Impact of regional diversity on production potential: an example of Russia

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ABSTRACT

Russia is often considered the most prominent country to become a leader on the world grain market. However, several issues slow down Russia's agricultural progress, for example: a lack of infrastructure and investments, unequal regional development, and inefficient use of production technologies. This study therefore examines the grain production potential of Russian regions by employing a modified approach to stochastic frontier analysis that allows us to include not only production technologies, but also indicators of country's heterogeneity and diversity among regions. Obtained results indicate that climate conditions in combination with the level of human and institutional development, and infrastructure have significant effect on the production structure of regions and therefore should not be neglected while assessing regional policies and production potential.

KEYWORDS: technical efficiency, SFA, Russia, heterogeneity, production potential

INTRODUCTION AND BACKGROUND

For many years the question of the development of Russian agriculture has been a matter of great concern for economists and politicians. Underdeveloped and old infrastructure, combined with large unoccupied territories, always prevented successful performance of agricultural markets in Russia and slowed down not only export growth rates of agricultural products, but also the transition of the country towards a more developed economy. We therefore aim to estimate the performance of Russia, as one of the most controversial examples of a transition economy, on the world agricultural market. One of the approaches of evaluating the performance of the country on the global market is to measure the country's production potential. Therefore, the objective of this research is to estimate the agricultural production potential of Russia on the regional level, taking into account that all regions are heterogeneous in their development, determined by availability of infrastructure, development of institutions, and climate conditions.

The analysis of the efficiency of agricultural production in transition economies has been a popular research topic in the last twenty years, especially focusing on Russia because of its production potential and vast resources. Previous research primarily concentrated on the measurement of farm-level efficiency (e.g. Bokusheva and Hockmann, 2006; Osborne and Trueblood, 2006). However, given the size of the country, as well as disparity of country's development together with climate zones and soil quality, it becomes more reasonable to conduct the analysis on the regional level, thus estimating the production potential of the whole country rather than of each separate region. In fact, there are several studies that focus on estimating the efficiency of production on regional level (Arnade and Gopinath, 2000; Sedik, Trueblood, and Arnade, 1999; Sotnikov, 1998).

These studies pay attention to changes in technical efficiency of Russian agricultural during the years of transition. For instance, Sotnikov (1998) reports an increase in technical efficiency in the early 90s, followed by a decline of efficiency scores in 1993-95. The author concludes that an increase in technical efficiency took place primarily due to improvements in the use of inputs, together with significant technical change, while a following decrease in efficiency score resulted from price controls and subsidies from the side of the government. These results go in line with findings of Sedik, Trueblood, and Arnade (1999), who, in addition, explain decreasing technical efficiency scores in 1993-95 by price changes for agricultural inputs as well as by subsidising the most inefficient farms. Furthermore, the authors conclude from their findings, the more specialised a region is in a particular crop, the more efficient is the production in this region, that specialisation leads to efficiency.

Arnade and Gopinath (2000) estimate production functions by measuring financial efficiency in addition to technical efficiency. They indicate that only six out of 73 examined Russian regions have achieved technical efficiency, while 19 regions were experiencing financial efficiency in 1994-95. Reasons for such inefficiency score could potentially be inefficient terms of trade, as concluded in previous studies, as well as unstable weather conditions, unsuitable for agricultural production. Arnade and Trueblood (2002) confirm the common finding that farms' efficiency tends to be responsive to input prices, and find the prevalence of technical and allocative efficiencies in the Russian agricultural production.

Based on regional level data, Osborne and Trueblood (2006) note a decreasing pattern of technical and allocative efficiency score in the period from 1993 to 1998. Voigt and Hockmann (2008) observe a considerable decrease in the original possibilities of production in this period, and indicate a positive development and restructuring of the sector only starting from 2003. In addition, the authors find evidence of different technologies of production across regions due to diversity of regional development. Bokusheva, Hockmann and Kumbhakar (2011) found a decreasing trend of regional efficiency until 2000, followed by steady improvement afterwards. Based on calculations of total factor productivity, the authors found heterogeneity of economic and institutional environment across the country. This is the crucial finding that has been outlining in almost all studies mentioned above: production in Russia is being influenced by other factors rather than by efficient (or inefficient) use of production inputs. Therefore, the current study aims to measure the production potential of Russian agriculture, and identify factors that determine heterogeneity of the country and, thus, influence productivity of the agricultural sector. We distinguish three indicators that could serve as proxies for factors that determine heterogeneous development of the country, precisely: level of human development, level of infrastructural development, and climate and soil conditions.

This study is organised as follows. Section 2 provides description of the theoretical approach used in the research and gives a/the methodological concept of the model. In section 3 we describe the used data and provide the empirical model. Section 4 reports obtained results and provides discussion and proofs regarding the validity of the model. Section 5 concludes the paper by presenting a brief review of methodology and obtained results.

THEORETICAL APPROACH AND METHODOLOGY

Conventional stochastic frontier theory implies that farms (or regions) are inefficient rather than influenced by institutional, economic, and climatic factors. Therefore, inefficiency scores are estimated assuming that all producers have access to homogeneous technology. However, this assumption cannot be the case while estimating production potential on the regional level (especially on the regional level of Russia, where the size of the country simply cannot allow for this kind of assumption). Therefore, choosing an incorrect model will most probably result in overestimated efficiency scores, while factors that influence potentially the most, will be left without attention. Moreover, with appearance of more advanced technologies and more experienced workers production is more likely to be efficient, and therefore heterogeneity of regions becomes the factor that could have negative impact on the production of the country.

The current study assumes that production is defined by particular characteristics of regions. These characteristics indicate level of regional development, and influence the implementation of production technologies. Among such characteristics we can name the level of economic and social development; system of transportation and infrastructure; climate and soil conditions and their suitability for agricultural production.

We develop the theoretical model based on the stochastic frontier for panel data framework, following the approach proposed by Alvarez et al. (2003) and further developed by Alvarez et al. (2004). We assume that the production function can take the form of the output distance function, and apply the homogeneity property to transform the function in order to estimate multiple outputs.

The homogeneity property of the output distance function (Kumbhakar and Lovell, 2000) states that:

$$D^o(x, \lambda y) = \lambda D^o(x, y) \; for \; \lambda > 0 \tag{1}$$

In the multiple output framework distance function is described as $D^o(x, y_1, y_2, \dots, y_N)$. Assuming that $1/y_1 = \lambda$ we can apply homogeneity property (1) to the distance function to get:

$$D^o\left(x, \frac{y_1}{y_1}, \frac{y_2}{y_1}, \dots, \frac{y_N}{y_1}\right) = 1/y_1 D^o(x, y_1, y_2, \dots, y_N) \tag{2}$$

Transforming equation (2) in the logarithmic form leads to:

$$\ln D^o\left(x, \frac{y_1}{y_1}, \frac{y_2}{y_1}, \dots, \frac{y_N}{y_1}\right) = \ln\left(\frac{1}{y_1} D^o(x, y_1, y_2, \dots, y_N)\right) \tag{3}$$

$$= -\ln y_1 + \ln D^o(x, y)$$

Following the specification above, we can describe the production as follows:

$$1/y_{it}^{act} = f(\mathbf{x}, \mathbf{y}, \boldsymbol{\beta})h(\mathbf{z}, \mathbf{x}) \tag{4}$$

where $\mathbf{y}$ is the vector of agricultural outputs, $\mathbf{x}$ is the vector of production inputs, $\mathbf{z}$ is the vector of heterogeneity indicators. Function $h(\cdot)$ captures the effect of specific time invariant conditions and production technologies on production possibilities through the turn of the marginal product curves and the shift of the production frontier. We expect that the production function is monotonically increasing in the heterogeneity effect, assuming that a higher value of the heterogeneity indicator increases production possibilities.

The stochastic production frontier in the translog form can be therefore expressed as:

$$\begin{aligned}\ln f(\mathbf{x}, y_{it}^{opt}) = {} & \beta_0 + \beta_t t + \beta_{\mathbf{y}} \ln \mathbf{y}_{\boldsymbol{it}} + \beta_{\mathbf{y}t}\, t \ln \mathbf{y}_{it} + \beta_{\mathbf{x}} \ln \mathbf{x}_{\boldsymbol{it}} + \beta_{\mathbf{x}t}\, t \ln \mathbf{x}_{it} \\ & + {}^{1}\!/_{2}\, \beta_{\mathbf{yy}} \ln \mathbf{y}_{it} \ln \mathbf{y}_{it} + {}^{1}\!/_{2}\, \beta_{\mathbf{xx}} \ln \mathbf{x}_{it} \ln \mathbf{x}_{it} + \beta_{\mathbf{yx}} \ln \mathbf{y}_{it} \ln \mathbf{x}_{it} \\ & + (\alpha_0 + \alpha_t t + \alpha_{\mathbf{x}} \ln \mathbf{x}_{\boldsymbol{it}})(\gamma_0^{opt} + \gamma_{\mathbf{z}}^{opt}\mathbf{z}) \\ & \forall\, i = 1,2 \ldots, N;\, t = 1, \ldots, T\end{aligned} \tag{5}$$

where superscript *opt* denotes values of the parameters at the frontier, i.e. optimal production and conditions for production.

However, regions usually are not capable of exploring their production possibilities at full capacity. Therefore, we assume that only y_{it}^{act} ($y_{it}^{act} \leq y_{it}^{opt}$) is being produced with the technology described by the following production function:

$$\begin{aligned}-\ln y_{1t}^{act} = {} & \beta_0 + \beta_t t + \beta_{\mathbf{y}} \ln \mathbf{y}_{\boldsymbol{it}} + \beta_{\mathbf{y}t}\, t \ln \mathbf{y}_{it} + \beta_{\mathbf{x}} \ln \mathbf{x}_{\boldsymbol{it}} + \beta_{\mathbf{x}t}\, t \ln \mathbf{x}_{it} \\ & + {}^{1}\!/_{2}\, \beta_{\mathbf{yy}} \ln \mathbf{y}_{it} \ln \mathbf{y}_{it} + {}^{1}\!/_{2}\, \beta_{\mathbf{xx}} \ln \mathbf{x}_{it} \ln \mathbf{x}_{it} \\ & + \beta_{\mathbf{yx}} \ln \mathbf{y}_{it} \ln \mathbf{x}_{it} + (\alpha_0 + \alpha_t t + \alpha_{\mathbf{x}} \ln \mathbf{x}_{\boldsymbol{it}})(\gamma_0^{act} + \gamma_{\mathbf{z}}^{act}\mathbf{z}) \\ & \forall\, i = 1,2 \ldots, N;\, t = 1, \ldots, T\end{aligned} \tag{6}$$

Applying the same technique to the multiple output production function we can calculate technical efficiency as:

$$\ln TE_{it} = -\ln y_{it}^{act} - \ln f(\mathbf{x}, y_{it}^{opt})$$
$$= (\alpha_0 + \alpha_t t + \alpha_{\mathbf{x}} \ln \mathbf{x}_{\boldsymbol{it}})(\gamma_0^* + \gamma_{\mathbf{z}}^* \boldsymbol{z}) \tag{7}$$

where $\gamma_0^* = \gamma_0^{opt} - \gamma_0^{act}$ and $\gamma_{\mathbf{z}}^* = \gamma_{\mathbf{z}}^{opt} - \gamma_{\mathbf{z}}^{act}$.

Because technical inefficiency is equal to the negative of technical efficiency we can get the following production function, expressed by the technical inefficiency term:

$$-\ln y_{it}^{act} = \ln f(\mathbf{x}, y_{it}^{opt}) - \ln TE$$
$$= \ln f(\mathbf{x}, y_{it}^{opt}) + u \tag{8}$$

Therefore, the final specification of the production function with heterogeneity effect can be written as:

$$\begin{aligned} -\ln y_{it}^{act} = {} & \beta_0 + \beta_t t + \beta_{\mathbf{y}} \ln \mathbf{y}_{\boldsymbol{it}} + \beta_{\mathbf{y}t}\, t \ln \mathbf{y}_{it} + \beta_{\mathbf{x}} \ln \mathbf{x}_{\boldsymbol{it}} + \beta_{\mathbf{x}t}\, t \ln \mathbf{x}_{it} \\ & + {}^{1}\!/_{2}\, \beta_{\mathbf{yy}} \ln \mathbf{y}_{it} \ln \mathbf{y}_{it} + {}^{1}\!/_{2}\, \beta_{\mathbf{xx}} \ln \mathbf{x}_{it} \ln \mathbf{x}_{it} \\ & + (\alpha_0 + \alpha_t t + \alpha_{\mathbf{x}} \ln \mathbf{x}_{\boldsymbol{it}})\big(\gamma_0^{opt} + \gamma_{\mathbf{z}}^{opt} \mathbf{z}\big) \\ & - (\alpha_0 + \alpha_t t + \alpha_{\mathbf{x}} \ln \mathbf{x}_{\boldsymbol{it}})(\gamma_0^* + \gamma_{\mathbf{z}}^* \mathbf{z}) \end{aligned} \tag{9}$$

In order to obtain unbiased estimators of the model above we impose a set of restrictions, designed to guarantee standard properties of the production function, i.e. convexity in outputs and quasi-convexity in inputs (Coelli et al. 1998).

DATA AND EMPIRICAL MODEL

The data used in the empirical analysis consist of a balanced panel of 61 Russian regions which were involved in grain production. The study had to intentionally exclude several regions whose data caused validity concerns and therefore could have significantly distorted the estimation results. The data comes from statistical publications of the Russian Federation Federal State Statistics Service, and covers the period from 1995 to 2011. Summary statistics of the main production characteristics of the country are presented in Table 1. In general, there is no clear specialisation of regions according to the type of agricultural production. Since the dominant type of farm is the large cooperative (or agroholding) in the majority of regions, production tends to be combined in order for a farm to maintain self-sufficiency.

Table 1. Descriptive statistics

Variable	Notation	Unit	Mean	SD	Minimum	Maximum

Gross harvest of grain	y_1	1000 tonnes	11648.5	16246.52	57.38	116343.5
Gross animal production	y_2	million rubles	5737.92	4531.34	158.43	29389.33
Gross crop production (excl. grain)	y_3	million rubles	3023.36	2711.46	76.09	19219.68
Labour	x_1	1000	106.02	84.59	4.04	485.12
Land	x_2	1000 hectares	1257.55	1265.06	20.4	5832.6
Capital	x_3	billion rubles	14610.17	20917.74	66.06	180622.5
Variable inputs	x_4	million rubles	4799.9	4422.16	19.11	25598.74

Source: Russian Federation Federal State Statistics Service, own calculations

The group of variables used in the analysis consists of output and input vectors. Output vector is defined by gross harvest of grain as the dependent variable and by gross animal production and production of other crops as the independent variable. The vector of inputs consists of the amount of land used in crop production, the number of workers involved in agricultural production, and the amounts of capital and variable inputs used in agriculture. Capital is defined as the net value of agricultural capital, and variable input costs are measured as the difference between gross agricultural production and gross regional agricultural product.

Our study focuses on identifying sources and measuring the country's heterogeneity determinants. Thus, we first define factors that could define the degree of region's development, its social and economic environment, and its climate. For this purpose we used three indices that determine the variety of conditions in each region:

- Climate index (z_1) is set to identify the level of climate and soil conditions. It is calculated as a cumulative mean of average temperature and precipitation in each region.
- Stable economic and social development is presented by the index of human development (z_2), defined following the methodology introduced by UNDP (UNDP 1990) and further developed by Klugman, Rodríguez, and Choi (2011). It is calculated as a geometric mean of three normalised indicators of populations' achievements, i.e. life expectancy at birth, gross regional income per person, and number of children enrolled in school each year[1].
- As a proxy for transportation system we used a normalized index of railways density in each region (z_3). Density of railways is not a perfect indicator of transportation development since there exist several regions with no railway connection at all, but unavailability of data prevents us from using a more precise indicator.

These indices combines serve as an aid in determining the level of differences across regions within Russia. Table 2 provides a brief overview of the distribution of average indices' values across federal districts[2], accompanied by Figure 1 that presents the map of Russia in the context of share of agricultural production in gross regional product of federal districts. The climate index shows that districts located in the European part of the country (Central, North-West, and South Federal districts) tend on average to have better conditions for agriculture that than those located beyond the Ural Mountains. Moreover, federal districts with high density of railroads are those located in the European part of the country, where the density of the population is high as well.

[1] Lately, it has been recommended to use expected years of schooling as a more precise measure of education dimension, but lack of data limits the possibility to calculate desired indicators.
[2] Federal districts in Russia present groups of federal subjects (oblasts, republics, krais, cities of federal importance, autonomous oblasts and autonomous okrugs). Hereinafter for the sake of simplicity we refer to federal subjects of Russia as regions.

The highest level of human development have regions located in the Ural district, that connects Asian and European parts of Russia and is considered to be the main mining district in Russia.

Table 2. Average indices of heterogeneity determinants.

Federal district	Climate index	Human development index	Transportation and infrastructure index
Central	0.572	0.353	0.465
North-West	0.623	0.295	0.494
South	0.663	0.351	0.238
Volga	0.482	0.386	0.283
Ural	0.391	0.436	0.217
Siberia	0.335	0.341	0.102
Far East	0.356	0.262	0.113

Source: own calculations

Figure 1. Agricultural production in Russia,
share of agricultural production in gross regional product.

Source: Russian Federation Federal State Statistics Service, own interpretation

Following the available data and the model specification, we can present the equation to be estimated as follows:

$$
\begin{aligned}
-\ln y_{1it}^{act} = \beta_0 + \beta_t t + \beta_{\mathbf{y}} \ln \mathbf{y}_{it} + \beta_{\mathbf{y}t}\, t \ln \mathbf{y}_{it} + \beta_{\mathbf{x}} \ln \mathbf{x}_{it} + \beta_{\mathbf{x}t}\, t \ln \mathbf{x}_{it} \\
+ {}^{1}/_{2}\, \beta_{\mathbf{yy}} \ln \mathbf{y}_{it} \ln \mathbf{y}_{it} + {}^{1}/_{2}\, \beta_{\mathbf{xx}} \ln \mathbf{x}_{it} \ln \mathbf{x}_{it} \\
+(\alpha_0 + \alpha_t t + \alpha_{\mathbf{x}} \ln \mathbf{x})\left(\gamma_0^{opt} + \gamma_{\mathbf{z}}^{opt} \mathbf{z}\right) - u_{it} + v_{it}
\end{aligned} \tag{10}
$$

where y_{1it}^{act} is the actual gross production of grain, $\mathbf{y}_{it} = (y_{2it}, y_{3it})$, with y_{2it} being the gross animal production and y_{3it} the gross production of other crops. We define the vector of inputs as $\mathbf{x}_{it} = (x_{1it}, x_{2it}, x_{3it}, x_{4it})$, where x_{1it} is the labour input, x_{1it} is the land input, x_{3it} and x_{4it} are the capital and material inputs respectively. The time trend variable t permits neutral technical change at a constant rate, allowing the shift of the frontier. Potential sources of heterogeneity are defined as $\mathbf{z} = (z_1, z_2, z_3)$, with z_1 denoting the climate index, z_2 the index of human development, and z_3 the index of infrastructure and transportation. The usual two-sided error term is denoted as v_{it}, while u_{it} is defined as the negative of $\ln TE_{it}$ (see eq. 7). We employ constrained maximum likelihood techniques to obtain consistent estimates of β, α and γ, and impose convexity restrictions for outputs and quasi-convexity for inputs, following Morey (1986).

RESULTS AND DISCUSSION

The results of the estimation of the stochastic cost frontier by constrained maximum likelihood are presented in Table 3. All the explanatory variables were normalised by their geometric mean, thus allowing us to interpret their first order coefficients as cost elasticities. Therefore, the function is increasing in output and is decreasing in input levels. In addition, due to the functional form and normalisation, parameters of output variables indicate the share of each type of output in agricultural output. Our results suggest that agricultural output in the country on 50 percent consists of animal output, on 22 percent of production of other crops, and on 28 percent of grain production. According to the official statistical data, on average, animal production accounts for 51 percent of the total agricultural production, with grain production contributing to 28 percent and production of other crops 21 percent, therefore making the results of our estimation valid.

The estimates of the production function indicate the importance of production factors for agricultural production, specifically for grain production. Inputs elasticities sum up to 90 percent, suggesting the existence of increasing returns to scale. The highest elasticity is observed for variable inputs (0.40). It indicates the close connection between materials and production without other factors that could potentially contribute to the production.

Table 3. Constrained maximum likelihood parameter estimates of the frontier.

Parameter	Estimate	Std.Err.	t-Ratio
β_0	0.025621	0.00956	2.679898
	Technical change		
β_t	-0.03165	0.00305	-10.3761
β_{tt}	0.01196	0.000425	28.16434
	Output effects		
β_{y_2}	0.4995	0.01643	30.40116
β_{y_3}	0.219853	0.008121	27.07138
$\beta_{y_2 t}$	-0.01966	0.004006	-4.90632
$\beta_{y_3 t}$	0.015046	0.003592	4.188822
$\beta_{y_2 y_2}$	0.475963	0.047887	9.939359
$\beta_{y_3 y_3}$	0.254158	0.007527	33.76737
$\beta_{y_2 y_3}$	-0.17296	0.017965	-9.62775
	Input effects		
β_{x_1}	-0.16395	0.015052	-10.8926
β_{x_2}	-0.21005	0.015123	-13.8893
β_{x_3}	-0.12908	0.017565	-7.34864
β_{x_4}	-0.40223	0.021381	-18.8121
$\beta_{x_1 t}$	-0.00469	0.00285	-1.64434
$\beta_{x_2 t}$	0.007157	0.003586	1.995656
$\beta_{x_3 t}$	0.00322	0.002143	1.502799
$\beta_{x_4 t}$	-0.00251	0.001432	-1.75346
$\beta_{x_1 x_1}$	-0.0835	0.055784	-1.49679
$\beta_{x_2 x_2}$	0.057653	0.021379	2.696682
$\beta_{x_3 x_3}$	0.004528	0.018271	0.247829
$\beta_{x_4 x_4}$	-0.13554	0.028415	-4.76997
$\beta_{x_1 x_2}$	0.042011	0.028891	1.454119
$\beta_{x_1 x_3}$	-0.02534	0.015127	-1.67543
$\beta_{x_1 x_4}$	0.036849	0.034394	1.071355
$\beta_{x_2 x_3}$	-0.0211	0.024411	-0.86446
$\beta_{x_2 x_4}$	-0.00741	0.007177	-1.03247
$\beta_{x_3 x_4}$	0.033687	0.032762	1.028219
	Output-input effects		
$\beta_{y_2 x_1}$	-0.02258	0.030768	-0.734
$\beta_{y_2 x_2}$	0.237941	0.029823	7.978497
$\beta_{y_2 x_3}$	-0.06294	0.023108	-2.72369
$\beta_{y_2 x_4}$	-0.17611	0.023216	-7.58561
$\beta_{y_3 x_1}$	-0.03387	0.020712	-1.63517
$\beta_{y_3 x_2}$	0.032587	0.01863	1.749115
$\beta_{y_3 x_3}$	-0.01607	0.019617	-0.81932
$\beta_{y_3 x_4}$	0.101337	0.022231	4.558385

Source: own calculations

Therefore, reduction in the use of materials (fertilisers and other variable inputs) would considerably reduce gross production of agricultural goods. Moreover, land has an elasticity of 0.21, indicating that production is becoming more material-intensive rather than land-intensive. And that is not surprising, taking into account a considerable decrease of land input during the observed period, which coincided with a significant increase in agricultural production. The estimated elasticities of labour and capital are slightly less intense but still statistically significant, with indicators of 0.16 and 0.13 respectively. The relatively low elasticity of labour with respect to materials and land indicate the decreasing importance of labour in agricultural production and its replacement with technological advancements. In fact, the coefficient of the correlation between technical change and labour is negative, suggesting the introduction of labour-saving technologies.

At the same time, technical change was found to be capital-intensive, thus proving the initial assumption of decreasing use of labour and increasing importance of capital as the part of production technology. Similarly, technical change is land-intensive, proving the statement that production has increased due to increase in yields rather than increase in land used. Overall, the impact of technical change on agricultural production is increasing annually at 3.1 percent with a decelerating rate of technology development.

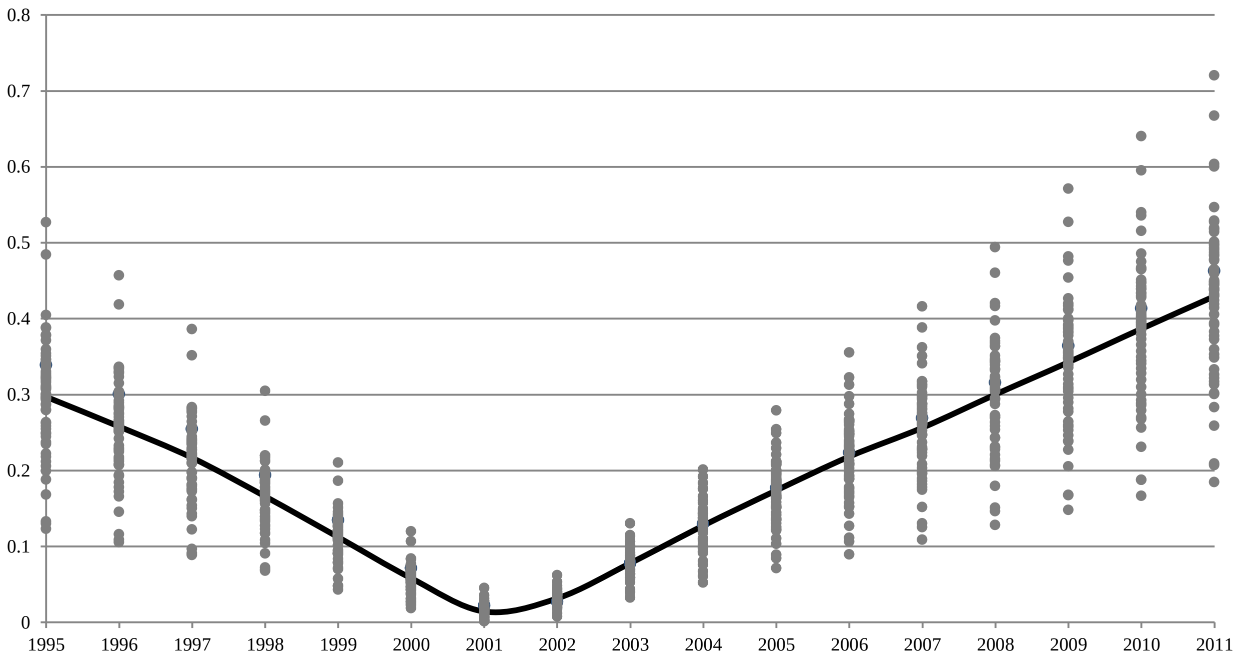
Table 4. Technology and heterogeneity

Parameter	Estimate	Std.Err.	t-Ratio
	Technology		
α_m	0.224796	0.017755	12.6612
α_{mt}	0.137213	0.01497	9.165888
α_{m1}	0.052615	0.039471	1.333005
α_{m2}	-0.00156	0.005526	-0.28319
α_{m3}	-0.03365	0.032908	-1.02242
α_{m4}	-0.03164	0.021196	-1.49253
	Heterogeneity		
γ_0	0.013183	0.024183	0.54513
γ_1	0.28427	0.060682	4.68459
γ_2	0.297972	0.04881	6.10471
γ_3	0.196324	0.043218	4.5426
σ_v	0.216769	0.004083	53.0878
σ_u	0.101913	0.152221	0.669504

Source: own calculations

The initial model assumption implies that production in the country is primarily determined by specific characteristics of each particular region. We measure these characteristics by means of three indices described in the data section. Estimation of technology and heterogeneity indicators (Table 4) suggests that there are two leading characteristics that shape the technology and determine the level of production, namely climate (z_1) and human development (z_2).

Figure 2. Estimated influence of heterogeneity effect on production levels



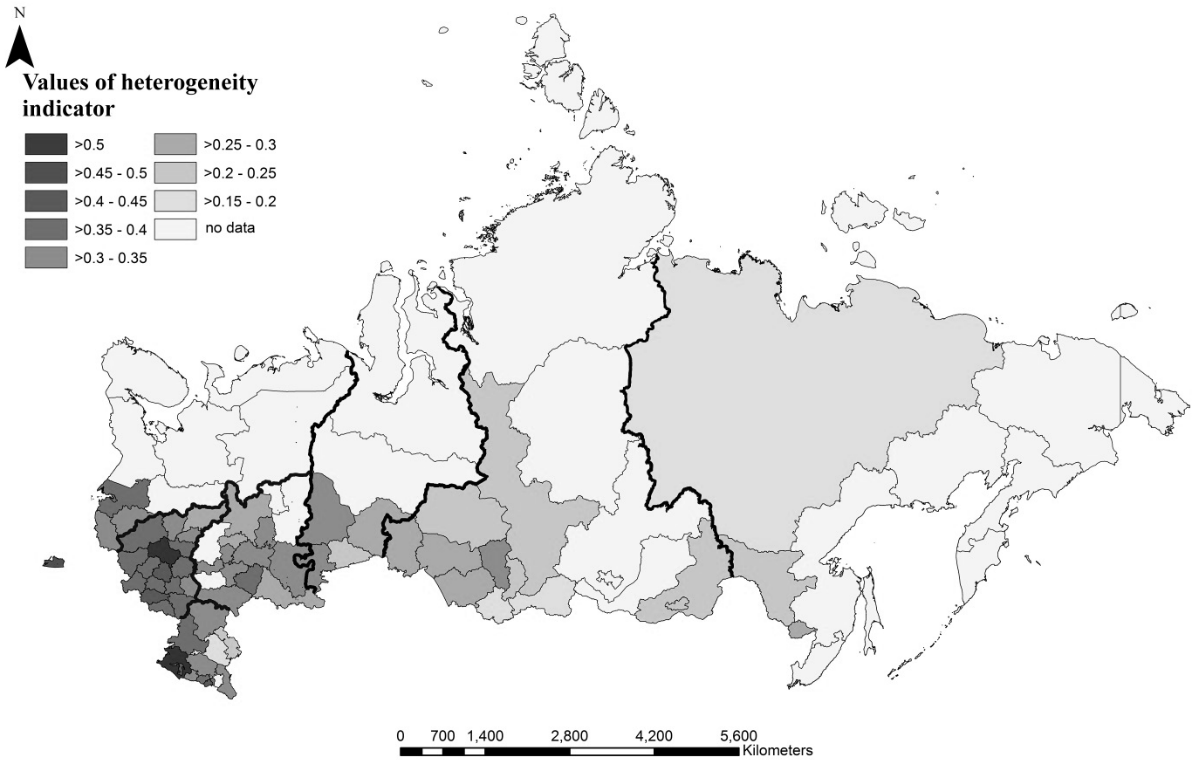
Source: own calculations

The effect of climate was expected to be high since Russia is the biggest country in the world with many climatic zones, and influence of climate conditions is of great importance to agriculture, especially to grain production. The level of economic and social development, reflected by the human development index, is positive and statistically significant, with a value similar to that of climate. Such results indicate that the higher is the level of region's development, the more investments is attracted to the region, and the better skills have workers and farm managers, the higher will therefore be the level of production. The indicator of transportation and infrastructure system (z_3) is significant in determining the level of heterogeneity of the country – it plays an important role in agriculture in general, occupying an important position in trade and in distribution process. Estimation of technology (Table 4) indicates that regions with higher values of heterogeneity effect tend to have higher levels of technical change, suggesting a more advanced development of agriculture in those regions.

As can be seen from Figure 2, heterogeneity effects play a notable part in determining the production potential: the higher the value of heterogeneity indicator is, the higher is the positive impact of heterogeneity indicators on technology implementation and production efficiency. It is worth noting that the level of influence of the heterogeneity indicators on production was decreasing in the period from 1995-2001. Such a decrease can be explained by an overall decrease of actual agricultural production, caused by economic instability and the transition to market economy.

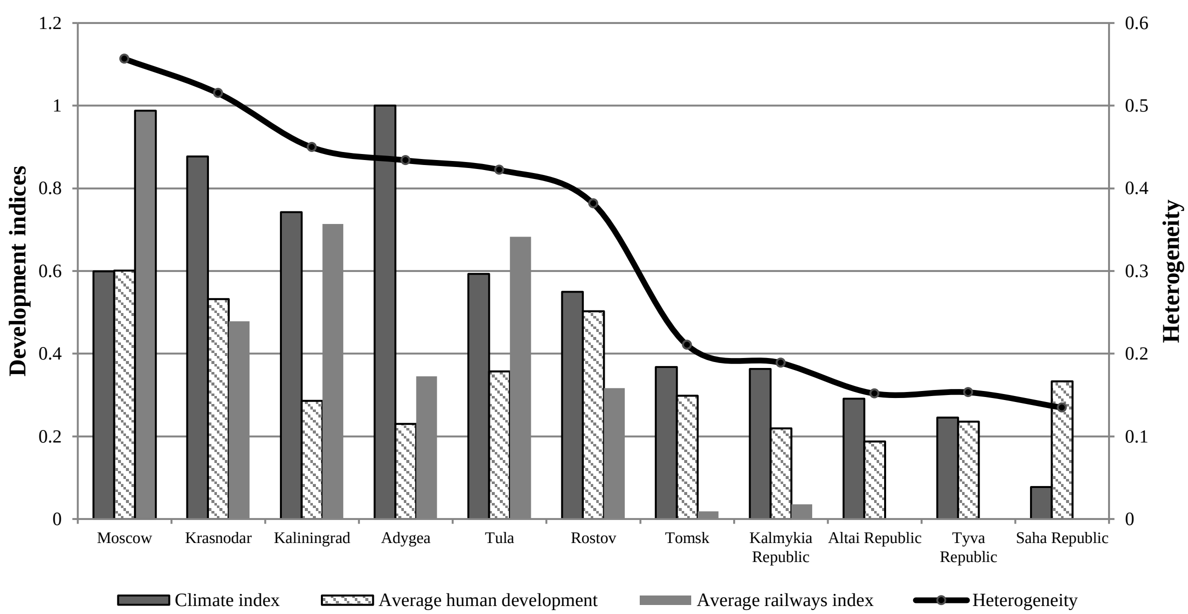
Figure 3 provides an overview of heterogeneity indicator values across the country. It can be seen that conditions for agricultural production become better in the Western and South-Western parts of the country, where climate allows for higher productivity, while higher development of regions implies better infrastructure and facilities for agricultural production and trade.

Figure 3. Values of heterogeneity indicators in Russian regions



Source: own calculations

Figure 4. Comparison of heterogeneity levels in selected regions



Source: own calculations

Figure 4 shows the heterogeneity indicator for selected regions (with favourable and unfavourable conditions for agricultural production). High indicator of heterogeneity implies that conditions in a region are better suited for agricultural production than in regions with a low value of heterogeneity. At first glance, Moscow region is the one with the highest production possibilities among all other regions. However, such suggestion is ambiguous upon examination of determinants of such high indicator: the highest density of roads provides the most favourable conditions for transportation and trade of grain, but relatively low climate index suggests that Moscow maybe not be the best suited for agricultural (especially crop) production. Krasnodar region, on the contrary, has favourable climate conditions, higher than average value of human development index, and well-developed infrastructure, which makes it the most attractive regions in terms of agricultural, and in particular crop, production. In contrast to regions with high values heterogeneity indicators, regions with poor heterogeneity value (e.g. Republics Saha, Tyva, Altai and Kalmykia, and Tomsk) suffer from severe climate that does not allow successful crop production, as well as a low level of railways density, indicating the underdevelopment of infrastructure across region and, therefore, bad connection with other regions and trading centres.

CONCLUSIONS

In this study, we extend the existing literature by evaluating the impact of regional diversity on production when farms in regions face different time-varying production technologies and time-invariant region-specific conditions. The consideration of heterogeneous regional impact essentially changes the traditional approach to stochastic frontier analysis, which implies that production is technically inefficient by default, and it is the technical inefficiency that does not allow farms to reach the frontier. Our study, on the contrary, assumes that production is defined by specific characteristics of regions that indicate the level of regional development and influence the implementation of production technology. The applied approach provides new insight into the analysis of agricultural production of the country, and allows for consistent estimation of production potential in general.

Using regional level data for Russia, we test the hypothesis that grain production in the country became efficient and entirely depends on production technology and regional conditions. We find evidence that climate in combination with the level of human and institutional development and infrastructure have significant effect on production structure of the region and therefore should not be neglected while assessing regional policies and production potential. Moreover, exploitation of production possibilities can potentially have a positive impact on transition process and lead to successful development of the region and its agriculture, thus, helping regional development to become a self-enforcing process.

REFERENCES

Alvarez, A., Arias, C., and Greene, W. (2003). Fixed Management and time invariant technical efficiency in a random coefficient model. *Working Paper*, Department of Economics, Stern School of Business, New York University.

Alvarez, A., Arias, C., and Greene, W. (2004). Accounting for unobservables in production models: management and inefficiency. Economic Working Papers at Centro de Estudios Andaluces E2004/72, Centro de Estudios Andaluces.

Arnade, C., and Gopinath, M. (2000). Financial constraints and output targets in Russian agricultural production. *Journal of International Development*, 12: 71–84.

Arnade, C., and Trueblood, M. A. (2002). Estimating a Profit Function in the Presence of Inefficiency : An Application to Russian Agriculture. *Journal of Agricultural and Resource Economics*, 27/1: 94–113.

Bokusheva, R., and Hockmann, H. (2006). Production risk and technical inefficiency in Russian agriculture. *European Review of Agricultural Economics*, 33/1: 93–118.

Bokusheva, R., Hockmann, H., and Kumbhakar, S. C. (2011). Dynamics of productivity and technical efficiency in Russian agriculture. *European Review of Agricultural Economics*, 39/4: 611–37.

Coelli, T., Rao, D. S. P., and Battese, G. E. (1998). *An Introduction to Efficiency and Productivity Analysis*. Boston, MA: Springer US.

Klugman, J., Rodríguez, F., and Choi, H.-J. (2011). The HDI 2010: new controversies, old critiques. *The Journal of Economic Inequality*, 9/2: 249–88.

Kumbhakar, S. C., and Lovell, Knox, C. A. (2000). *Stochastic Frontier Analysis*.

Morey, E. R. (1986). An Introduction to Checking , Testing , and Imposing Curvature Properties : The True Function and the Estimated Function. *The Canadian Journal of Economics*, 19/2: 207–35.

Osborne, S., and Trueblood, M. A. (2006). An examination of economic efficiency of Russian crop production in the reform period. *Agricultural Economics*, 34/1: 25–38.

Sedik, D., Trueblood, M. A., and Arnade, C. (1999). Corporate farm performance in Russia, 1991-1995: an efficiency analysis. *Journal of Comparative Economics*, 27: 514–33.

Sotnikov, S. (1998). Evaluating the effects of price and trade liberalisation on the technical efficiency of agricultural production in a transition economy : The case of Russia. *European Review of Agricultural Economics*, 25/3310: 412–31.

UNDP. (1990). *Human Development Report 1990*.

Voigt, P., and Hockmann, H. (2008). Russia’s transition process in the light of a rising economy : Economic trajectories in Russia's industry and agriculture. *The European Journal of Comparative Economics*, 5/2: 179–95.