to technical inefficiency; u is identically and independently distributed and are also assumed to be truncated normal$|N(\mu_{it},\sigma_u^2)|$, where $\mu_{it} = Z_{it}\delta$ and Z_{it} is a vector of variables that are assumed to influence technical efficiency and δ is a vector of parameters to be estimated.

To take advantage of the panel nature of the data and to increase efficiency the cross-section and time series data were pooled. A series of likelihood ratio tests was performed to arrive at a statistically plausible specification of the final model.

The computer program Frontier Version 4.1[18], developed by COELLI (1996), was used for maximum likelihood estimation of the stochastic frontier production function. Along with the parameters of the function itself, Frontier program also estimates the following parameters of the likelihood function $\sigma^2 = \sigma_V^2 + \sigma_U^2$, $\gamma = \sigma_U^2 / \sigma^2$ and testing the significance of the parameter γ; its of interest from the point of view of model specification. It must be in the range [0,1], and measures the proportion of total variation to that is attributed to technical inefficiency. If $\gamma = 0$, it means that $\sigma_U^2 \to 0$. In this case, the production frontier is not a good specification, and the model could alternatively be estimated by ordinary least squares – means the frontier approach is obviously not appropriate.

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16 For problems related to the accounting of neutral and non-neutral technological progress in an inefficient economic environment see GROSSKOPF (1993), pp. 160-194.

17 Defined as: $m_o(y_{t_0}, x_{t_0}, y_{t_1}, x_{t_1}) = \frac{d_o^{t_1}(y_{t_1}, x_{t_1})}{d_o^{t_0}(y_{t_0}, x_{t_0})}\left[\frac{d_o^{t_0}(y_{t_1}, x_{t_1})}{d_o^{t_1}(y_{t_1}, x_{t_1})} * \frac{d_o^{t_0}(y_{t_0}, x_{t_0})}{d_o^{t_1}(y_{t_0}, x_{t_0})}\right]^{0.5}$ where the ratio outside the square brackets measures the change in the output-oriented measure of Farrell's technical efficiency between period t_0 and t_1. The remaining part of the index is the measure of technological change (geometrical mean of the shift in technology between the two periods). [d_o^t] refers to the output-distance-function with the technology available in t.

18 The FRONTIER 4.1 is a computer program for Stochastic Frontier Production and Cost Function Estimation. FRONTIER 4.1 is an update of the 2.0 version, includes two primary model specifications considered an error components specification with time-varying efficiencies permitted (version 2.0), and a model specification in which the firm effects are directly influenced by a number of explanatory variables.

5 DATASET

In our analysis, the basic dataset contains information about the value of agricultural production, use of land, labour, mineral fertiliser and the amount of horse power of machinery (as a proxy for energy and – indirectly – for capital) in nearly all regions of Russia (covers 75 of 89 regions). Region-level value of production, quantity of inputs used in production and financial and institutional variables pertaining to the economic environment of producers are all taken or derived from official Russian State Committee on Statistics sources. During data collection, three major conceptual issues are faced: choice of appropriate proxies for inputs, adjustment for differences in input quality, adjustments on prices and the problem of an unbalanced panel (lack of data for several regions). In response to these issues, the data have been adjusted.

5.1 Basic data – aggregated output and production factors

For calculation of the relative levels of technical efficiency, a production function can be constructed, using the variables $X_1,\ldots,X_4$ for each region considered. These variables were defined as follows:

[Y] Value of output. Gross value of output from regions using 1996 prices.[19] The use of 1996 prices for output aggregation may introduce a bias.[20] However, use of alternative output aggregation methods, based, for example, on evaluation of different components of output at current producer prices or on deflation of aggregate output numbers at current prices by the producer/consumer price index is very complicated and partly even impossible, also resulted in practically identical estimates of aggregate output.[21]

[$X_{(L)abor}$] Amount of labour input (thousand men worked in production). It should be mentioned that labour use for the subsistence sector of Russia is not reported in the official statistics. Therefore, the study includes only officially reported information.[22] Furthermore, the statistics mostly do not provide any distinction between different qualities of labour, and which kind of enterprises employ the workers. Therefore, the total labour input was calculated under the assumption that labour productivity in all regions and enterprises was approximately the same.[23] This assumption may seem too restrictive, but has been used by other authors (for example, SOTNIKOV, 1998) because of the lack of alternatives.[24]

[$X_{(F)ertiliser}$] Amount of fertiliser. It should be noticed that for several years statistics gives the number of tons of fertiliser delivered in agricultural enterprises and for other years – purchased by agricultural enterprises. We suggest that all these numbers of tons were approximately used by agricultural enterprises. For simplicity we also consider only mineral fertiliser.

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[19] We've taken the Gross Agricultural Output (GAO) from the Russian Statistic Committee – Goscomstat – and adjusted it by the physical quantity index to obtain the comparable GAO-values.

[20] It should be mentioned that – even in a situation of drastic price variations over the analysed period and partly governmental influenced prices – always these regions will find to be more efficient that produce products which relative prices has been raised very quickly. Therefore, in the case of Russia – the regions which has produced grain (particularly wheat) should found to be higher efficient.

[21] See SOTNIKOV (1998) for selection of appropriate output data for a regional efficiency analysis, pp. 418-419.

[22] At the time when regional data of the household plots in Russia will be available it seems to be an important field for upgrading the study.

[23] Perhaps, a calculation of total labour input in relation to the aggregated net-wages is a better approximation. But the statistics regarding nominal / real / net wages in Russia are strong biased due to the notable amount of wage arrears. Therefore, such a way of formulation introduce a new bias.

[24] Since the private sector tends to produce more labour-intensive commodities, total labour input may be underestimated because of this assumption.

[$X_{(L)and}$] Land area. Quantity of agriculturally used land (in thousand ha).

[$X_{(E)nergy}$] Total machinery's horse power as a proxy for energy and – indirectly – for capital. The amount of total horse power of agricultural machinery and electric engines was taken from Goscomstat. The use of this variable as a proxy for capital is reasoned by the lack of data regarding the amount of fixed assets (per region/sector) and seems to be the most appropriate alternative. This proceeding has been used also in other studies. Based on the same dataset Sotnikov has found the coefficient of correlation between the fixed asset data series (available only for 1995) and the data of horse power of agricultural machinery for the same year was the highest (0.92) compared to other optional proxies. To avoid any misunderstandings we call this variable "Energy" because we have an explanatory variable (see below) that covers financial conditions and which is called "Capital".

5.2 External environmental factors

5.2.1 Explanatory variables

First, it should be mentioned that there exists a wide range of factors that can explain the differences in technical efficiency. Other than some "hard" factors – that can easily be measured – there exist many institutional conditions that raise suspicion considering influence level and growth rate of technical efficiency. It is very difficult to extract the factors that have a separate significant influence on efficiency. One can find – in most cases – a complex external environment and it is necessary to simplify the interdependencies[25] for a sufficient analysis. In the study's inherent pre-selection of those factors – which we consider as important factors influencing technical efficiency – we were using the experiences of previous studies concerning Russia's agriculture. The previous studies[26] have found that the following factors were very important in explaining the relative efficiency of the Russian agricultural production:

Average farm size: SEDIK et al. (1999) has found that larger (crop) farms tend to be least efficient. This finding suggests that farms in Russia, on average, employ too much land in production. This is not surprising, since the average corporate farm in Russia is six times larger in comparison with the average one in the United States. Otherwise, SOTNIKOV (1998) has estimated a positive influence of farm size on efficiency.

Employees per farm: Both studies (SEDIK et al. (1999) and SOTNIKOV (1998) ò only indirectly) – pointed out that labour is quite scarce on Russian farms. They argued that before reforms, state and collective farms traditionally employed military troops, students, and other city dwellers during the harvest period to augment their labour force. Now that these practices have been curtailed, this result seems to indicate that there are labour shortages, probably during the harvest season. As a result, for corporate farms identical in all other respects, the marginal return per worker most likely exceeds the marginal costs.[27]

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25 It should be mentioned that this is the common approach but, it's possible that the results are biased.

26 See SOTNIKOV (1998); SEDIK et al. (1999). Compare also chapter 2 in this paper.

27 This result seem surprising, since it is often found that joint stock companies with soft budget constraints in transition economies retain excess labour, so that the added benefit of employing another worker is smaller than the extra cost of keeping that worker. However, the finding of those studies are not as surprising as they might appear at first glance. Recall that SEDIK et al. (1999) concerns exclusively workers employed in crop production. It may be the case that corporate farms tend to retain excess labour for livestock production, but the authors did not consider the livestock sector in the study. Temporary labour was not and is not used for livestock production. This result highlighted important differences between the two sectors in Russia.

Temperature above the long term average (in connection with occasional droughts) in critical growing months in some regions led to sharp declines in production after inputs had already been used, which had the effect of a sharp decrease in efficiency.

Share of individual plots in the total production:[28] For example, actually, most crop production (by value) is produced on small (0.5 to 1 hectare) individual plots attached to the large corporate farms. It was found that the greater the portion of the value of crop output produced in the private sector (primarily on these individual plots, engaged in intensive cultivation of fruits and vegetables), the less efficient has been crop production on corporate farms. This finding may be a result of the widely reported pilfering of corporate farm inputs (including labour time) by individual plot holders. An increase in production on these plots could lead to increased pilfering, and so it would tend to lower the apparent efficiency of corporate farms.

Changes in the agricultural terms of trade (the ratio of output prices to input prices): The more radical the worsening in the agricultural terms of trade, the more farms were forced to improve their efficiency or leave the market. Such improvement through adversity reflect the fact that price shocks on the input side led to more rational use of inputs, especially for fertilisers, which were (compared to other countries) previously overused.

Subsidies as a percent of revenues: The higher percentage of subsidies (compared to total revenues), the more inefficient are corporate farms. This suggests that government support policies provide the subsidies to the least efficient corporate farms, and/or that support policies tend to encourage less efficient production.

Percent of output (crop) marketed through state channels: The distribution through old state marketing channels is considered as more efficient way to provide production to the customers. Hence, regions that relied on the old channels did not have to incur short-run search and transaction costs. It allows them to concentrate entirely on the production rather than on marketing.[29] Alternatively, perhaps the state only tends to purchase from the more efficient farms.

Quality of infrastructure and institutions: There exist many proxies apt to capture infrastructure's quality and regional characteristics of institutions; for example, road and / or railway density, number of phones per thousand inhabitants, precision of weather predictions, level of social security, quality of regional education infrastructure, etc., respectively.

Management: Managers may pursue goals other than profit maximisation or cost minimisation, such as retaining workers or land, rent-seeking or seeking to carry out the wishes of the local authorities. Increasing managerial transaction costs connected with the size or scope of the enterprise is another possible cause of relative differences in the level of technical efficiency between regions (WILLIAMSON, 1985).

Moreover, some additional factors could also be responsible for differences in the technical efficiency between several regions: weather, institutional differences, different political environments associated with the political affiliation of regional administrations.

There are also a number of possible institutional causes of technical efficiency differences; in Russian agriculture, those are difficult to measure. These institutional differences cannot be integrated into the production function, which is typically concerned with quantities of inputs,

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[28] It should be mentioned that only SEDIK et al. (1999) has found that this variable to be statistically significant. SOTNIKOV (1998) has eliminated the variable “share of private sector on agricultural production” from the model because it was found to have a statistically in-significant effect (during transition period).

[29] Recall that the study only covered the early transition period. Perhaps a test of significance in a longer-term analysis provides a quite different result.

outputs, and a specific production technology. The degree of budget softness has been discussed extensively in the literature of transition economics as an institutional source of technical inefficiency (GOMULKA, 1985; SCOTT, 1990; RAISER, 1997; KORNAI, 1985). Lack of functional output markets and low production specialisation are other possible causes of technical inefficiency. A further potential cause of inefficiency mentioned in the literature is the effect of economic disorganisation in the transition process (BLANCHARD, 1997). The presence of reliable and unchanging channels for both inputs and outputs as well as the uncertainty associated with the transition increase the transaction costs of attending markets. Thus, preservation of the old channels of state input supply and output sales could be associated with shortfalls in technical efficiency.

5.2.2 Selection of relevant structural and institutional variables

For the estimation of the determinants of technical inefficiency, we considered the following variables, $Z_1,\dots,Z_{12}$, as weather, structural and institutional variables which we believe to explain different levels in technical efficiency among regions. The Z variables are defined as follows:

[Z_1] Number of agricultural enterprises per region (NaE). Since there exist a great number of enterprises in a region the probability is high enough that one can observe a stronger competition and a workable economic network of several enterprises (what is commonly known as spin-over and spill-over effects). If this assumption is widely true, the NE – variable should be positively related to a higher level of technical efficiency. Otherwise, it is imaginable, if the number of enterprises in a region is so high that most of all are undersized from an economic point of view then there could be a negative relationship between number of enterprises and technical efficiency observed, which might be due to a lack of economies of scale.

[Z_2] Average farm size (AfS). For each region, area per agricultural enterprise was taken as a proxy.[30] The average size of collective farms should be negatively related to technical efficiency due to the difficulties of monitoring that usually increase with farm size (principal-agent problems). On the other hand, larger farms could tend to use resources more efficiently due to economies of scale.

[Z_3] Employees per agricultural enterprise (EpE). For each region, total average number of workers and employees over the year employed in all productions (includes permanent and seasonal) divided by the total number of agricultural enterprises in the region was used. If the variable is positively related to technical efficiency it is a hint that labour is a scarce factor in the Russian agricultural enterprises and, therefore, a growing employment could improve technical efficiency. Alternatively, the number of employees could be negative related to technical efficiency because the problem of monitoring or simply because of over-employment (inadequate capacity / education level, etc.).

[Z_4] Number of tractors per agricultural enterprises (NoT). Normally, this variable should be positively related to technical efficiency. A higher number of tractors indicates a more engineered agricultural production that should show higher efficiency than a farm that do not use any technical equipment. A higher number of tractors should provide an improvement in technical efficiency: in the case of new founded enterprises due to the shift from manual produc-

[30] The variables Z_1-Z_3 should interpreted in common because they are all proxies for the average structure of regional agricultural enterprises.

tion to an engineered one, and in the case of corporate farms (former Kolkhozes or Sovkhozes) because of positive efficiency effects of the substitution of old by new machinery.[31, 32]

[Z_5] Average wages (AW).[33] Theoretically, a higher wage level should indicate a higher labour productivity and, therefore, a more efficient production. In Russia this principle is partly destroyed by non-competitive labour market and by the traditional absence of agricultural labour force migration. Furthermore, a higher wage level leads to a regional higher level of purchasing power, which means higher probability of sufficient demand structures and therefore economies of scale in marketing induced by higher marketed quantities. Moreover, higher wages increases the motivation of employees.

[Z_6] Soil Quality (SQ). We use a comparable statistical survey of soil quality published by Russian statistics. A higher soil quality should be related to a higher value of technical efficiency of agricultural production. This variable as well as Z_{10} and Z_{11} can be interpreted as explanatory variables for the different regional natural conditions of agricultural production (bridge the potentially gap between the "real" production frontier of the region and the overall production frontier (see the concept of Metaproduction Frontier – discussed above).

[Z_7] Average fuel/diesel[34] delivery to agricultural enterprises (FD). Tons of fuel products delivered/purchased to/by agricultural enterprises and used in production. This variable could be seen as an additional indicator for the utilisation of machinery, with the contrast to Z_4: This variable indicates the effective utilisation of fuel for agricultural machinery and heating. Another reason why we have included the Z_7 variable are the regional differences of the ability of enterprises for purchasing intermediate inputs for money. Therefore, a region where enterprises (in average) purchase a great amount of fuel should be stamped by a high utilisation of machinery, by functioning input markets, and by solvent enterprises. Therefore, we believe a higher fuel/diesel purchasing/delivery should be positively related to technical efficiency. Otherwise, a negative relation could indicate an inefficient allocation of these inputs.

[Z_8] Share of new legal organisational forms (the ratio of number of enterprises under new legal organisational forms to total number of enterprises) (NlF). The share of private farms in total production was used as a proxy for the effect of privatisation on efficiency, and was expected (though with great precaution) to be positive since private ownership ideally should provide better work incentives, management, and reduction in waste. In fact, one can dispute such a way of implementing and interpreting this variable.

[Z_9] Precipitation – mean rainfall [mm].[35] (RF)

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31 But it should be mentioned that the scarcity of capital and availability of credits could provide a biased picture. The enterprises mostly have no access to technical equipment because of the lack of money and, consequently, they often use old machinery from the Soviet period, that – with respect to the number of machines – gives a better picture than in reality (many very old machines are not up to date or out of order from technical point of view and, therefore, are very expensive in use).

32 Since we only consider the number of tractors and not, for example, the costs of utilisation of machinery, we could not believe on a negative relation of this variable to technical efficiency scores. An additional consideration of utilisation-costs of machinery could provide a different picture. It is believable that for any (mostly new founded) enterprises the capital-costs are so high that a production without (or only with low level) utilisation of machinery is individual rational. In this cases, the relation of number of tractors to (economic / cost) efficiency could be negative.

33 Only the "net-wages" was taking into account (i.e.: exclusive the outstanding wage-payments).

34 We have tested both fuel and diesel as explanatory variables. In the final restricted model we have only included fuel because both variables were found to be highly correlated with each other.

35 We have had access only for rainfall data for January and July. Therefore, we have used the values for July. But, since for several products July are not the critical growing month, the results could be biased.

[Z_{10}] Mean Temperature [degrees Fahrenheit in July] (MT).

[Z_{11}] Infrastructure / transportation [railway density in km's per 1 ha]. (IS) This variable was selected as a proxy for infrastructure situations and for transport / transaction costs. A higher density (quality) of infrastructure should be positively related to technical efficiency.

[Z_{12}] Financial conditions (FC). We have integrated the development of fixed assets (proxy for availability of credit and the financial situation)[36] which are expected to be positively correlated to technical efficiency, because the ability of management to obtain the necessary inputs at the critically important periods of planting and harvesting may affect the technical efficiency of a farm substantially.[37]

We did not include such factors as phone service and import competition because they did not affect technical efficiency of agricultural production during the transition period according to the investigation of SOTNIKOV (1998).

6 RESULTS

6.1 Econometric properties of the model

The estimation of the initial model showed that the coefficient of the variable "$X_{(L)and}$" is non-significant. Furthermore, there were few non-significant variables explaining technical efficiency. Hence, land use, fuel / diesel delivery, mean rainfall were excluded from the model. Then the model was re-estimated. The numerical results of the one–stage estimation are summarised in Table 1.

All coefficients for time-independent regressors are highly significant (even at 1% significance level) except the coefficient for $0,5*\ln F^2$ (P-value close to 37%). As the value of this coefficient is not high, we did not exclude it. As for coefficients for time-dependent regressors, they are not so significant as previous ones, but their values were considered as appropriately significant.

Explanatory variables (Z's) as a group are found to be statistically significant. The gamma parameter was found to be highly significant and close to 1, meaning that the variation in technical efficiency explains a large part of the total variance of the error term. It indicates that the stochastic frontier model doesn't differ significantly from the deterministic model, in which there are no random errors in the production function specification. This is a surprising result for an agricultural production function where one would normally expect data noise to play a large role. It can be only partly explained by including variables reflecting the weather and soil quality. In general the signs and magnitudes of coefficients explaining technical efficiency were plausible and fit with our expectations.

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36 We were trying to implement "capital" direct as an input factor, but, because of the lack of (reliable) data we have integrated only the development of fixed capital (given by regional agricultural fixed asset data for 1995, regional investments in agriculture over the analysed period and an estimated constant depreciation rate). For further work it will be very usefully to integrate capital as an input factor – especially because of the importance of new investments and substitution of the deadbeats – Soviet period – fixed capital and the problems which are connected with the access to new capital (as discussed below).

37 An alternative way to represent the financial situation could be given by integration of liabilities as explanatory variable. But the level of liabilities could provide a biased picture, because, it could be also interpreted as a sign of the failure to manage the enterprise properly, partly due to the existence of soft budget constraints. Here, we do not use short and long term debt liabilities because they introduce a high bias and they do not describe the real financial situation in Russia due to the features of accounting and tax system.

Econometric problems, including multicollinearity, could effect the estimated variances.[38] However, the directions of change in the variables proved to be essentially the same when different specifications of the model and proxies were used. Hence, the general conclusions of the analysis about the determinants of technical efficiency, seem to be robust.

Table 1: Translog function's coefficients estimations

The Final MLE estimates are:				
variable	Coeffi-cient	standard error	t-ratio	P-value
intercept	23.24	4.87	4.77	0.00
$ln_{(L)abour}$	3.63	1.13	3.21	0.00
$ln_{(F)ertiliser}$	1.56	0.31	5.07	0.00
$ln_{(E)nergy}$	-3.25	0.91	-3.58	0.00
ln_L*ln_F	0.12	0.03	3.66	0.00
ln_L*ln_E	-0.35	0.11	-3.06	0.00
ln_F*ln_E	-0.14	0.03	-4.98	0.00
$0,5*ln_L^2$	0.43	0.16	2.60	0.01
$0,5*ln_F^2$	0.01	0.01	0.89	0.37
$0,5*ln_E^2$	0.34	0.09	3.90	0.00
Time trends & time dependent variables				
$t*ln_L$	-0.08	0.03	-3.00	0.00
$t*ln_F$	0.01	0.01	1.59	0.11
$t*ln_E$	0.05	0.02	2.05	0.04
t	-0.54	0.25	-2.16	0.03
t^2	0.01	0.01	1.82	0.07
Variables explaining technical inefficiency				
intercept	7.94	0.93	8.51	0.00
$ln_{[Z1]\ NaE}$	-0.36	0.08	-4.32	0.00
$ln_{[Z2]\ AS}$	0.02	0.02	0.68	0.50
$ln_{[Z3]\ EpE}$	-0.35	0.10	-3.51	0.00
$ln_{[Z4]\ NoT}$	-0.10	0.08	-1.25	0.21
$ln_{[Z5]\ AW}$	-0.40	0.05	-8.26	0.00
$ln_{[Z6]\ SQ}$	-0.21	0.08	-2.80	0.01
$ln_{[Z8]\ NIF}$	-0.05	0.03	-1.67	0.09
$ln_{[Z10]\ MT}$	0.53	0.19	2.76	0.01
$ln_{[Z11]\ IS}$	0.02	0.01	1.47	0.14
$ln_{[Z12]\ FC}$	-0.06	0.05	-1.36	0.17
Sigma squared & Gamma				
sigma-squared	0.04	0.00	10.38	0.00
gamma	1.00	0.00	284.70	0.00
Log likelihood function				84.02
LR test of the one-sided error				287.55

The OLS estimates are:				
variable	coeffi-cient	standard error	t-ratio	P-value
intercept	65.81	7.28	9.03	0.00
$ln_{(L)abour}$	8.38	1.39	6.01	0.00
$ln_{(F)ertiliser}$	1.90	0.39	4.91	0.00
$ln_{(E)nergy}$	-10.51	1.32	-7.98	0.00
ln_L*ln_F	0.10	0.04	2.62	0.01
ln_L*ln_E	-0.73	0.14	-5.30	0.00
ln_F*ln_E	-0.15	0.04	-4.32	0.00
$0,5*ln_L^2$	0.73	0.18	3.97	0.00
$0,5*ln_F^2$	0.02	0.01	1.51	0.13
$0,5*ln_E^2$	0.93	0.12	7.59	0.00
Time trends & time dependent variables				
$t*ln_L$	-0.16	0.03	-5.19	0.00
$t*ln_F$	0.00	0.01	0.51	0.61
$t*ln_E$	0.15	0.03	5.64	0.00
t	-1.66	0.29	-5.72	0.00
t^2	0.01	0.01	1.59	0.11
Sigma squared & Gamma				
Sigma-squared				0.08
Log likelihood function				-59.76

Source: Estimation of the final restricted model (by using FRONTIER 4.1).

[38] The estimated parameters are unbiased, but the estimated variances of the parameters could be biased due to the problem of multicollinearity.

6.2 Economic interpretation

Production function specification is proved to be appropriate.[39] The main results of estimation are summarised in Table 1. The negative sign before (t) covers the decline of production in the short run while in the long run we have the weak opposite trend according to positive sign of the (t^2)-parameter.

The derivatives of the first and second order can be derived from this formula. Their values vary from one region to the other and hinge upon the values of the input factors. On the other hand the first order derivatives represent the factor elasticities and the second order derivatives can be useful in describing the smooth technology. The factor elasticities have the following forms:

$$E_Y^L = \frac{\partial Y}{\partial L}\frac{L}{Y} = \frac{\partial \ln Y}{\partial \ln L} = 3.63 + 0.12 * \ln F - 0.35 * \ln E + 0.225 * \ln L - 0.08 * t$$

$$E_Y^F = \frac{\partial Y}{\partial F}\frac{F}{Y} = \frac{\partial \ln Y}{\partial \ln F} = 1.56 + 0.12 * \ln L - 0.14 * \ln E + 0.005 * \ln F + 0.01 * t \qquad (7)$$

$$E_Y^E = \frac{\partial Y}{\partial E}\frac{E}{Y} = \frac{\partial \ln Y}{\partial \ln E} = -3.25 - 0.35 * \ln L - 0.14 * \ln F + 0.17 * \ln E + 0.05 * t$$

The elasticities of different inputs has changed substantially due to reform-induced adjustments (for the mean regional factor elasticities see Appendix: Table 4). The output elasticity of labour decreases during the period from 1993 to 1998 while the output elasticity of fertiliser use and energy (capital)[40] use increase.[41]

Output elasticity for labour declined in accordance with the dynamics of labour productivity change[42] while the returns to fertiliser and energy/capital increased steadily. This is not surprising, given the fact that capital becomes more and more scarce factor and with respect to the problems that are connected with access to capital for investments, and the commonly negative trends of the fixed assets, respectively, it will be increasingly difficult to provide an additional labour unit with production facilities. This circumstances determine the substantial changes of input importance and underline once more the essential importance of improvement of the financial situation of the enterprises.

As against previously mentioned the two others (fertiliser and energy/capital elasticities) have a positive trend. Fertiliser elasticity does not significantly differ from zero. Low and not very elastic returns on fertiliser use may be not quite compatible with strong increasing real fertil-

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39 The null hypothesis that the Cobb-Douglas form is an adequate representation of the data, given the specifications of the translog model, was rejected at the 5% significance level.

40 Recall that capital was not direct included in the model due to the shortage of data (only a variable for the use of machinery/energy). But it is very interesting to analyse influence on output. We can predict that real returns to capital increases as capital becomes scarcer. These findings may have important implications for international lending institutions and foreign and domestic investors.

41 SOTNIKOV has found the same results regarding labour and capital. For the fertiliser use he has found a decreasing trend of elasticities. (SOTNIKOV, 1998, p. 425).

42 The decreasing returns to labour should also be seen in the context of pilfering on corporate farms. SEDIK et al. (1999) has found that the greater the portion of the value of crop output produced in individual plots (usually engaged in intensive cultivation of fruits and vegetables), the less efficient has been crop production on corporate farms. This finding may be a result of the widely reported pilfering of corporate farm inputs (including labour time) by individual plot holders. An increase in production on these plots, is connected with an increased pilfering, would tend to lower the apparent efficiency of corporate farms and tends to lower the overall returns to labour. (One should be seen this fact also in the context of the statistically weakness of capturing the individual plots correctly).

iser prices during the transition period. Maybe the notable reduction of fertiliser input among regions will give a higher effect in the future.

The energy/capital elasticity demonstrated a permanent growth during the examined period. In average it increased by 4% per year, which means that the production became more energy/capital intensive. The highest level of energy/capital elasticity in 1998 was in West-Siberian region. Volga-Vyatka and the Central Chernozem regions have the lowest elasticities.

Altogether, this production technology has non-constant return to scale diminishing over the time: $RoS = 1.94 + 0.27 * \ln L - 0.01 * \ln F - 0.15 * \ln E + 0.03 * \ln p - 0.02 * t$ (8)
where p is the scale rate[43]. For each region RoS value was calculated and compared (see Table 2). All regions are characterised by decreasing returns to scale (RoS<1). Since we have not used farm level data for estimating the parameters we cannot deduce any direct conclusions from the RoS. Therefore, the values in Table 2 should be interpreted with caution.

Table 2: Returns to scale

	1993	*1994*	*1995*	*1996*	*1997*	*1998*
Max	1.01	0.93	0.93	0.88	0.87	0.91
Min	0.48	0.45	0.46	0.41	0.37	0.39
Mean	0.72	0.71	0.68	0.65	0.63	0.63
Standard deviation	0.10	0.10	0.10	0.10	0.10	0.10

Source: Own calculations based on the results of the final restricted frontier model.

6.2.1 Technical efficiency

The signs and magnitudes of coefficients explaining technical efficiency in general were plausible. Agricultural output and technical efficiency are positively related[44] to number of agricultural enterprises, number of employees and workers as well as tractors per agricultural enterprise, average wage level, soil quality, the share of new legal form enterprises on all enterprises and the financial conditions. We could expect such results. According to the estimation procedure the technical efficiency can be described as follows:

$$TE = \exp(u_i) = \exp(-7.94 + 0.36*\ln Z_{NaE_i} - 0.02*\ln Z_{AS_i} + 0.35*\ln Z_{EpE_i} + 0.10*\ln Z_{NoT_i} + 0.4*\ln Z_{AW_i} + \\ +0.21*\ln Z_{SQ} + 0.05*\ln Z_{NIF_i} - 0.53*\ln Z_{MT_i} - 0.02*\ln Z_{IS_i} + 0.06*\ln Z_{FC_i}) \quad (9)$$

The positive relation of numbers of agricultural enterprises to technical efficiency [Z_1] can be justified by higher competition in the region among producers and / or by possible positive impacts of an employable economic network between the enterprises / regions. The estimation has also shown that further concentration effort of the (average) enterprise has no positive influence on the efficiency scores (see [Z_2] – average size of agricultural enterprise), because, as expected, the predominantly large-scale Russian agricultural sector operates with negative economies of scale[45] (as discussed above; see, for example, Table 3 and Table 5 in the appendix), mainly due to problems of monitoring.

[Z_3] – number of workers has a positive influence to technical efficiency. With respect to the result of variable [Z_2] – average size of farms – this result seems to be surprising, but it shows

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43 $f(tX) = t^p f(X)$.

44 Recall that a negative coefficient of the explanatory variables means that the variable has a positive relation to technical efficiency (TE = exp(-u_i)).

45 It is not strange because in Russia the average size of agricultural enterprise is six times larger than in the USA.

also that the use of land and labour is probably not balanced. Furthermore, the results give no evidence for the existence of over-employment in the Russian agriculture. In contrast, a growing number of (adequate employed) workers seems to increase the technical efficiency of the enterprises (in spite of the monitoring problem).

Machinery [Z_4] – number of tractors have positive relations to higher efficiency scores. According to these findings, an improvement of the financial situation of the agricultural enterprises should lead to an increasing technical efficiency due to the ability of higher investment in new and higher productive technical equipment.

The coefficient of [Z_5] – the average regional wage level is negative – means the variable has a strong positive relation to the technical efficiency – and is highly significant. According to this finding, it seems that the average wage level in the Russian agricultural sector has still room for substantial growth. We have found no evidence of a wage level higher than productivity which could weaken the economic performance of the enterprises. But it should be added, that we only considered the "net-wages" (i.e. absolute payments, without pay arrears). This procedure is important due to considerable differences between Russian regions in respect to reliability of wage payments and the amount of pay arrears. The differences of "net-wage" levels among regions was increasing compared to nominal wage levels due to using this procedure. Therefore, the findings should not be interpreted as a call for increasing the wage levels in a financial difficult situation of enterprises but rather for more reliability of punctual wage payments, which in several regions were nearly the same than increasing wages. Since in most of all regions the predominant market form is barter, this measure could stimulate a "normal" market system with money as the common mode of payment.

The variables that capture the natural conditions of agricultural production have the expected shape. A higher soil quality [Z_6] is strongly positive and temperature [Z_{10}] is strongly negative related to better technical efficiency. It means that in many regions the temperatures in the critical planting and growing months are too high.[46] Interestingly, the average rainfall [Z_9] was found to be non-significant. Hence, we excluded the variable from the estimation.[47]

The privatisation – or the transformation of "old" into "new" legal forms of the farms [Z_8] has a positive effect regarding technical efficiency. The private ownership provides better working incentives, management, and thus improved the resource allocation. Admittedly, the coefficient doesn't have the significance which we were expecting. Perhaps this is a result of the widely practised "passive restructuring" (see below next chapter). If this assumption is true, then will provide a further restructuring of the large-scale agriculture of Russia (to enterprises that are really market oriented) a substantially enhancement of the technical efficiency; with respect to the dominance of the large-scale enterprises in the Russian agriculture provide it perhaps also a shift of the overall production possibility set and consequently also a shift for the production frontier.

It is interesting that the coefficient for railway density [Z_{11}] is positive – meaning it is negative related to technical efficiency and the agricultural output. Given that the coefficient is non-significant, we can suppose that railway infrastructure is sufficient for agricultural producers in most regions in Russia and so it has no influence on production. On the other hand, that could underline the actual (in)significance of interregional trade of agricultural products in

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46 Maybe technical efficiency is negatively related to mean temperature due to the fact that in recent years there were draughts in many Russian regions.

47 Since we used only rainfall in July the result could be biased (critical growing month differ among regions and/or between kind of crops). In future, we try to implement the annual sum of rainfall as variable.

Russia.[48] When a number of regions that today are self-sufficient becomes an exporter of agricultural products then the importance of infrastructure (especially railway for transporting a great amount of agricultural products, for example wheat) will grow again.

The proxy for financial conditions [Z_{12}] also has the expected shape. According to our findings, regions that can be characterised by one of the following situations achieve better technical efficiency: high amount of fixed assets or a positive growth rate of them, net-investments or at least a slower decrease of the fixed assets than the average, respectively.[49] The same results could also be made by interpreting the coefficients [Z_3-Z_5] because all of this variables are strongly influenced by the financial conditions and external environment of the enterprise.

All these findings imply that there is still room for improvements in technical efficiency, through restructuring of agricultural enterprises, a forced market liberalisation, increases in wages (reduction of pay arrears) and availability of loans and credits. These findings may have important implications for international lending institutions and investors.

6.2.2 Development over time

Having the tendencies of regional disaggregated developments of technical Efficiency (TE), technological change and the overall agricultural performance (Total Factor Productivity (TFP)) during the analysed six years (see appendix: Table 5) one can summarise the following trends and approximate the influence of transition on technical efficiency of the agriculture. According to the Table 5 the average technical efficiency went up by 7% during the period from 1993 to 1998. The maximum TE was reached in 1997. From 1993 to 1997 the level of TE have been constantly increasing and only in 1998 have decreased by 6,6%[50] (see Table 3 and 6). It should be noticed that average dynamics like that do not match the dynamics of technical efficiency in different "Economic Regions".

The most encouraging results were found in the Ural- and Povolzhski Region while the less efficient regions were the Far-Eastern and Northern Region (see detailed description below). Admittedly, the results indicate also that there was no positive technical progress during the period 1994 to 1998. In all (11) Economic Regions the average agricultural TE has been raising or at least has been stagnating at a constant level over the analysed period connected with a substantial negative technological change over the analysed period (approximately 20% in the period of 1993 to 1998).[51]

The range of TE scores among regions and also among Oblasts in an Economic Region was increasing what gives a hint of growing divergences. Indeed, sometimes adjoining regions which have shown initially similar economic performance and which are characterised by approximately the same natural conditions follow nearly opposite trends (see Map 1 to 4 in the appendix).

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48 The low significance of the parameter of "infrastructure" shows the regional market-segmentation in Russia. Actually, we can find in several regions of Russia nearly autarky regarding agricultural products. Therefore plays over-regional infrastructure not an important role.

49 It is difficult to say whether the technical efficiency is higher due, for example, the higher amount of fixed assets or the other way around.

50 The notable enhancement of the mean technical efficiency in 1997 was probably determined by the relative positive weather conditions and consequently a harvest above average.

51 This result is not surprising because of the deterioration of quality and amount of fixed assets and the shortage of new investments, respectively. But, from theoretically point of view an interpretation of negative technological progress is not so easy. Here, we suggest that a negative technological progress belittled the production possibility set and reduced therefore the maximal available output by given inputs.

The major reasons behind these variations seem to stem from different developments regarding external environmental conditions of the local / regional economy. Given that the initial natural conditions were approximately constant (by neglecting, for example, water availability what in this study has been considered as a natural factor) the consistence of political programs, market reforms and restructuring were the essential determinants of development of technical efficiency and economic performance above or below the common trend.

Table 3: Trends of technical efficiency (TE), technical change and overall productivity (TFP) of Russia's agriculture per region from 1993 to 1998

Regions	TE in relation to mean TE in Russia for 1998	Trend of TE per region		Absolute TE scores per region (1998) 3		Technical change 1993 - 1998 [1993 = 1.0]		Mean regional technical change 1993 - 1998 [%]	Trend of TFP 1993 = 100 [%]		
		absolute1 1998	trend of mean TE2	min	max	min	max		min	max	mean
Russian Federation	---	0,45	1,07	0,08	0,86	0,42	1,80	- 20,0	0,38	2,16	0,85
Northern	0,73	0,33	1,00	0,22	0,43	0,72	0,91	- 16,0	0,63	1,12	0,86
North-Western	0,98	0,44	0,98	0,27	0,69	0,79	1,03	- 10,0	0,74	1,23	0,88
Central	0,93	0,42	1,05	0,26	0,86	0,76	0,92	- 13,0	0,75	1,13	0,93
Volga-Vyatka	0,89	0,40	1,14	0,28	0,51	0,68	0,86	- 22,0	0,80	0,98	0,89
Central Chernozem	1,09	0,49	1,02	0,43	0,57	0,73	0,82	- 23,0	0,70	0,83	0,78
Povolzhski	1,04	0,47	1,07	0,08	0,77	0,67	0,89	- 25,0	0,38	0,93	0,79
North-Caucasian	0,98	0,44	1,02	0,16	0,85	0,42	0,87	- 30,0	0,53	1,12	0,72
Ural	1,31	0,59	1,18	0,40	0,78	0,67	0,82	- 24,0	0,63	1,09	0,89
West-Siberian	1,20	0,54	1,12	0,22	0,70	0,64	1,80	- 19,0	0,69	2,16	0,92
East-Siberian	1,02	0,46	1,10	0,15	0,75	0,60	0,85	- 23,0	0,50	1,17	0,84
Far-Eastern	0,82	0,37	1,00	0,12	0,52	0,48	1,04	- 16,0	0,43	1,52	0,83

Notes: 1) Average of absolute TE-scores in a region in 1998 (1.0 = 100% efficiency).
2) Trend of the mean absolute TE-scores in a region 1993–1998 (1993 = 1.0).
3) 1.0 means 100% efficiency ò value on the frontier.

Source: Own calculations based on the results of the final restricted frontier model.

We have detected the most favourable TE- trends for the Ural Region (especially Ufa, Perm and Ekaterinburg), Omsk and Novosibirsk (West Siberia), and Irkutsk (East Siberia) where, starting from relative high values in 1993, the TE-scores went up and have surpassed the common Russian trend. Otherwise, the Northern and Far Eastern regions did not enhance their TE in spite of initially very low efficiency levels. However, the technological change in these regions were less negative than the common Russian trend.[52]

Notwithstanding the development of the mean regional trends there are at least one example for a surprising development notable above or below or with the opposite algebraic sign than the regional and / or Russian trend in every Economic Region. Subsequently, we try to describe briefly the regional results and illustrate such positive and negative examples.

For the *Northern Region* as a whole we have found a worsening situation. The mean TE was stagnating at a low level and the gap to the mean TE of Russia was raising by 14% (1993-1998). This gap would be even more drastic if we solely compare trends from 1993 to 1997. However, Arkhangelsk is the positive exception. The Oblast has provided a TE growth by 23% and nearly caught the Russian average. Furthermore, the technological change of -9% is

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52 One possible explanation could be the fact that the amount of technical equipment in these regions were related to the Russian Federation quite lower (in 1993 and in 1998) and, therefore, the reduction of the production possibility set due to worsening of fixed assets has been smaller (by 5%) than Russia's mean.

notable smaller (half) than the regional and the Russian trend. Altogether, Arkhangelsk has improved the economic performance by 12% compared to 1993 (regional mean: -14%).

A more heterogeneous situation shows the *North-Western Region*. First of all, the Leningrad Oblast should be seen separately, because of the overwhelming importance of the city Leningrad. The Leningrad Oblast and also the Moscow Region (see Central Region below) have TE-levels substantially higher than the regional average, mainly because of the huge influence of the metropolies on the enterprises in their neighbourhood and, for example, the advanced access of local enterprises to markets, a higher purchasing power of the regional customers, better infrastructure, etc. This finding underlines the importance of the "soft facts" discussed above and discover the possibilities to enhance the TE everywhere in Russia through improvement of the economic environmental conditions (see policy recommendations).

The development of Novgorod – an Oblast not seldom labelled as a reform leader – is also notable for the North-West Region. Novgorod is one of only 3 Oblasts (among 75 analysed) which provide both a positive trend in TE and in technological progress between 1993 and 1998. Admittedly, the initial TE-scores of Novgorod were relative small but the circumstances which are responsible for this enhancement in both criterions are more than interestingly.

The *Central Region* should also consider with exception of the Moscow Oblast due to same reasons mentioned above in the context of Leningrad. In fact, also Moscow provides a substantially higher TE level than the region and the mean of Russia (in 1998: absolute the highest). Nevertheless, one should interpret the score and the trend with caution because the less economic importance of agriculture for the Oblast Moscow. All other Oblasts in the Central Region have shown approximately the same trends like Russia as a whole. Solely, the technological progress was less negative than the average trend.

The *Volga-Vyatka Region* is stamped by a relative homogeneously development of all Oblasts. Every Oblast has shown a positive TE-trend (starting from intermediate levels). Therefore, the region is one of only four regions which have a notable positive TE-trend. The technological change and the trend of TFP are similar to the Russian mean.

The *Central Chernozem* and the *Povolzhski Region* have been developed quite similar. Both have shown a mean absolute TE above the Russian average (in 1993 and 1998) but a trend less it. Both regions have had more negative technological changes than the Russian average and, therefore, a development of TFP below the common trend (worsening by more than 20% between 1993-1998). Noteworthy is the heterogeneity of the TE-scores among the Oblasts. Whereas Kalmykia has the lowest absolute TE-scores in the Russian Federation determine Tatarstan with a 100% efficiency in 1997 the frontier (by the way, we have perceived in all Oblasts of the Povolzhsky Region in 1997 an uncommonly positive result for agriculture).

A very heterogeneous picture were given by the North-Caucasian Region. There are five Oblasts (Adygea, Dagestan, Nalchik, Cherkessk and Vladikavkas) which have initially very low TE-levels (in average below 50% of the Russian mean). All regions have improved their scores (sometimes notable from a percentage point of view) but no region has reached the Russian mean. Therefore, all these regions are underdeveloped regarding their TE. Furthermore, the technological change in these regions was more negative than in Russia as a whole (Dagestan shows the most negative trend in Russia).

The other three Oblasts of the region were characterised by a quite different situation. They started from TE-scores above-average (Krasnodar has had the highest TE-scores in 1993) and they have saved approximately their position among regions (Krasnodar: second highest TE-score in 1998 – only 1% topped by Moscow). The outcome of high TE-scores for the Oblasts of Krasnodar, Stavropol and Rostov-on-Don was not surprising because they have favourable natural conditions for agriculture and were (and are) some of the most important agriculturally Oblasts in Russia. Needless to say, they are fundamental determinants for the position and shape of the production possibility set – due to the importance for the Russian agriculture of the mentioned regions. In this context, the fact that particularly these Oblasts which have a major importance for Russia's agriculture have shown the most drastic negative trend of technological change is alarming (regional mean: -30%, for the traditional agricultural Oblasts even more). Altogether, one can summarise a notable negative development of the economic performance between 1993 and 1998 for the North-Caucasian Region by -28%, for Krasnodar -35%, for Rostov-on-Don even -40%. Since these Oblasts personify (traditional) agriculture areas these trends could be a hint of alarming tendencies.

A slightly more optimistic interpretation could provide the results regarding the Ural and the West-Siberian Regions. Both are characterised by initial TE-levels above the Russian mean and a substantial further improvement of their efficiency. As a result, the gap of TE between all Russian regions was growing. Particularly the Oblasts Ufa, Perm, Ekaterinenburg, Novosibirsk and Omsk should be mentioned regarding their notable enhancement of efficiency – starting from initially relative high levels. But the negative technological change has widely over-compensated these improvements so that the aggregated trend of economic performance was negative, but less negative than the Russian mean.

In East Siberia one can see a heterogeneous development again. Altogether the region has average levels of TE, average trends of it and follow approximately the same technological progress compared to Russia as a whole. But in detail, the Oblasts have been developed quite different. Buryatia, Irkutsk and Krasnodar all have improved their TE (starting from low, intermediate and advanced levels) and were following a common (negative) technological change and have, altogether, performed better than the Russian mean. Moreover, Irkutsk and Buryatia have even improved their TFP compared to 1993. On the other hand, Chita, Tuva and Khakassia have shown stagnating or negative trends regarding their TE and also a notable negative technological change. Needless to say, the overall performances were decreasing substantially (by approximately -27%, -45% and -50%).

As described above, the Far-Eastern Region was characterised with similar negative trends as the Northern Region. Here one can find the lowest absolute scores for TE and the most negative trend of technological change (Sakha). Moreover, there was no enhancement of the low efficiency. Altogether, one can identify a growing gap of TE to the average efficiency of Russia – resulting in a divergence of regional performances. But also in Far East was a mentionable exception – the Oblast Khabarovsk, which has realised a substantial improvement of TE (by 46%; from a level of 17% below the Russian mean in 1993 to a level of 15% above the mean Russian efficiency in 1998) as well as a positive technological change. Therefore, the circumstances and institutional / environmental conditions what have provided this development seems to be quite interesting.

Summarising the detailed description of the developments among Oblasts and Regions we have not found any region with notable positive technological progress (only three with a slightly progress). The heterogeneity of developments of technological change among regions is – compared to the TE-trends – quite smaller. Alarming is the fact that we have found the most negative technological change in the Ural- and North-Caucasian Regions – regions which are known as main agricultural regions in Russia. This underlined the importance of efforts to a reanimation of investments in the Russian agriculture as soon as possible. Otherwise, one should expect a further and perhaps accelerated negative trend of the technological change and a further worsening of the equipment and thereby a down-going agricultural production and a sharply decreasing competitiveness of the sector on international markets.

In aggregation of the slightly positive overall TE-trend and the drastic commonly negative development regarding technological change one can conclude: the average Russian performance in the agricultural sector was worsening in the analysed period. Only with a minor number of exceptions all Russian regions have shown TFP – index values for 1998 below 1.00 – means a deterioration of the overall agricultural performance between 1993 and 1998.

Regarding the question of convergence or divergence of the agricultural TE and the overall economic performance, respectively, we need to recognise the tendency of divergence among Oblasts and regions. This is mainly determined by the growing divergence of TE. How quickly this divergence is growing and which Regions are affected in particular (positive as well as negative) is easy to see in table 3 in column 4 (grey backgrounded), where the Russian Federation has an average improvement of TE between 1993 and 1998 by 7%; some regions are above and other below this trend and altogether we resume a divergence of TE.[53]

To answer the question – which regions have enhanced their position and which have lost – compare the table 3 and 6 or the maps 1–4 (see appendix). The most efficient regions before reform maintain their highest levels of technical efficiency and following trends above the average (see, for example, Ural- and West-Siberian Region) but the scores of marginal regions has been stagnating or continuing downwards (see, for example, Northern or Far Eastern Region; with the exception of Volga-Vyatka Region – that has improved their low TE-level over-averaging). Investigating the regional patterns of technical efficiency in Russia and their connections to overall regional economic performance, the resource-rich regions offer the brightest overall economic prospects, thereby deepening the disparities between regions.

Our general pattern of stagnating or slow recovering efficiency scores in most regions over time is consistent with earlier studies that concluded that Russian corporate farms had been engaged, on the whole, in “passive restructuring”[54]. One of the most interesting points, however, is the large variation in performance observed among regions (see Table 5 in appendix). Map 1 and Map 2 (see appendix) illustrate the development of TE and particularly the even surprising differences and divergences among regions. For example, in the western part of Russia one can see adjoining regions with quite opposite efficiency trends. Starting from intermediate initial levels of efficiency, some regions have shown a substantial improvement of their average agricultural technical efficiency, for some regions we have not found any notable alterations and for several regions we have found a further deterioration of TE. It's impossible to explain this results only with "hard facts" – like availability of inputs, natural resources or conditions or, for example, regional infrastructure. The initial conditions of such adjoining regions have been quite similar and, nevertheless, they are now following different trends of agricultural performance. These regional divergences are predominantly caused by differences in the institutional environment of the various regions – especially the political institutions

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53 An additional hint of a growing divergence is the growing variation-coefficient (0.35 in 1993 to 0.43 in 1997; in 1998 we detect an opposite trend back to 0.39 variations-coefficient).

54 It means defensive restructuring of a survival oriented enterprise (following ICKES and RYTERMAN, 1994). Such restructuring can be characterised by a predominant emphasis on current cash flow with a nominal adjustment in product mix, continued soft budget constraints, informal administrative controls, mainly from local governments, and cosmetic changes in ownership and management. By contrast, real or positive restructuring would be characterised by significant hardening of the enterprise budget constraint, outside ownership of the enterprise, and the establishment of institutions promoting good corporate governance, such as accurate financial disclosure, democratic boards of directors, and independent shareholder registers (ERNST et al., 1996, pp. 31-78; SEDIK et al., 1999, p. 515).

and the regional different implementation of reforms. In fact, the regionalisation-trends in Russia has also led to a diversification of individual environmental conditions for enterprises in the several regions. The fact that adjoining regions, starting from similar initial conditions, show contrary developments of their agricultural performance underlines the importance of the "soft facts" – means in this context the importance of local / regional policy and the implementation of appropriate and well adjusted reforms.

The results have also shown that there remain a wide range of improvements of agricultural TE and the possibility for policy makers to initiate such a process only by implementing positive environmental conditions for the regional economy. For the further analysis it seems to be promising to analyse the differences of political environments among regions and separate these measures which strongly influence the efficiency level – both positively and negatively. As a result of such an analysis one could provide an agenda of politically suitable measures which improve the regional efficiency and thereby the regional economic perspectives. In the next chapter we try to go some steps on this direction.

The results presented in this chapter are partly different from the previous studies (SEDIK et al., 1999; SOTNIKOV, 1998). Comparing the features of both previous studies with the present report, first, one should underline the larger disparity in TE scores which has been found in the present investigation during 1993-1995 (the period which was analysed in previous works as well as the current) and, second, the smaller differences in TE scores across the regions in every specific year. However, the present estimation provides results which seems to be more stabile in time for every region and, on the other hand, reflects more sensitive the influence of different external environmental conditions and circumstances across the regions - resulting in the deeper disparity. Altogether, these attributes seems to be more consistent with the real situation in the Russian agriculture. Indeed, the current estimation is based on more homogeneous panel data. Hence, the results of SOTNIKOV (1998) and SEDIK et al. (1999) might be influenced by statistical problems connected with the chosen period of 1991-1995 (instead of 1993-1998) which is characterised by substantial breaks in institutional, economic and political environment due to the transition.

6.3 Policy implications

The main conclusion from the analysis is that the transformation of the economic environment and the producers themselves has not led to an substantial increase in the level of technical efficiency. In the same time, the more efficient regions could adapt better to transition because they could minimise the losses in technical efficiency in agriculture. The strengthening of budget constraints leads to more effective use of resources in agricultural production.

Theoretically, one should expect a positive trend of efficiency induced by a better factor allocation when a planned system shifted to a market system. What we have found is a widespread decreasing economic performance of the Russian agriculture. The small enhancement of technical efficiency was dominated by the notable negative technical change. Commonly were the following facts held responsible for the deterioration of the economic performance: the lack of information regarding marketing channels and opportunities and the strong local government regulation, resulted in spatial market segmentation. High transaction costs prohibit the exploration of trade opportunities and deeper specialisation. All these aspects are especially true for agriculture. Furthermore, at least some agricultural policy-induced imperfections are still in place, partly because it is easier for agricultural entrepreneurs to allocate efforts to get subsidised credits from the local government rather than to concentrate on improving production efficiency. Third, the protectionist policies of some regional governments are an obstacle to competition in Russian. Fourth, incomplete and informal privatisation may result in an inadequate supply of managerial effort.[55]

Of course, the absolute level of productivity is strongly determined by the initial conditions.[56] But the main determinants for the tendency since the beginning of transition seems to be predicted by the generally external economic environment of the regions that was strongly influenced by the local governments and their individual goals, for instance self-sufficiency (up to regional autarky), still employment of price controls and subsidies, control of trade etc. or forced economic restructuring, installation of market institutions and internal integration, respectively. Stability, market oriented institutions and the existence of liberal markets are the main aspects and preconditions for reanimation of the low level investment and, that is why, they will be essential for a positive technological progress. The importance of these arguments is shown by the indices of technological change in several regions (see Table 3 and Table 5 – in the appendix for regional disaggregated indices). Most of them have a negative trend. Indeed, it shows the potential for improvement of the Russian agriculture situation and is probably the main condition for a sustainable and long term recovery of the sector and monetary income maintenance in many rural areas of Russia.

All of this suggests that it is possible to obtain an increase in technical efficiency through the higher levels of wages for effective workers, the transformation of the large agricultural enterprises and more effective use of production factors. In our opinion the emergence of the "new enterprises" will strengthen the concurrence and lead to the formation of the viable producers and owners oriented on long perspective.

But, what policy recommendation could be made according to our findings? What are the essentially political and institutional determinants for the development of Russia's agriculture?

Changes in efficiency and productivity, as defined by the model, can occur for various reasons as described above. For the enhancement of the overall agricultural performance it is of particular importance to improve the efficiency to catch the production frontier and to participate on the technological progress as well as to push technological progress which can shift the production frontier due to the enlargement of the production possibility set. Therefore, policy implications should focus to both targets and be harmonised in an package.

For accounting of the influence of the several explanatory variables and to specify the following policy recommendation we were accounting eleasticities of the Z_i-variables regarding the technical efficiency scores. According to the model specification the coefficients for the Z_i-variables (δ_i) also represent these elasticities (e):

$$e = \frac{\partial TE}{\partial Z_i}\frac{Z_i}{TE} = \frac{\partial (e^{-(\delta_0 + \sum \delta_i Z_i)})}{\partial Z_i}\frac{Z_i}{TE} = -\delta_i \qquad (10)$$

On the base of our findings and previous studies we have identified several policy implications for the improvement in the efficiency of Russian producers. They concerns nine issues:

Promotion of technical change: One of the main tasks of developing policy is the promotion of technological progress (also) in the agricultural sector. First of all, technological progress is

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55 See SOTNIKOV (1998), p. 413, see also MCKINSEY GLOBAL INSTITUTE (1999), chapter 4 or www.mckinsey.ru.

56 According to this fact, our results are very similar to the previous study of SEDIK et al. (1999). The authors pointed out that the initial situation was the essential factor for the development during the period of transition. We have found, regions that was initially relative high efficient were in the most cases be able to keep their position or improving them. That means, the differences among regions growing up.

strong related to the amount of investment (assumed investments are always spend for the best available technology).[57] In Russia, the bad financial situation and the unsteadily economic environment prohibit a higher amount of investments and, therefore, prohibit also substantial technological progress. There remain a wide range of possible political measures which improve the overall economic environment and provide a recovery of investments in the Russian economy. Some of the following points gives recommendations in detail.

Creation of fixed assets and land market: Agricultural capital is an important determinant of agricultural production. This is especially significant, since land, another important determinant of production, varies little over time. Moreover, agricultural capital is also important in closing the gap between available and applied technologies. Therefore, policies facilitating access to agricultural capital will facilitate growth, given that the capital is used efficiently. This implies that the overall economic environment must be conducive to the efficient use of capital. The development of asset and credit markets will help to improve technical efficiency and realise the potential welfare gains. Another important factor is land policy. One of the main resources of agricultural production – the land – has been withdrawing from the market mechanism of the distribution between the market agents. The absence of a comprehensive land code that gives clear principles to land ownership and leasing can also increase investment risks. Although the option to privatise the land has been given to local governments, the privatisation has been slow and uneven across regions.[58] Furthermore, allocation of government owned land is often in-transparent and may be subject to political rather than economic incentives. Soil degradation is an additional problem. According to the analysis of IIASA (conducted by STOLBOVOI and FISCHER, 1997) more than 14.5% (243 million ha) of the Russian territory is affected by soil degradation caused by a variety of reasons, including socio-economic changes, and improper management and technology. The assessment reveals that the rate of soil degradation and loss of soil productivity in Russia has been fairly rapid.

Elimination of regional disparities: The problem of regional inequality is nothing special; typical only of the Russian reform. It is urgent for all countries with a federal system of government or an extensive territory. The differentiation in the economic position of the population in different regions leads often to a strengthening of socio-economic disparities, and serves as a ground for inter-regional conflicts. The maintenance of regional parity by means of various methods of state regional policy, and the maintenance of national social standards in particular, is an essential item of the governmental charges in many countries and consequently the processes of divergence or convergence in regional development serve as the subject of the steadfast attention of researchers and politicians. For the transitional Russian economy, the problem of regional differentiation, besides the purely economic aspects, frequently gets a political taste, since it provides an economic base for the development of regional separatism. The polarisation of the regions to a small number of "rich" regions with a high level of income and economic activity, and the basic bulk of "poor" and "becoming poor" regions, which will, most probably, deepen. A strengthening of the differentiation in the socio-economic situation among regions will subsequently lead to aggravating the social contradictions between rich and poor regions and require active governmental intervention in their regulation – in particular, the implementation of governmental regional policy, aimed at overcoming the sharp distinctions in the socio-economic situation of the regions. The mandate to

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[57] The R&D-expenditures, the access to technology markets, the average qualification level of employees, and the availability of information / knowledge are additional examples for determinants of technological change.

[58] It underlined once more the heterogeneity of the strictness of implementation of reforms among regions and the importance of additional efforts to improve the external economic environment for entrepreneurs.

enhance the regional economic environment and to realise economic reforms is also given to the regional / local policymakers, who are responsible for the individually regional implementation of the policies.

Development of infrastructure: As a related sector, infrastructure[59] can affect productivity either through the demand side (e.g. inefficient distribution of goods) or through the supply/cost side (e.g. input procurement). In a large country like Russia, the capacity of the whole economy to function as one market hinges on efficient infrastructure that reduces transportation costs and exposes producers to inter-regional/national competition. First, the nature and coverage of the physical infrastructure (e.g. rail links and roads) determines how and where inputs and outputs can be transported. Second, the competitive nature of the distribution services affects the cost in which these goods will be distributed. Therefore, a functioning infrastructure is one of the absolute necessary environmental conditions to force an inter-regional/national competition for inputs and markets and therefore to enhance the TE, push the technological progress and improve the overall economic performance.[60] With respect to these facts, the restoration and expansion of the infrastructure are one of the major task for policymakers – in Moscow and on regional level.

Elimination of favouritism and subsidisation-mentality: Another area of importance is an unequal allocation of government procurement and land which includes discretionary procedures for government procurement contracts and land allocation. Unequal allocation often means direct tax breaks and/or subsidies to specific players as well as indirect tax benefits through arrears and non-payments. In a fair market economy, the same laws and rules (e.g. prices, taxes, etc.) are applied to all market participants. In contrast, unfair procurement reflects distortions that result from differential treatment of industry producers by parties outside the industry (e.g. government). Within the same market, unfair procurement may result in more productive firms not being the most profitable ones. In order to cease discretionary procedures the government must undertake concrete actions contributing to a fair market economy. The next area in which efficiency could be improved by policy measures is the granting of soft government loans. The practice of subsidised credits and depreciation of debts may have had only short-run supply effects on production, but it clearly leads to higher technical inefficiency. The problem of long-run debt should be addressed and solved through mortgage arrangements. The elimination of price controls and unbalanced producer subsidies that remain in some regions could cut welfare losses that are due to technical inefficiency.

Reallocation of labour force: From the practice we know that skilled labour is quite scarce on some corporate farms due to immobility of workers. Moreover, the widespread practice of non-paying wages (observable by the amount of wage arrears), and the disability of the enterprises to pay wages, respectively, reduce the availability of appropriate labour force, particularly in the harvest season. On the other hand, such a situation stimulates the preservation of the excess unskilled labour force in agriculture from the soviet period. With respect to this point the policy could improve the situation in several ways. One should see the policy recommendations commonly as a package – here are given 9 issues – and the implementation of efforts with respect to every point should provide an enhancement of the situation, in general and particular. In the context of this and the following point it seems promising to install an education program by the government that establish the spirit and the rules of the market sys-

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[59] Includes differences in the country's infrastructure such as roads, rail links and communications, etc.

[60] It should be mentioned that we have found a negative relation between the explanatory variable "infrastructure" and the TE. That is surprising only at the first glance (see comments in the previous chapter regarding Z_{11}).

tem to provide a comprehensive basis for operating under the new conditions. An additional important point seems to be the cutback of the common practice of non-wage-paying (first of all by the government itself as an employer). For enhancing the labour mobility the quality of infrastructure plays also an important role.

Enhancement of managerial skills: Another important factor (strongly related to the previous item) is the quality of management or entrepreneurship. We tend to believe that – besides the institutional environment of the region – a main reason why agricultural enterprises in some regions have performed better than in others is the quality of management, understood in a broad sense. However, the quality of management depends partly on institutional and/or environmental factors, though it is not entirely determined by them. It is important to recognise that farm managers may be "rational" while allowing the technical efficiency of their farms to fall. For example, managers may pursue goals other than profit maximisation or cost minimisation, such as retaining workers or land, rent-seeking or seeking to carry out the wishes of the local authorities. Moreover, if a region is relatively remote and faces very high transportation costs, it may be prudent to be relatively self-sufficient. Therefore, needless to say, that the policy implications, for example, with respect to reducing the gap of management skill must also be adjusted regarding all other policy measures and environmental conditions. Otherwise, the outcomes of the measures are uncertainly and probably counterproductive.

The incentive-problem: The extent to which management is exposed to pressure from owners or shareholders can influence the rate at which productivity is improved. It is critical for companies under government ownership because their managers may pursue objectives different from profit maximisation that leads to lower productivity in favour of other goals (principle-agent problem ò problem of monitoring). Moreover, allowing decentralisation without establishing a legal framework for private ownership is likely to give managers access to rents, leading to a drain of resources from the state-controlled sector of the economy to the informal or illegal sector. Therefore, further efforts to a widespread (and real) privatisation should tend to wards an improvement in efficiency and could also provide equal positions among the market players, for example, due to the reduction of unfair (and unbalanced) governmental procurement (see the point "Elimination of favouritism and subsidisation-mentality" above).

Liberalisation of markets and opening of the economy: As the 9th point, we want to emphasise the importance of the exposure to best practice of production includes competitive pressures from foreign best practice companies either via imports or through foreign direct investments. Therefore, to provide an entrance for investors (particularly foreign investors) to the Russian agriculture promise an enhancement of technological progress and technical efficiency due to two reasons: additional investments in "best practice" technologies and strengthening of competition. An important pre-condition for FDI's in the Russian agriculture seems to be the possibility and legal guaranty of land property.

7 CONCLUSION

In this paper, we consider how Russian Agriculture has developed since the constitution of the Russian Federation and why. The analysis is based on Oblast level data of 75 territorial units during the period from 1993 to 1998 and focusing on the technical efficiency. Needless to say that numeric evidence of the performance of Russian agriculture is very important for those economists who engaged in different development programs. Technical efficiency estimation can support Russian policy makers and gives an impression which potential of the analysed sector is un-exploited. Beyond it, the study is also able to detect which factors impede faster improvements of technical efficiency.

The following issues were discussed in this paper:

1. The approaches to measure a performance of the agricultural sector;
2. The regions' levels of technical efficiency;
3. The pattern in the changes in technical efficiency by region as a result of reforms;
4. The economic and institutional factors explaining the levels of technical efficiency;
5. The conclusions which can be drawn about the extent of producers transformation.

1. For the technical efficiency analysis it is common to use one of both Stochastic Frontier Analysis (SFA) and Data Envelopment Analysis (DEA). SFA has the virtue of being stochastic, and so attempts to distinguish the effects of statistical noise from those of productive inefficiency. DEA lumps noise and inefficiency together and calls the combination inefficiency. That is why the Stochastic frontier method is recommended for use in agricultural applications, because measurement error, missing variables and weather, etc. are likely to play a significant role in agriculture.

2. The results have shown that the agricultural technical efficiency and the progress of technological change varies dramatically between different regions; there are some regions with a notable positive development of the performance (improvement of technical efficiency and / or substantial progressive technological change) and on the other side there are a wide range of regions with reverse trends (two digits negative). That gives an evidence for divergence in the sectoral performance of agriculture.[61] Because agriculture is for many regions the fundamental source of income this fact is alarming, especially when the local agriculture becomes in comparison to other regions non-competitive, actually or in future. The average regional technical efficiency score improved from 0.42 to 0.48 in 1993–1997 and declined to 0.45 in 1998, mainly because of an overall poor harvest.[62]

3. The initial conditions play the most important role regarding development of efficiency. Those regions which have had good initial conditions are prosperously and their technical efficiencies increase over time, and those regions that were marginal become more and more inefficient. Furthermore, the strictness of following a path of reforms and the political consequence of implementation of all necessary requirements for a functioning market economy vary dramatically among regions. Moreover, these facts are strongly positive related to a notable enhancement of the regional economic performance.

4. In principle, there were four major reasons to believe that the transition - that began in 1992 - results in a significant growth of welfare and enhancement of the regional performance, respectively, due to improvement of efficiency:

   - Improvement of input and output allocation;
   - Hard budget constraints and partial cutbacks of subsidies;
   - Stronger competitive pressure;
   - Private property / ownership.

   Theoretically, all these aspects should provide a more technically efficient economy and give the external environment for producers to realise an input/output–combination at the

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61 The variation coefficients raise from 0.36 to 0.43 in 1993-1997; 0.39 in 1998.

62 This average scores are relative small in comparison with other studies (SOTNIKOV: 0.77 to 0.92; SEDIK et al.: 0.74 to 0.99 for the period 1990-1995, 1991-1995, respectively).

current production possibility frontier rather than inside it. Although all of the four major sources are ongoing for potential improvements in the efficiency, there remain a lot of evidences of incomplete institutional reforms in Russia. First of all, among frequently cited causes for low levels of production are the macroeconomic instability, incomplete market reforms, corruption, and a skill gap on Russian managers due to the soviet legacy.

5. What we have found is a widespread decreasing economic performance of the Russian agriculture. The small enhancement of technical efficiency was dominated by the notable negative technical change. Commonly were the following facts held responsible for the deterioration of the economic performance: the lack of information regarding marketing channels and opportunities, and high monopolistic transportation tariffs, resulted in geographically market segmentation. Our findings and previous research identified several policy implications for the improvement in the efficiency of Russian producers:

- Promotion of technical change;
- Creation of sound assets and land market;
- The elimination of the regional disparities;
- Development of the infrastructure;
- Elimination of favouritism and subsidisation-mentality;
- Reallocation of labour force;
- Enhancement of managerial skills;
- The incentive-problem;
- Liberalisation of markets and opening of the economy.

The main conclusion of the study is that the efficiency is not likely to be further improved through a simple contraction of inputs. Creation of sound asset and land markets have to assist in a more efficient allocation of land and capital resources. Additional gains in efficiency, however, will require more investment in new technologies and human capital.

APPENDIX

Table 4: Factor elasticities for the 11 Economic Regions

	Labour elasticity						Fertiliser elasticity					
	1993	***1994***	***1995***	***1996***	***1997***	***1998***	***1993***	***1994***	***1995***	***1996***	***1997***	***1998***
Russian Federation	0.40	0.32	0.24	0.16	0.08	*0.004*	-0.02	-0.01	0.00	0.01	0.03	0.04
Northern region	0.33	0.25	0.17	0.09	0.01	-0.07	0.03	0.04	0.05	0.06	0.08	0.09
North-western region	0.32	0.24	0.16	0.09	0.01	-0.07	-0.05	-0.04	-0.02	-0.01	0.00	0.01
Central region	0.43	0.35	0.27	0.20	0.12	0.04	-0.04	-0.03	-0.02	-0.01	0.01	0.02
Volga-Vyatka region	0.57	0.49	0.41	0.33	0.25	0.17	-0.01	0.00	0.02	0.03	0.04	0.05
Central chernozem region	0.58	0.50	0.42	0.34	0.27	0.19	-0.02	-0.01	0.00	0.01	0.02	0.04
Povolzhski region	0.41	0.33	0.25	0.17	0.09	0.01	-0.04	-0.03	-0.02	-0.01	0.00	0.02
North-Caucasian region	0.48	0.40	0.32	0.24	0.17	0.09	0.01	0.02	0.03	0.04	0.05	0.07
Ural region	0.50	0.42	0.34	0.26	0.18	0.10	-0.04	-0.02	-0.01	0.00	0.01	0.02
West-Siberian region	0.20	0.12	0.04	-0.04	-0.12	-0.20	-0.07	-0.06	-0.04	-0.03	-0.02	-0.01
East-Siberian region	0.29	0.21	0.13	0.05	-0.03	-0.11	-0.02	-0.01	0.00	0.02	0.03	0.04
Far-Eastern region	0.24	0.16	0.08	0.00	-0.08	-0.15	0.03	0.04	0.05	0.06	0.08	0.09

	Energy/Capital elasticity					
	1993	***1994***	***1995***	***1996***	***1997***	***1998***
Russian Federation	0.05	0.09	0.14	0.19	0.24	0.28
Northern region	0.06	0.11	0.16	0.20	0.25	0.30
North-western region	0.09	0.14	0.19	0.23	0.28	0.33
Central region	0.00	0.05	0.09	0.14	0.19	0.23
Volga-Vyatka region	-0.11	-0.06	-0.02	0.03	0.08	0.12
Central chernozem region	-0.11	-0.06	-0.02	0.03	0.08	0.12
Povolzhski region	0.07	0.12	0.16	0.21	0.26	0.30
North-Caucasian region	-0.01	0.04	0.08	0.13	0.18	0.22
Ural region	-0.02	0.02	0.07	0.12	0.16	0.21
West-Siberian region	0.25	0.30	0.35	0.39	0.44	0.49
East-Siberian region	0.16	0.20	0.25	0.30	0.34	0.39
Far-Eastern region	0.14	0.19	0.24	0.28	0.33	0.38

Source: Own calculations based on the results of the final restricted frontier model.

Table 5: Scores of technical efficiency

		Technical Efficiency scores						Technical Efficiency Index (1993 = 100)					Technical Change Index (1993 = 100)					Malmqvist Index (1993 = 100)				
		1993	1994	1995	1996	1997	1998	1994	1995	1996	1997	1998	1994	1995	1996	1997	1998	1994	1995	1996	1997	1998
	Russian Federation	**0.42**	**0.41**	**0.43**	**0.44**	**0.48**	**0.45**	**0.97**	**1.01**	**1.04**	**1.14**	**1.07**	**0.91**	**0.85**	**0.82**	**0.80**	**0.80**	**0.88**	**0.86**	**0.85**	**0.91**	**0.85**
1	**Northern Region**	**0.33**	**0.33**	**0.33**	**0.31**	**0.31**	**0.33**	**1.01**	**1.02**	**0.94**	**0.96**	**1.03**	**0.92**	**0.87**	**0.84**	**0.83**	**0.84**	**0.94**	**0.89**	**0.80**	**0.80**	**0.86**
1	Petrozavodsk (Karelia)	0.30	0.30	0.27	0.22	0.21	0.22	1.00	0.92	0.74	0.72	0.74	0.93	0.88	0.85	0.84	0.85	0.93	0.81	0.63	0.60	0.63
2	Syktyvkar (Komi)	0.32	0.32	0.33	0.30	0.30	0.37	0.99	1.02	0.93	0.92	1.15	0.89	0.82	0.76	0.73	0.72	0.88	0.84	0.71	0.67	0.82
3	Arkhangelsk	0.35	0.36	0.36	0.36	0.37	0.43	1.04	1.02	1.02	1.08	1.23	0.94	0.90	0.89	0.89	0.91	0.98	0.92	0.91	0.96	1.12
4	Vologda	0.37	0.39	0.44	0.41	0.43	0.40	1.05	1.19	1.10	1.16	1.06	0.94	0.90	0.88	0.88	0.90	0.98	1.07	0.97	1.02	0.96
5	Murmansk	0.28	0.27	0.24	0.23	0.22	0.24	0.97	0.87	0.83	0.80	0.84	0.92	0.87	0.84	0.83	0.84	0.89	0.76	0.70	0.66	0.70
2	**North-Western Region**	**0.45**	**0.41**	**0.42**	**0.43**	**0.46**	**0.44**	**0.91**	**0.94**	**0.95**	**1.02**	**0.97**	**0.94**	**0.90**	**0.88**	**0.88**	**0.90**	**0.85**	**0.85**	**0.84**	**0.91**	**0.88**
6	Leningrad	0.74	0.66	0.67	0.67	0.75	0.69	0.89	0.91	0.91	1.01	0.93	0.91	0.85	0.81	0.79	0.79	0.81	0.77	0.74	0.81	0.74
7	Novgorod	0.27	0.26	0.28	0.28	0.29	0.32	0.95	1.03	1.03	1.07	1.20	0.96	0.95	0.95	0.98	1.03	0.92	0.98	0.98	1.05	1.23
8	Pskov	0.30	0.28	0.29	0.30	0.31	0.27	0.92	0.96	0.99	1.02	0.89	0.94	0.91	0.89	0.90	0.92	0.86	0.87	0.88	0.91	0.82
3	**Central Region**	**0.40**	**0.40**	**0.42**	**0.45**	**0.44**	**0.42**	**1.01**	**1.07**	**1.15**	**1.11**	**1.07**	**0.93**	**0.88**	**0.86**	**0.85**	**0.87**	**0.94**	**0.95**	**0.98**	**0.95**	**0.93**
9	Bryansk	0.44	0.42	0.42	0.43	0.42	0.47	0.98	0.96	1.00	0.97	1.07	0.92	0.87	0.83	0.82	0.82	0.90	0.83	0.83	0.80	0.88
10	Vladimir	0.35	0.36	0.43	0.42	0.46	0.43	1.04	1.25	1.21	1.33	1.23	0.94	0.91	0.89	0.89	0.92	0.98	1.13	1.08	1.18	1.13
11	Ivanovo	0.30	0.27	0.29	0.29	0.27	0.26	0.91	0.96	0.99	0.91	0.87	0.93	0.89	0.87	0.87	0.88	0.85	0.86	0.86	0.79	0.77
12	Kaluga	0.36	0.37	0.40	0.41	0.37	0.39	1.03	1.11	1.15	1.02	1.09	0.94	0.90	0.88	0.88	0.90	0.97	1.00	1.01	0.90	0.97
13	Kostroma	0.26	0.26	0.31	0.31	0.31	0.31	1.00	1.16	1.16	1.18	1.17	0.94	0.91	0.89	0.90	0.92	0.94	1.05	1.04	1.06	1.07
14	Moscow Region	0.75	0.72	0.75	0.93	0.91	0.86	0.96	1.01	1.25	1.22	1.15	0.90	0.84	0.79	0.77	0.76	0.87	0.85	0.99	0.94	0.87
15	Orel	0.36	0.32	0.32	0.33	0.33	0.33	0.90	0.90	0.92	0.93	0.94	0.93	0.89	0.86	0.86	0.87	0.84	0.80	0.79	0.80	0.82
16	Ryazan	0.38	0.39	0.39	0.47	0.50	0.48	1.02	1.01	1.23	1.30	1.27	0.93	0.88	0.86	0.85	0.87	0.95	0.89	1.06	1.11	1.10
17	Smolensk	0.31	0.36	0.34	0.34	0.32	0.26	1.16	1.10	1.11	1.05	0.84	0.94	0.90	0.88	0.88	0.90	1.09	0.99	0.98	0.93	0.75
18	Tver	0.36	0.37	0.43	0.48	0.41	0.44	1.03	1.19	1.33	1.15	1.21	0.92	0.86	0.83	0.82	0.82	0.95	1.03	1.11	0.94	0.99
19	Tula	0.50	0.53	0.56	0.54	0.48	0.45	1.06	1.11	1.06	0.95	0.89	0.93	0.89	0.87	0.87	0.89	0.99	0.99	0.93	0.82	0.79
20	Yaroslavl	0.31	0.34	0.38	0.39	0.40	0.34	1.10	1.20	1.25	1.28	1.08	0.93	0.89	0.86	0.86	0.87	1.02	1.07	1.08	1.10	0.94
4	**Volga-Vyatka Region**	**0.35**	**0.34**	**0.39**	**0.39**	**0.42**	**0.40**	**0.98**	**1.10**	**1.12**	**1.20**	**1.14**	**0.91**	**0.85**	**0.80**	**0.78**	**0.78**	**0.89**	**0.93**	**0.90**	**0.94**	**0.89**
21	Yohkar-Ola (Mariy El)	0.23	0.24	0.27	0.26	0.28	0.28	1.06	1.16	1.13	1.20	1.21	0.92	0.86	0.82	0.81	0.81	0.97	1.00	0.93	0.97	0.98
22	Saransk (Mordovia)	0.33	0.36	0.37	0.37	0.41	0.38	1.08	1.10	1.12	1.24	1.13	0.91	0.85	0.81	0.79	0.79	0.98	0.94	0.91	0.98	0.89
23	Cheboksary (Chuvashia)	0.29	0.28	0.33	0.33	0.38	0.35	0.94	1.11	1.14	1.28	1.17	0.88	0.80	0.74	0.70	0.68	0.83	0.89	0.84	0.90	0.80
24	Kirov	0.43	0.39	0.47	0.46	0.49	0.47	0.92	1.10	1.09	1.14	1.10	0.93	0.88	0.86	0.85	0.86	0.85	0.97	0.93	0.97	0.95
25	Nizhni-Novgorod	0.45	0.43	0.48	0.52	0.53	0.51	0.95	1.07	1.15	1.18	1.13	0.91	0.84	0.79	0.77	0.76	0.86	0.90	0.91	0.91	0.86
5	**Central Chernozem Region**	**0.48**	**0.43**	**0.43**	**0.45**	**0.49**	**0.49**	**0.88**	**0.90**	**0.93**	**1.02**	**1.02**	**0.91**	**0.84**	**0.80**	**0.77**	**0.77**	**0.80**	**0.76**	**0.75**	**0.79**	**0.78**
26	Belgorod	0.50	0.44	0.46	0.48	0.51	0.51	0.89	0.92	0.97	1.03	1.02	0.90	0.84	0.79	0.77	0.76	0.80	0.77	0.76	0.79	0.77
27	Voronezh	0.60	0.51	0.51	0.50	0.59	0.57	0.86	0.85	0.83	0.98	0.95	0.90	0.83	0.78	0.75	0.73	0.77	0.70	0.64	0.73	0.70
28	Kursk	0.47	0.41	0.44	0.45	0.47	0.50	0.88	0.93	0.97	1.00	1.07	0.91	0.85	0.81	0.78	0.78	0.80	0.79	0.78	0.78	0.83
29	Lipetsk	0.45	0.41	0.40	0.43	0.45	0.43	0.91	0.90	0.96	0.99	0.96	0.92	0.86	0.83	0.81	0.82	0.84	0.77	0.79	0.81	0.78
30	Tambov	0.39	0.35	0.36	0.38	0.43	0.44	0.89	0.94	0.99	1.12	1.13	0.90	0.84	0.79	0.77	0.76	0.81	0.79	0.78	0.86	0.86
6	**Povolzhski Region**	**0.44**	**0.44**	**0.44**	**0.48**	**0.60**	**0.47**	**1.00**	**0.99**	**1.08**	**1.34**	**1.05**	**0.90**	**0.83**	**0.79**	**0.76**	**0.75**	**0.90**	**0.83**	**0.85**	**1.02**	**0.79**
31	Elista (Kalmykia)	0.16	0.12	0.12	0.12	0.13	0.08	0.76	0.76	0.73	0.81	0.53	0.89	0.82	0.76	0.73	0.71	0.68	0.62	0.56	0.59	0.38
32	Kazan (Tatarstan)	0.64	0.65	0.76	0.87	1.00	0.77	1.02	1.19	1.38	1.57	1.22	0.90	0.83	0.78	0.75	0.74	0.92	0.99	1.08	1.18	0.90
33	Astrakhan	0.25	0.22	0.21	0.17	0.23	0.22	0.89	0.84	0.69	0.92	0.89	0.93	0.89	0.87	0.87	0.89	0.83	0.75	0.60	0.80	0.79
34	Volgograd	0.55	0.51	0.53	0.53	0.70	0.59	0.93	0.95	0.97	1.26	1.06	0.89	0.81	0.76	0.72	0.70	0.83	0.77	0.73	0.91	0.75
35	Penza	0.35	0.38	0.37	0.39	0.47	0.43	1.10	1.07	1.13	1.36	1.25	0.90	0.83	0.78	0.75	0.74	0.99	0.89	0.89	1.03	0.93
36	Samara	0.54	0.54	0.53	0.58	0.73	0.62	0.99	0.98	1.07	1.34	1.14	0.91	0.84	0.80	0.78	0.77	0.90	0.82	0.86	1.04	0.88
37	Saratov	0.56	0.59	0.51	0.61	0.88	0.61	1.06	0.90	1.08	1.58	1.09	0.88	0.79	0.73	0.69	0.67	0.93	0.72	0.79	1.09	0.73
38	Ulianovsk	0.41	0.43	0.39	0.42	0.47	0.28	1.05	0.97	1.04	1.14	0.69	0.91	0.85	0.80	0.78	0.78	0.95	0.82	0.83	0.89	0.54

Table 5: Scores of technical efficiency (continuation)

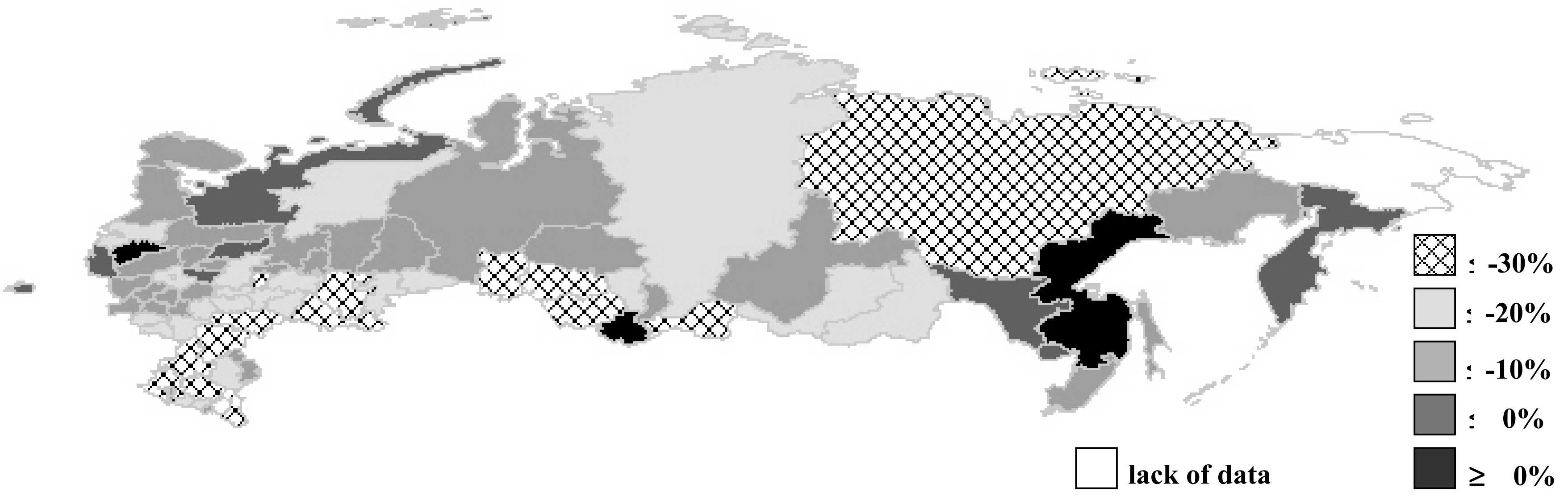
		Technical Efficiency scores						Technical Efficiency Index (1993 = 100)					Technical Change Index (1993 = 100)					Malmqvist Index (1993 = 100)				
		1993	1994	1995	1996	1997	1998	1994	1995	1996	1997	1998	1994	1995	1996	1997	1998	1994	1995	1996	1997	1998
7	**North-Caucasian region**	**0.43**	**0.41**	**0.44**	**0.43**	**0.46**	**0.44**	**0.96**	**1.03**	**1.02**	**1.08**	**1.03**	**0.89**	**0.81**	**0.75**	**0.71**	**0.70**	**0.86**	**0.83**	**0.77**	**0.77**	**0.72**
39	Maikop (Adygea)	0.22	0.21	0.22	0.23	0.20	0.22	0.97	1.01	1.07	0.92	1.01	0.93	0.89	0.86	0.86	0.87	0.90	0.89	0.93	0.79	0.88
40	Makhachkala (Dagestan)	0.19	0.24	0.23	0.30	0.35	0.24	1.26	1.23	1.56	1.83	1.27	0.80	0.66	0.55	0.48	0.42	1.01	0.81	0.86	0.87	0.53
41	Nalchik (Kabardino-Balkaria)	0.26	0.29	0.32	0.33	0.36	0.37	1.12	1.25	1.26	1.39	1.45	0.91	0.84	0.80	0.78	0.78	1.02	1.06	1.02	1.08	1.12
42	Cherkessk (Karachai-Circassia)	0.19	0.20	0.23	0.23	0.22	0.22	1.08	1.21	1.23	1.16	1.16	0.91	0.86	0.82	0.80	0.80	0.99	1.03	1.00	0.93	0.93
43	Vladikavkas (North Ossetia)	0.13	0.16	0.17	0.15	0.16	0.16	1.20	1.26	1.13	1.19	1.24	0.92	0.87	0.84	0.83	0.83	1.11	1.10	0.95	0.99	1.04
44	Krasnodar	0.85	0.77	0.85	0.84	0.89	0.85	0.90	1.00	0.99	1.04	1.00	0.88	0.79	0.72	0.68	0.65	0.79	0.79	0.72	0.71	0.65
45	Stavropol	0.62	0.57	0.62	0.61	0.65	0.60	0.92	1.00	0.99	1.04	0.97	0.89	0.80	0.74	0.71	0.68	0.82	0.80	0.74	0.73	0.66
46	Rostov-on-Don	0.67	0.61	0.62	0.54	0.61	0.60	0.91	0.93	0.81	0.91	0.90	0.88	0.80	0.74	0.70	0.67	0.80	0.74	0.60	0.63	0.60
8	**Ural region**	**0.50**	**0.48**	**0.52**	**0.56**	**0.69**	**0.59**	**0.96**	**1.04**	**1.13**	**1.38**	**1.18**	**0.90**	**0.84**	**0.79**	**0.77**	**0.76**	**0.87**	**0.87**	**0.89**	**1.05**	**0.89**
47	Ufa (Bashkortostan)	0.56	0.56	0.64	0.79	0.92	0.78	0.99	1.15	1.41	1.64	1.40	0.89	0.80	0.75	0.71	0.69	0.88	0.93	1.06	1.16	0.96
48	Izhevsk (Udmurtian Republic)	0.38	0.39	0.44	0.43	0.47	0.47	1.03	1.18	1.14	1.25	1.25	0.92	0.86	0.82	0.81	0.81	0.94	1.01	0.94	1.00	1.01
49	Kurgan	0.38	0.34	0.37	0.41	0.52	0.40	0.89	0.99	1.09	1.39	1.05	0.91	0.84	0.79	0.77	0.76	0.81	0.83	0.86	1.07	0.80
50	Orenburg	0.43	0.42	0.36	0.40	0.64	0.40	0.99	0.85	0.93	1.49	0.93	0.88	0.79	0.73	0.69	0.67	0.87	0.67	0.68	1.03	0.63
51	Perm	0.50	0.50	0.57	0.59	0.67	0.68	0.99	1.13	1.18	1.33	1.35	0.92	0.86	0.82	0.81	0.81	0.91	0.97	0.97	1.07	1.09
52	Ekaterinburg	0.65	0.59	0.71	0.73	0.77	0.73	0.91	1.10	1.13	1.19	1.13	0.92	0.87	0.83	0.82	0.82	0.83	0.95	0.94	0.98	0.93
53	Chelyabinsk	0.59	0.56	0.51	0.56	0.79	0.63	0.96	0.87	0.95	1.35	1.07	0.91	0.84	0.79	0.77	0.76	0.87	0.73	0.75	1.04	0.81
9	**West-Siberian region**	**0.48**	**0.44**	**0.52**	**0.51**	**0.56**	**0.54**	**0.93**	**1.10**	**1.06**	**1.17**	**1.13**	**0.92**	**0.86**	**0.83**	**0.81**	**0.81**	**0.85**	**0.94**	**0.88**	**0.94**	**0.92**
54	Gorno-Altaisk (Republic of Altai)	0.19	0.17	0.19	0.17	0.18	0.22	0.91	1.01	0.90	0.95	1.20	1.08	1.20	1.34	1.54	1.80	0.98	1.20	1.21	1.46	2.16
55	Barnaul (Altai Territory)	0.53	0.41	0.59	0.56	0.52	0.57	0.77	1.12	1.05	0.98	1.08	0.87	0.78	0.71	0.67	0.64	0.67	0.87	0.75	0.65	0.69
56	Kemerovo	0.56	0.57	0.60	0.59	0.68	0.59	1.01	1.06	1.04	1.20	1.04	0.89	0.82	0.76	0.73	0.71	0.90	0.86	0.79	0.88	0.74
57	Novosibirsk	0.55	0.54	0.65	0.62	0.73	0.70	0.99	1.19	1.14	1.34	1.28	0.88	0.80	0.74	0.70	0.68	0.88	0.95	0.85	0.94	0.87
58	Omsk	0.54	0.47	0.60	0.63	0.70	0.66	0.87	1.10	1.15	1.29	1.22	0.87	0.78	0.71	0.67	0.64	0.76	0.86	0.83	0.86	0.78
59	Tomsk	0.37	0.37	0.38	0.32	0.39	0.39	1.00	1.02	0.85	1.05	1.05	0.93	0.89	0.86	0.86	0.87	0.93	0.91	0.74	0.91	0.91
60	Tyumen	0.52	0.50	0.57	0.58	0.60	0.56	0.96	1.08	1.10	1.14	1.06	0.93	0.88	0.85	0.85	0.86	0.89	0.95	0.94	0.96	0.91
10	**East-Siberian region**	**0.42**	**0.41**	**0.43**	**0.43**	**0.49**	**0.46**	**0.99**	**1.03**	**1.04**	**1.17**	**1.10**	**0.91**	**0.84**	**0.80**	**0.77**	**0.77**	**0.89**	**0.86**	**0.83**	**0.91**	**0.84**
61	Ulan-Ude (Buryatia)	0.32	0.30	0.36	0.41	0.45	0.49	0.94	1.13	1.27	1.41	1.51	0.91	0.84	0.80	0.78	0.77	0.86	0.95	1.01	1.09	1.17
62	Kyzyl (Tuva)	0.17	0.17	0.19	0.17	0.17	0.16	1.00	1.11	1.01	1.02	0.93	0.86	0.76	0.68	0.63	0.60	0.86	0.84	0.69	0.64	0.55
63	Abakan (Khakassia)	0.26	0.21	0.24	0.23	0.28	0.15	0.82	0.96	0.91	1.10	0.59	0.93	0.88	0.85	0.84	0.85	0.76	0.84	0.77	0.93	0.50
64	Krasnoyarsk	0.71	0.64	0.73	0.70	0.85	0.75	0.90	1.03	0.99	1.20	1.06	0.92	0.86	0.82	0.80	0.80	0.83	0.89	0.81	0.96	0.85
65	Irkutsk	0.56	0.71	0.62	0.64	0.69	0.71	1.26	1.11	1.14	1.23	1.26	0.92	0.86	0.83	0.81	0.81	1.15	0.95	0.94	1.00	1.02
66	Chita	0.38	0.33	0.32	0.35	0.36	0.37	0.86	0.83	0.90	0.93	0.96	0.91	0.84	0.79	0.77	0.76	0.78	0.69	0.71	0.71	0.73
11	**Far-Eastern region**	**0.37**	**0.37**	**0.31**	**0.31**	**0.32**	**0.37**	**0.98**	**0.84**	**0.82**	**0.86**	**0.98**	**0.92**	**0.87**	**0.85**	**0.84**	**0.84**	**0.90**	**0.73**	**0.69**	**0.72**	**0.83**
67	Yakutsk (Sakha)	0.49	0.66	0.41	0.39	0.54	0.51	1.35	0.84	0.80	1.10	1.04	0.82	0.69	0.60	0.53	0.48	1.10	0.58	0.48	0.58	0.50
68	Judish autonom republic	0.13	0.12	0.11	0.11	0.10	0.12	0.93	0.86	0.81	0.76	0.91	0.95	0.91	0.90	0.91	0.94	0.88	0.79	0.73	0.69	0.85
69	Vladivostok (Primorski Kray)	0.40	0.33	0.36	0.35	0.35	0.48	0.84	0.91	0.89	0.89	1.21	0.93	0.88	0.86	0.85	0.86	0.78	0.80	0.76	0.76	1.05
70	Khabarovsk	0.35	0.35	0.42	0.39	0.35	0.52	1.00	1.18	1.09	1.00	1.46	0.97	0.95	0.96	0.99	1.04	0.97	1.13	1.05	0.99	1.52
71	Blagoveshchensk (Amur)	0.37	0.32	0.30	0.32	0.31	0.33	0.87	0.81	0.85	0.83	0.89	0.94	0.90	0.89	0.89	0.92	0.82	0.73	0.76	0.74	0.82
72	Petropavlovsk-Kamchatska	0.43	0.39	0.33	0.34	0.35	0.37	0.90	0.76	0.80	0.81	0.86	0.95	0.93	0.92	0.94	0.97	0.86	0.71	0.74	0.76	0.84
73	Magadan	0.28	0.21	0.13	0.17	0.16	0.14	0.77	0.47	0.59	0.58	0.50	0.93	0.88	0.86	0.85	0.86	0.71	0.42	0.51	0.50	0.43
74	Yuzhno-Sakhalinsk (Sachalin)	0.49	0.47	0.38	0.34	0.37	0.41	0.97	0.78	0.70	0.74	0.83	0.92	0.86	0.83	0.82	0.82	0.89	0.68	0.58	0.61	0.68
75	**Kaliningrad Region**	**0.26**	**0.24**	**0.23**	**0.23**	**0.25**	**0.27**	**0.92**	**0.87**	**0.88**	**0.93**	**1.01**	**0.95**	**0.92**	**0.92**	**0.93**	**0.96**	**0.87**	**0.80**	**0.80**	**0.87**	**0.97**

Source: Own calculations based on the final restricted model.

Map 1: Technical efficiency in the Russian agriculture (total, 1998)

Map 2: Technical efficiency in the Russian agriculture (development 1993 to 1998)

Map 3: Technological change in the Russian agriculture (1993 to 1998, in %)



Map 4: Change of Total Factor Productivity in the Russian agriculture (1993 to 1998, in %)

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