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

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 the country's heterogeneity and diversity among regions. The results obtained indicate that climate conditions in combination with the level of human and institutional development, and infrastructure have significant effects on the production structure of regions and therefore should not be neglected while assessing regional policies and production potential.

Keywords: technical efficiency, stochastic frontier analysis, heterogeneity, production potential

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Introduction

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 growth rates of agricultural product exports, 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 the disparity of the 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 at a regional level (Arnade and Gopinath, 2000; Sedik *et al*., 1999; Sotnikov, 1998). These studies pay attention to changes in technical efficiency of Russian agricultural production during the years of transition. For instance, Sotnikov (1998) reported an increase in technical efficiency in the early 1990s, followed by a decline in efficiency scores in the period 1993-95. The author concluded that an increase in technical efficiency took place primarily due to the efficient use of inputs, together with significant technical changes, while a following decrease in efficiency resulted from state price controls and government subsidies. These results are in line with the findings of Sedik *et al*. (1999), who, in addition, explained the decreasing technical efficiency scores in the period 1993-95 by price changes for agricultural inputs as well as by subsidising the most inefficient farms. Furthermore, from their findings, the authors concluded the more specialised a region is in a particular crop, the more efficient is the production in this region, i.e. that specialisation leads to efficiency.

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

Based on regional level data, Osborne and Trueblood (2006) noted a decreasing pattern of technical and allocative efficiency scores in the period 1993-98. Voigt and Hockmann (2008) observed a considerable decrease in the original possibilities of production in this period, and indicated a positive development and restructuring of the sector only starting from 2003. In addition, the authors found evidence of different technologies of production across regions due to diversity of regional development. Bokusheva *et al*. (2011) found a decreasing trend in regional efficiency until 2000, followed by steady improvement afterwards. Based on calculations of total factor productivity, the authors found heterogeneity of the economic and institutional environment across the country. This is the crucial finding that has been outlined 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

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Russian agriculture and identify factors that determine the heterogeneity of the country and, thus, influence the productivity of the agricultural sector. We distinguish three indicators that could serve as proxies for factors that determine heterogeneous development of the country, namely: level of human development, level of infrastructural development, and climate and soil conditions.

This study is organised as follows. The next section describes the theoretical approach used in the research and gives a/the methodological concept of the model. Then we describe the data used and provide the empirical model. The results obtained are then presented, together with discussion and proofs regarding the validity of the model. The final section concludes the paper by presenting a brief review of the methodology and results obtained.

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 the heterogeneity of regions becomes the factor that could have a negative impact on the production of the country.

The current study assumes that production is defined by particular characteristics of regions. These characteristics indicate the level of regional development and influence the implementation of production technologies. Among such characteristics we can include the level of economic and social development; system of transport and infrastructure; and 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 Álvarez *et al*. (2003) and further developed by Álvarez *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 Knox Lovell, 2003) states that:

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

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

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

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

$$\begin{aligned}&\ln D^o\left(x,\frac{y_1}{y_1},\frac{y_2}{y_1},\ldots,\frac{y_N}{y_1}\right) = \ln\left(\frac{1}{y_1}D^o(x,y_1,y_2,\ldots,y_N)\right) = \\ &-\ln y_1 + \ln D^o(x,y)\end{aligned} \tag{3}$$

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

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

where y is the vector of agricultural outputs, x is the vector of production inputs, 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:

$$\begin{aligned}&\ln\ f(x,y_{it}^{opt}) = \beta_0 + \beta_t t + \beta_y \ln y_{it} + \beta_{yt} t \ln y_{it} + \beta_x \ln x_{it} + \\ &\beta_{xt} t \ln x_{it} + ½\beta_{yy} \ln y_{it} \ln y_{it} + ½\beta_{xx} \ln x_{it} \ln x_{it} + \\ &\beta_{yx} \ln y_{it} \ln x_{it} + (\alpha_0 + \alpha_t t + \alpha_x \ln x_{it})(y_0^{opt} + y_z^{opt} z) \\ &\forall i = 1,2,\ldots,N;\ t = 1,\ldots,T\end{aligned} \tag{5}$$

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} $(y_{it}^{act} \le y_{it}^{opt})$ is being produced with the technology described by the following production function:

$$\begin{aligned}&-\ln\ y_{it}^{act} = \beta_0 + \beta_t t + \beta_y \ln y_{it} + \beta_{yt} t \ln y_{it} + \beta_x \ln x_{it} + \\ &\beta_{xt} t \ln x_{it} + ½\beta_{yy} \ln y_{it} \ln y_{it} + ½\beta_{xx} \ln x_{it} \ln x_{it} + \\ &\beta_{yx} \ln y_{it} \ln x_{it} + (\alpha_0 + \alpha_t t + \alpha_x \ln x_{it})(y_0^{opt} + y_z^{opt} z) \\ &\forall i = 1,2,\ldots,N;\ t = 1,\ldots,T\end{aligned} \tag{6}$$

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

$$\begin{aligned}&\ln TE_{it} = -\ln y_{it}^{act} - \ln f(x,y_{it}^{opt}) = \\ &(\alpha_0 + \alpha_t t + \alpha_x \ln x_{it})(y_0^* + y_z^* z)\end{aligned} \tag{7}$$

where $y_0^* = y_0^{opt} - y_0^{act}$ and $y_z^* = y_z^{opt} - y_z^{act}$.

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

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

Table 1: Main characteristics of Russian regional production: agricultural inputs and outputs, 1995-2011.

Variable	Notation	Unit	Mean	SD	Min	Max	Growth rate, 1995-2011 (%)	Average annual growth rate (%)
Gross harvest of grain	y_1	1000 tonnes	11,649	16,247	57	116,344	50.9	2.45
Gross animal production	y_2	RUR million	5,738	4,531	158	29,389	1.1	0.06
Gross crop production (excluding grain)	y_3	RUR million	3,023	2,711	76	19,220	-22.8	-1.51
Labour	x_1	1000 workers	106	85	4	485	-20.4	-1.33
Land	x_2	1000 hectares	1,258	1,265	20	5,833	-24.3	-1.62
Capital	x_3	RUR billion	14,610	20,918	66	180,623	-68.3	-6.53
Variable inputs	x_4	RUR million	4,800	4,422	19	25,599	-41.9	-3.15

Source: Rosstat, own calculations

Table 2: Average indices by federal district of the determinants of heterogeneity in Russia.

Federal district	Climate index	Human development index	Transport 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: authors' calculations

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

$$\begin{aligned} -\ln y_{it}^{act} &= \beta_0 + \beta_t t + \beta_y \ln y_{it} + \beta_{yt} t \ln y_{it} + \beta_x \ln x_{it} + \\ &\beta_{xt} t \ln x_{it} + \tfrac{1}{2}\beta_{yy} \ln y_{it} \ln y_{it} + \tfrac{1}{2}\beta_{xx} \ln x_{it} \ln x_{it} + \\ &(\alpha_0 + \alpha_t t + \alpha_x \ln x_{it})(y_0^{opt} + y_z^{opt} z) - \\ &(\alpha_0 + \alpha_t t + \alpha_x \ln x_{it})(y_0^* + y_z^* z) \end{aligned} \tag{9}$$

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 intentionally to exclude several regions whose data caused validity concerns and therefore could have significantly distorted the estimation results. The data come from statistical publications of the Russian Federation Federal State Statistics Service (Rosstat) and cover the period 1995-2011. 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 in the majority of regions the dominant type of farm is the large cooperative (or agroholding), production tends to be combined in order for a farm to maintain self-sufficiency.

The group of variables used in the analysis consists of output and input vectors. The 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 firstly define factors that could determine the degree of a region's development, its social and economic environment, and its climate. For this purpose we used three indices:

- 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 *et al.* (2011). It is calculated as a geometric mean of three normalised indicators of achievements of populations: life expectancy at birth, gross regional income per person and number of children enrolled in school each year[1].
- As a proxy for transport system we used a normalised index of the density of railways in each region (z_3). This is not a perfect indicator of transport 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 combined serve as an aid in determining the level of differences across regions within Russia. Table 2 shows the distribution of average indices' values across federal districts[2] and Figure 1 illustrates the share of agricultural

[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.

Figure 1: Agricultural production in Russia, share of agricultural production in gross regional product, 2011.
Source: Rosstat, authors' interpretation

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) on average tend to have better conditions for agriculture than those located beyond the Ural Mountains. Moreover, federal districts with high density of railways are those located in the European part of the country, where the density of the population is high as well. The highest level of human development occurs in regions located in the Ural federal district that connects the Asian and European parts of Russia and is considered to be the main mining district in the country.

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

$$-\ln y_{1it}^{act} = \beta_0 + \beta_t t + \beta_y \ln y_{it} + \beta_{yt} t \ln y_{it} + \beta_x \ln x_{it} + \beta_{xt} t \ln x_{it} + \tfrac{1}{2}\beta_{yy} \ln y_{it} \ln y_{it} + \tfrac{1}{2}\beta_{xx} \ln x_{it} \ln x_{it} + (\alpha_0 + \alpha_t t + \alpha_x \ln x)(y_0^{opt} + y_z^{opt} z) - u_{it} + v_{it} \tag{10}$$

where y_{1it}^{act} is the actual gross production of grain, $y_{it} = (y_{2it}, y_{3it})$, with y_{2it} being the gross animal production and y_{3it} the gross production of other crops. We define the vector of inputs as $x_{it} = (x_{1it}, x_{2it}, x_{3it}, x_{4it})$, where x_{1it} is the labour input, x_{2it} is the land input, and 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 $z = (z_1, z_2, z_3)$, with z_1 denoting the climate index, z_2 the index of human development, and z_3 the index of infrastructure and transport. The usual two-sided error term is denoted as v_{it}, while u_{it} is defined as the negative of $\ln TE_{it}$ (see equation 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

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, owing 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 consists 50 per cent of animal output, 22 per cent of production of other crops and 28 per cent of grain production. According to the official statistical data, on average, animal production accounts for 51 per cent of total agricultural production, with grain production contributing 28 per cent and production of other crops 21 per cent, 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 per cent, 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.

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. 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.

Table 3: Constrained maximum likelihood parameter estimates of the stochastic cost frontier.

Parameter	Estimate	Standard error	t-ratio
β_o	0.026	0.010	2.680
Technical change			
β_t	-0.032	0.003	-10.376
β_{tt}	0.012	0.000	28.164
Output effects			
β_{y_2}	0.500	0.016	30.401
β_{y_3}	0.220	0.008	27.071
β_{y_2t}	-0.020	0.004	-4.906
β_{y_3t}	0.015	0.004	4.189
$\beta_{y_2y_2}$	0.476	0.048	9.939
$\beta_{y_3y_3}$	0.255	0.007	33.767
$\beta_{y_2y_3}$	-0.173	0.018	-9.628
Input effects			
β_{x_1}	-0.164	0.015	-10.893
β_{x_2}	-0.210	0.015	-13.889
β_{x_3}	-0.129	0.018	-7.349
β_{x_4}	-0.402	0.021	-18.812
β_{x_1t}	-0.005	0.003	-1.644
β_{x_2t}	0.007	0.004	1.996
β_{x_3t}	0.003	0.002	1.503
β_{x_4t}	-0.003	0.001	-1.754
$\beta_{x_1x_1}$	-0.084	0.056	-1.497
$\beta_{x_2x_2}$	0.058	0.021	2.700
$\beta_{x_3x_3}$	0.004	0.018	0.248
$\beta_{x_4x_4}$	-0.136	0.028	-4.770
$\beta_{x_1x_2}$	0.042	0.029	1.454
$\beta_{x_1x_3}$	-0.025	0.015	-1.675
$\beta_{x_1x_4}$	0.037	0.034	1.071
$\beta_{x_2x_3}$	-0.021	0.024	-0.864
$\beta_{x_2x_4}$	-0.007	0.007	-1.032
$\beta_{x_3x_4}$	0.034	0.033	1.028
Output-input effects			
$\beta_{y_2x_1}$	-0.023	0.031	-0.734
$\beta_{y_2x_2}$	0.238	0.030	7.979
$\beta_{y_2x_3}$	-0.063	0.023	-2.724
$\beta_{y_2x_4}$	-0.176	0.023	-7.586
$\beta_{y_3x_1}$	-0.034	0.021	-1.635
$\beta_{y_3x_2}$	0.033	0.019	1.749
$\beta_{y_3x_3}$	-0.016	0.020	-0.819
$\beta_{y_3x_4}$	0.101	0.022	4.558

Source: authors' calculations

Our estimates indicate that returns to scale at the regional level are lower than one. Given the dominance of agroholdings and large farms in the Russian market this result is quite astonishing. Often it is argued that a Russian farm can benefit from its enormous size and realise its potential for cost reductions. However, the cost reduction does not result in extraordinary increase in production. In addition, the reduction in costs due to economies of scale and an increase in production is most likely to be compensated by additional transaction and transport expenses. Estimation results, presented in Table 3, support our view. Firstly, decreasing economies of scale are consistent with reductions in sown areas: according to Rosstat data, during the analysed period the planted area fell by 30 per cent on average. Taking into account the fact that the number of farms did not change significantly over the period 1995-2011, the average farm size has declined. This development was accompanied by intensive technical progress (3 per cent annually). 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. In principle, these changes in technologies cannot be separated and require a minimum farm size to operate profitably. This suggests that size itself does not necessarily result in positive economies of scale, but it might foster technical progress. Such a strategy is more efficient than concentrating on an increase of purely technical economies of scale. Similarly, technical change is land-intensive, proving the statement that production has increased due to increase in yields rather than increase in land farmed. Overall, the impact of technical change on agricultural production is increasing at a rate of 3.1 per cent annually with a decelerating rate of technology development.

The initial model assumption implies that production in the country is primarily determined by the specific characteristics of each particular region. We measure these characteristics by means of the 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).

The effect of climate was expected to be high since Russia is the biggest country in the world with many climatic zones, and the influence of climate on agriculture is of great impor-

Table 4: Technology and heterogeneity parameter estimates.

Parameter	Estimate	Standard error	t-ratio
Technology			
α_m	0.225	0.018	12.661
α_{mt}	0.137	0.015	9.166
α_{m1}	0.053	0.040	1.333
α_{m2}	-0.002	0.006	-0.283
α_{m3}	-0.034	0.033	-1.022
α_{m4}	-0.032	0.021	-1.493
Heterogeneity			
γ_0	0.013	0.024	0.545
γ_1	0.284	0.061	4.685
γ_2	0.298	0.049	6.105
γ_3	0.196	0.043	4.543
σ_v	0.217	0.004	53.088
σ_u	0.102	0.152	0.670

Source: authors' calculations

tance, especially for 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. These results indicate that the higher is the level of region's development, the more investment is attracted to the region, and the better the skills workers and farm managers have, the higher will therefore be the level of production. The indicator of transport 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 the 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.

Heterogeneity effects play a notable part in determining the production potential: the higher is the value of heterogeneity indicator, the higher is the positive impact of heterogeneity indicators on technology implementation and production efficiency (Figure 2). The level of influence of the heterogeneity indicators on production decreased in the period 1995-2001. Such a decrease can be explained by an overall decrease of actual agricultural production, caused by economic instability and the transition to a market economy.

Figure 3 provides an overview of heterogeneity indicator values across Russia. We assume that characteristics of

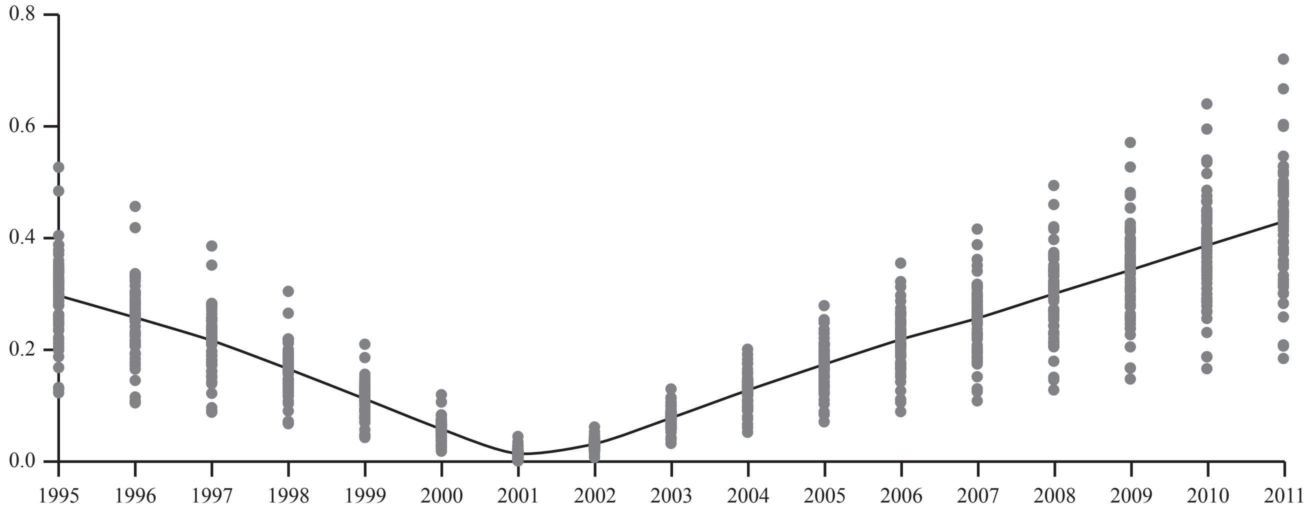

Figure 2: Estimated influence of heterogeneity effect on agricultural production levels (1995-2011).
Source: authors' calculations

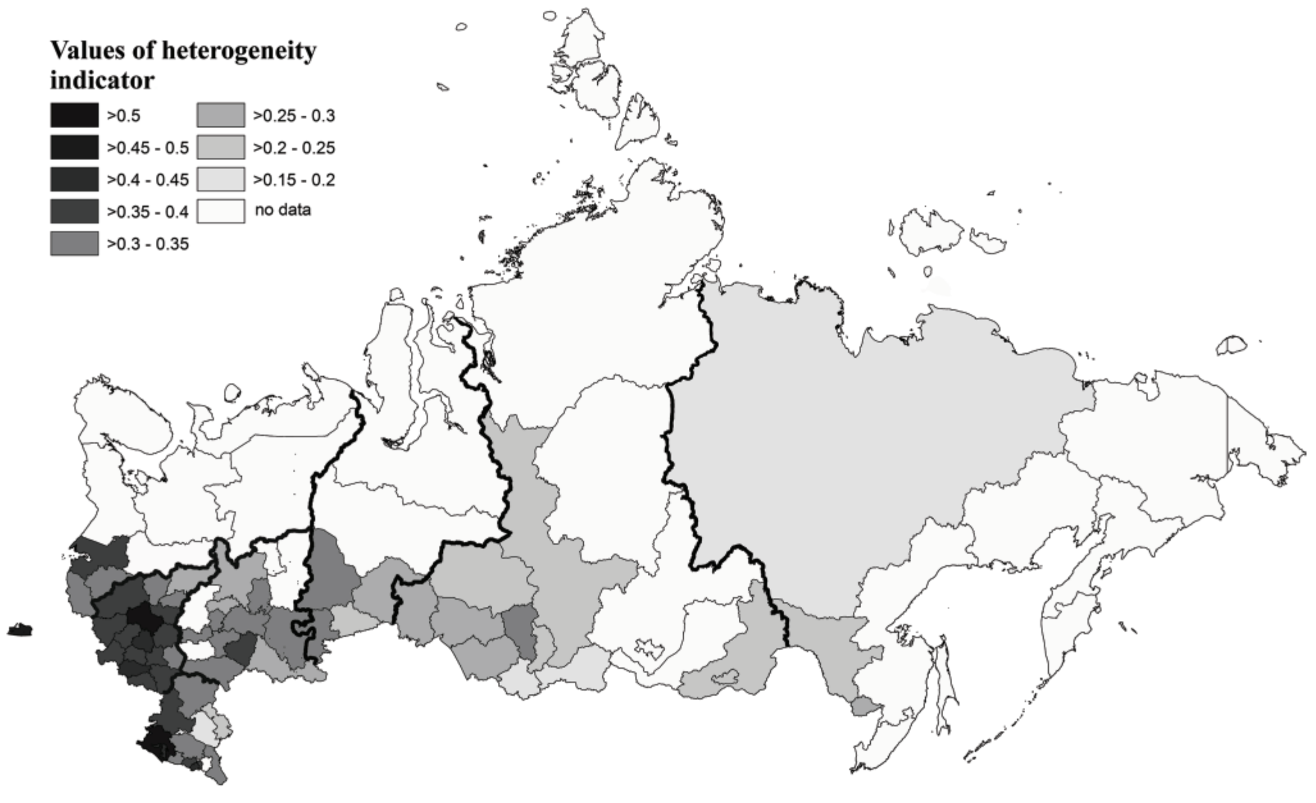

Figure 3: Values of heterogeneity indicators in Russian regions (average 1995-2011).
Source: authors' calculations

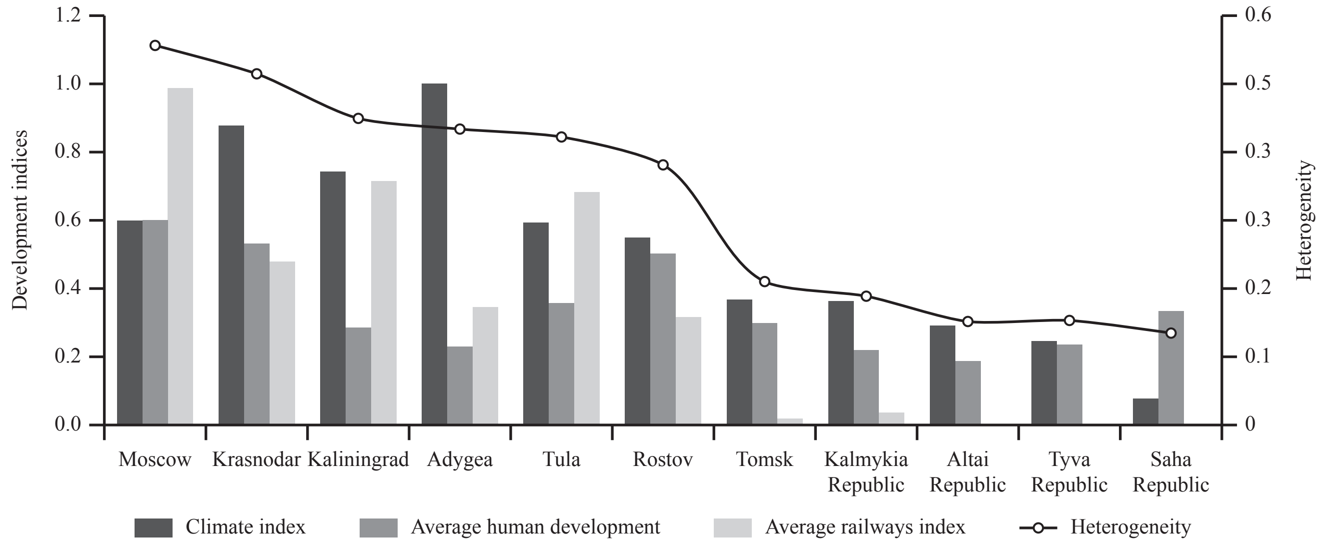

Figure 4: Comparison of heterogeneity levels in selected regions (average 1995-2011).

Source: authors' calculations

environment and social and infrastructural development did not change significantly over the observed period. Therefore, heterogeneity values can be interpreted as indicators of the diversity of each region, average for the observed period. Conditions for agricultural production are 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 4 shows the heterogeneity indicator for selected regions (with favourable and unfavourable conditions for agricultural production). A high indicator of heterogeneity implies that conditions in a region are better suited for agricultural production than they are in regions with a low value of heterogeneity. At first glance, Moscow region is the one with the highest production possibilities among all regions. However, such a suggestion is ambiguous upon examination of the determinants of such a high indicator: the highest density of roads provides the most favourable conditions for transport and trade of grain, but relatively low climate index suggests that Moscow may not be the best suited for agricultural (especially crop) production. Krasnodar region, on the contrary, has favourable climate conditions, a higher than average value of human development index and well-developed infrastructure, which makes it the most attractive region 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. the Saha, Tyva, Altai and Kalmykia Republics, and Tomsk) suffer from a severe climate that does not allow successful crop production, as well as a low density of railways, indicating the underdevelopment of infrastructure across the region and, therefore, poor connections with other regions and trading centres.

Conclusions

In this study, we extend the existing literature by evaluating the impact of regional diversity on agricultural 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 paper, 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 a 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 has become efficient and entirely depends on production technology and regional conditions. We find evidence that climate in combination with the levels of human and institutional development and infrastructure has a significant effect on the production structure of the region and therefore should not be neglected while assessing regional policies and production potential. Moreover, exploitation of production possibilities potentially can have a positive impact on the transition process and lead to successful development of the region and its agriculture, thus helping regional development to become a self-enforcing process.

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