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# HOW LARGE IS THE MARGINAL PRODUCT OF LAND IN THE MOSCOW REGION?

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## ABSTRACT

The marginal product of arable land and grassland is estimated by a shadow price parameterization. The shadow prices are obtained from multiple runs of a linear programming model of the Moscow region land market that randomly uses varying crop yields. The marginal product of land approximates the possible price of agricultural land from 2001-2003 under the assumption of a properly functioning land market. In 2003, this value (for arable land) varied from 290 to 1,309 roubles, depending on distance from Moscow and soil fertility. Higher crop yields negatively influence the marginal land product values. There is a declining trend of these values during the studied period, which impedes emerging market institutions.

***Keywords:*** *Agricultural land, marginal product, land value, transitional economies, parameterization, Moscow region.*

## 1 INTRODUCTION

The agricultural land market in Russia, and specifically in the Moscow region, is still underdeveloped, although most of the juridical pre-conditions for its normal operation have already been formed. This can be explained by the low marginal product of land and high land transaction costs. Because of the limited number of transactions, land prices and land rent vary greatly and only weakly relate to the true marginal product of agricultural land. To address these problems, the true marginal land product has to be determined. It is also useful to inform land market agents for taxation purposes and project analysis.

The aim of this paper is to determine the marginal product value of arable land and grassland in the Moscow region. The research questions are defined as follows:

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a) What is the most applicable methodology for approaching the marginal product value of agricultural land given the Moscow region's current situation?

b) How large is this marginal product and how is it affected by current economic reforms?

c) What are the policy implications of the discovered changes in the marginal product of land?

Moreover, we test the following three hypotheses in this study:

a) The marginal product of land increases during the second stage of economic reforms in the agricultural sector (from 2001-2003).

There are three reasons for this hypothesis. The first is increasing agricultural production in Russia and, particularly, in the Moscow region, both gross and per unit of land. The second reason is the relative stabilization of farming's institutional environment. The third is that developing the agro-industrial complex was declared a national priority by the President of the Russian Federation. Because of this, the investment climate in Russian agriculture is expected to turn for the better, forming favorable conditions for the growing agricultural land marginal product.

b) The marginal product of land positively depends on proximity to Moscow city.

In developed markets, the closer a plot of land is to a major food market and industrial center, the higher its agricultural land prices will be. A similar situation is likely with land marginal product in an underdeveloped land market which is the result of non-market land allocation processes.

c) Given the fixed capacity of the agricultural product market, increasing crop yields causes land marginal product to decline.

Assuming that sales cannot be increased (which implies price-making behavior of market actors) and agricultural land cannot be used for non-agricultural purposes, a global increase of yields releases a portion of land from intensive production. It is likely that the latter causes the reduction of land marginal product and, consequently, devaluates the property. This can be applicable to the situation in the Moscow region.

A review of the current state of agricultural land price studies can be found in TRIVELLI (1997). A great deal of international experience with modeling land markets (e.g. LLOYD, RAYNER and ORME, 1991) is scarcely applicable for answering the research questions of our study; this is due to a lack of data on actual land transactions.

The estimates of land shadow prices based on common micro-economic approaches can often be found in publications that are not specifically aimed at land marginal product analyses (see e.g. BOOTS, 1997; OSBORNE and TRUEBLOOD, 2002;

BEZLEPKINA, OUDE LANSINK and OSKAM, 2005). The marginal product of land is commonly found – following the basic theory presented in CHAMBERS (1988) – by estimating either a production function or a profit function for agricultural farms.

Useful experience in valuing agricultural land in the absence of a land market has been gained by the Soviet school of agricultural economics, which includes two streams. The first, founded by V. Dokuchaev in the 19th century, determined chemical, mechanical, biologic and geographical factors of soil fertility and measured their contribution to land value. For this purpose, simple statistical tools such as analytical grouping and linear regressions of net farm income were used (TYAPKIN, 1987). This stream emphasized the importance of eliminating differences in the economic conditions of land use. These studies are mostly applicable to the problems of cadastral valuation.

The second stream of the Soviet school focused on measuring land marginal product in actual economic conditions. This approach is particularly relevant to agricultural land market studies, and is characterized by the presence of a model of agricultural land's marginal product. The models differ with respect to specific research tasks and available data (e.g. BOBYLEV, 1987; BELENKIY, 2003) and sometimes such models are accompanied with land market simulations in partial equilibrium models (GATAULIN and SVETLOV, 1995).

In the case of the Moscow region, production or profit functions analyses are hindered by the heterogeneity of farm data. Attempts to compile the homogeneous sets of farms result in the large variation of estimates of land marginal product due to the loss of representativeness.

Partial equilibrium models are more practical, but labor-intensive to implement and very sensitive to missing data. Moreover, in the case of transitional economies, farm data is not sufficient to derive land supply and demand functions in the vicinity of equilibrium.

All this justifies the choice of a linear program as the most suitable research tool for this study. KANTOROVICH's (1965) idea of obtaining land rental values directly from a mathematical program meets a reasonable criticism (e.g. DANILOV-DANILYAN, 2004): The mathematical program for agricultural land use displays land shadow prices' great sensitivity to small changes in those parameters, which in principle cannot be precisely defined. As a consequence, the opinion has prevailed among economists that this type of model is not applicable to land value applications.

It is noticeable that the large variability of resources' marginal value is their inherent feature rather than a distortion caused by the mathematical programming methodology. Decision-makers acting on real land markets face uncertainty and fickleness in land marginal product to the same extent as an economist working with a mathematical programming model does.

The practice of real decision-making provides the idea of dampening this problem. The factors of land marginal product variation can be split into unidentifiable noise and factors that can be explicated. For this purpose, we engage the parameterization of agricultural land shadow prices obtained from 6,000 tests. For testing, we vary (at random) the productivity of the most important crops in the linear program to simulate agricultural land allocation in the Moscow region.

## 2 THEORETICAL FRAMEWORK

This study originates with the neo-classical representation of a price-taking firm $n$ acting in a competitive environment:

$$\max(\mathbf{w}\mathbf{y}_n - \mathbf{v}\mathbf{x}_n \mid \mathbf{y}_n = \mathbf{f}_n(\mathbf{x}_n,\mathbf{z}_n),\ \mathbf{z}_n \le \mathbf{b}_n), \tag{1}$$

where $\mathbf{x}_n$, $\mathbf{y}_n$, $\mathbf{z}_n$ are non-negative vectors of variable inputs, outputs and fixed inputs, respectively; $\mathbf{v}$ is a constant non-negative vector of prices of variable inputs; $\mathbf{w}$ is a constant non-negative vector of output prices; $\mathbf{b}_n$ is a constant non-negative vector of amounts of freely-disposable fixed inputs; $\mathbf{f}_n(\cdot)$ is a production function.

In this specification, a firm-specific net marginal product of a resource is equal to the Lagrangean multiplier of the corresponding inequality $\mathbf{z}_n \le \mathbf{b}_n$.

*Assumption 1.* Instead of classical fixed inputs, there exist semi-fixed inputs that are marketable within a region but cannot be traded outside it.

*Assumption 2.* The firms are price-makers with respect to semi-fixed inputs.

*Assumption 3.* Transaction costs at the regional market of semi-fixed inputs are negligible.

These assumptions aim to represent a regional land market. Thinking of agricultural land as a semi-fixed input and the price-making assumption stems directly from the research question (b): We have to develop a framework that can address this question. Nearly zero transaction costs are assumed because we are interested in the analysis of the land market when transaction costs are reasonably low and virtually do not affect decisions. The situation under actual (high) transaction costs does not call for modeling, as it can be observed directly.

Given the assumptions 1-3 and introducing set $N$ of firms in the region such that $n \in N$, it can be derived from (1) that the totality of the firms belonging to the set $N$ reaches the state

$$\max(\mathbf{w}\mathbf{y} - \mathbf{v}\mathbf{x} \mid \mathbf{y} = \Sigma_{n\in N}\,\mathbf{y}_n,\ \mathbf{x} = \Sigma_{n\in N}\,\mathbf{x}_n,\ \ \mathbf{y}_n = \mathbf{f}_n(\mathbf{x}_n,\mathbf{z}_n),\ \Sigma_{n\in N}\,\mathbf{z}_n \le \Sigma_{n\in N}\,\mathbf{b}_n). \tag{2}$$

In this specification, the regional value of the marginal product of a specific kind of land is equal to the Lagrangean multiplier associated with the inequality that represents the corresponding quasi-fixed input. All consequent specifications and generalizations of (2) inherit this property.

*Assumption 4.* All firms in $N$ have the same production function $\mathbf{f}(\cdot)$.

This assumption is quite restrictive with respect to the actual situation in the Moscow region. However, it is determined by two reasons: The excess complexity of the empirical model otherwise and robustness considerations.

*Assumption 5.* There exists a set $Q$ of classes of semi-fixed inputs that are mutually-exclusive at the firm level.

This way we allow for differences in soil fertility and in plot location. Land plots that differ in at least one of these two factors are treated as different resources that cannot be jointly available to the same farm.

With the imposed assumptions 4 and 5 we can rewrite (2) as:

$$\max(\mathbf{wy} - \mathbf{vx} \mid \mathbf{y} = \Sigma_{n\in N}\, \mathbf{y}_n,\ \mathbf{x} = \Sigma_{n\in N}\, \mathbf{x}_n,\ \ \mathbf{y}_n = \mathbf{f}(\mathbf{x}_n,\mathbf{z}_n),\\ \forall q\ \Sigma_{n\in N(q)}\, \mathbf{z}_n \le \Sigma_{n\in N(q)}\, \mathbf{b}_n), \tag{3}$$

where $q \in Q$ and $N(q)$ is a class of firms belonging to $N$ that use the resources from class $q$.

*Assumption 6.* Firms are long-term profit maximizers.

This assumption transforms (3) into the following problem:

$$\max(\mathbf{wy} - (\mathbf{v}+\mathbf{d})\mathbf{x} \mid \mathbf{y} = \Sigma_{n\in N}\, \mathbf{y}_n,\ \mathbf{x} = \Sigma_{n\in N}\, \mathbf{x}_n,\\ \mathbf{y}_n = \mathbf{f}(\mathbf{x}_n,\mathbf{z}_n),\ \forall q\ \Sigma_{n\in N(q)}\, \mathbf{z}_n \le \Sigma_{n\in N(q)}\, \mathbf{b}_n), \tag{4}$$

where $\mathbf{d}$ is a non-negative constant vector of incremental capital recovery costs per unit of an input.

This assumption attempts to capture the actual decision-making process on the land market, where the bargains have long-term consequences and are thus expected to be justified by long-term utility.

*Assumption 7.* The firms' decision-making processes are subject to the constraints of the economic environment.

The corresponding generalization of (4) is the following:

$$\max(\mathbf{wy} - (\mathbf{v}+\mathbf{d})\mathbf{x} \mid \mathbf{y} = \Sigma_{n\in N}\, \mathbf{y}_n,\ \mathbf{x} = \Sigma_{n\in N}\, \mathbf{x}_n,\ \mathbf{y}_n = \mathbf{f}(\mathbf{x}_n,\mathbf{z}_n),\\ \forall q\ \Sigma_{n\in N(q)}\, \mathbf{z}_n \le \Sigma_{n\in N(q)}\, \mathbf{b}_n,\ \mathbf{y}_{\min} \le \mathbf{y} \le \mathbf{y}_{\max}), \tag{5}$$

where $\mathbf{y}_{\max}$ is a non-negative vector of satiation levels of exogenous demand and $\mathbf{y}_{\min}$ is a non-negative vector of the lower boundary of outputs. The purpose of vector $\mathbf{y}_{\min}$ is to reflect long-term intents, expectations about the future, etc., that can neither be identified precisely nor, consequently, explicitly expressed by a specification of the utility function. Any component of both $\mathbf{y}_{\max}$ and $\mathbf{y}_{\min}$ can be infinitely large.

## 3 EMPIRICAL MODEL

In the empirical model the production function $\mathbf{f}(\cdot)$ is assumed to be linear. This results in a linear programming specification of (5) and facilitates the determination of values of Lagrangean multipliers from the solution of a dual linear program.

Although restrictive, the linear specification is predetermined by the scarcity of available data, which does not permit the derivation of a true form of production functions. Modeling under the linearity assumption requires controlling for the closeness of linear dependencies in the vicinity of an optimum to tangents to actual production functions, using both formal and informal analytical procedures.

In our model the technologies are assumed to have a neutral return to scale. To derive $\mathbf{f}(\cdot)$, we use average consumption of resources throughout $N(q)$ in all production processes reflected by the available data, both empirical and technical. In comparison to farm data envelopment, this approach allows for optimal inter-farm resource allocation when changing land usage. Another important advantage is a maintainable size of the linear program matrix.

The detailed representation of the agricultural production technologies is not presented here due to space limits. It can be found in IL'INA and SVETLOV (2004).

The empirical model considers the following commodities:

a) Quasi-fixed input groups: Arable land; grassland[1].

For each group, nine mutually exclusive types of quasi-fixed inputs are defined, differing in distance from the major Moscow city market (three grades), and in soil fertility (also three grades). The grades in distance and fertility are chosen to roughly minimize the differences in agricultural land area between subsets of farms using a particular type of quasi-fixed inputs. Below we refer to these subsets as *q-groups*, following the notation of (3).

b) Outputs: Grain; potatoes; vegetables; milk; beef; pork.

c) Intermediate products in crop production: Grain for fodder; hay from permanent grasses grown in arable lands; haylage; corn silage; grass silage; grass from annual grasses; grass from permanent grasses grown in arable lands; roots for fodder; hay from haylands; gramma grass.

d) Intermediate products in animal production: Milk for fodder; milking cows; sows.

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[1] The reservation is made in the model-supporting software for three more resource groups representing labour, stalls for cattle and pigpens. However, the specification used in this study does not consider these quasi-fixed inputs: Because of the previous recession of agricultural production, they are abundant.

Vector $\mathbf{y}_{\min}$ includes finite components for all six outputs. Vector $\mathbf{y}_{\max}$ has two finite components: For potatoes and for vegetables.

The above-formulated problem was solved 6,000 times (2,000 times for each year from 2001-2003) varying the normalized (mean = 1) yields per unit of land.

For each of the 6,000 tests, these parameters are chosen separately and at random for four crops: Cereals, potatoes, vegetables and all other crops (i.e., fodder crops).

The random values are chosen from the interval between 0.7 and 1.3 assuming uniform distribution. The corresponding crop yields per hectare are calculated and placed into the matrix of the linear program, then the model is solved with Sunset software XA and the solution is saved for further statistical processing.

Some of the tests (929 in 2001, 608 in 2002 and 473 in 2003) resulted in unfeasible solutions and were excluded from the analysis. For all feasible solutions, common logarithms of shadow prices of arable land and of grassland were subjected to both linear and quadratic parameterization using the normalized incremental yields per unit of land as exogenous variables.

## 4 DATA

Four sources of data were used: Annual data from the Moscow region corporate farms registry for the period 1998-2003, provided by Rosstat[2]; soil rates of the Moscow region corporate farms provided by the department of Statistics of Moscow Timiryazev agricultural academy; maps of the Moscow region as a source of data on distances between farms and Moscow; data on animal rations (KALASHNIKOV et al., 1995).

The annual data of the Moscow region corporate farms registry include more than 200 variables for each of more than 300 corporate farms, of which the following categories were used:

a) Gross annual sales of each product (in kind);
b) Annual revenues from sales of each product (in thousand roubles);
c) Gross annual intermediate production (in kind);
d) Production costs of annual outputs and annual intermediate production, including depreciation costs as a proxy for **d** in equation (4) (in thousand roubles);
e) Numbers of milk cows, fattening herd and sows (annual average);
f) Sown area per crop (hectares);
g) Arable land and grassland areas as of November 1 (hectares).

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[2] Rosstat (former Goskomstat) is a federal statistical agency of the Russian Federation.

These data are used for calculating parameters of the linear program. We use a four-year period prior to the year of estimation to smooth the randomness of crop yields. Additionally, data on annual depreciation accrued in agricultural production and annual average number of workers in agricultural production are used when calculating crop yields per hectare to be used as parameters of the linear program. This data enables smoothening (by means of linear regression) the differences in intensity between the farms in different $q$-groups. The reason for this procedure is to capture the impact of given distance from Moscow and soil fertility. Otherwise, the results would also depend on specific intensity in terms of labor and fixed assets consumption.

The finite components of $\mathbf{y}_{\min}$ ($\mathbf{y}_{\max}$) are set to the lowest (highest) of the corresponding values throughout the available annual data.

## 5 RESULTS

The estimated linear functions of the common logarithm of the land marginal product are presented in Table 1. The values of $F$ indicate that the confidence in the parameterization model is very high, with the influence of fodder crop yields on the land marginal product being the greatest. As the majority of crops in terms of land share are fodder, this conforms our expectations. The second most influential crop is cereals.

It is noticeable that higher crop productivity (excluding potatoes) is associated with lower land marginal product. This supports hypothesis (c). In the case of higher crop yields, the market for relatively profitable production is satiated while smaller land area is used. The empirical model suggests that land released from meat production is used for more efficient vegetable production. Such land reallocation takes place until vegetable production reaches the limit of market capacity, which is caused by lacks of both market infrastructure and payable demand. The situation with potatoes is similar. A further increase of crop productivity expands less profitable activities (specifically, cereals and milk production) which negatively affects the land marginal product.

In the majority of cases, the parameters of functions in Table 1 vary from one $q$-group to another within their confidence intervals. The significant differences are mostly observed between the parameters relating to the fodder crop yields. This gives weak evidence in support of the research hypothesis (b). Wholesale prices, herd productivity and other factors varying throughout the groups, excluding crop yields per unit of area, appear to have insignificant influence on the agricultural land marginal product.

**Table 1: Common logarithm of marginal agricultural land product in the Moscow region, 2003 (thousand roubles per hectare) as a linear function of crop productivity**

| Distance from Moscow | Rate of soil fertility* | Type | Land marginal product function | $R^2$ | $F$ |
|---|---|---|---|---|---|
| <60 km | 110 and above | A | $\mathbf{5.75}-\mathbf{0.85}x_1+\mathbf{0.14}x_2-\mathbf{0.10}x_3-\mathbf{1.59}x_4$ | 0.443 | 304.4 |
| | | G | $\mathbf{4.55}-\mathbf{0.70}x_1+\mathbf{0.13}x_2-\mathbf{0.09}x_3-\mathbf{1.21}x_4$ | 0.420 | 277.7 |
| | 90…110 | A | $\mathbf{5.79}-\mathbf{0.89}x_1+\mathbf{0.15}x_2-\mathbf{0.10}x_3-\mathbf{1.65}x_4$ | 0.429 | 287.9 |
| | | G | $\mathbf{4.84}-\mathbf{0.79}x_1+\mathbf{0.14}x_2-\mathbf{0.09}x_3-\mathbf{1.44}x_4$ | 0.451 | 314.1 |
| | less than 90 | A | $\mathbf{6.01}-\mathbf{0.98}x_1+\mathbf{0.19}x_2-0.13x_3-\mathbf{2.00}x_4$ | 0.366 | 221.1 |
| | | G | $\mathbf{5.45}-\mathbf{1.15}x_1+\mathbf{0.20}x_2-\mathbf{0.14}x_3-\mathbf{2.19}x_4$ | 0.474 | 345.0 |
| 60…110 km | 110 and above | A | $\mathbf{5.90}-\mathbf{0.93}x_1+\mathbf{0.15}x_2-\mathbf{0.11}x_3-\mathbf{1.72}x_4$ | 0.432 | 291.7 |
| | | G | $\mathbf{4.59}-\mathbf{0.71}x_1+\mathbf{0.13}x_2-\mathbf{0.09}x_3-\mathbf{1.27}x_4$ | 0.435 | 296.5 |
| | 90…110 | A | $\mathbf{5.89}-\mathbf{0.93}x_1+\mathbf{0.15}x_2-\mathbf{0.11}x_3-\mathbf{1.75}x_4$ | 0.426 | 283.7 |
| | | G | $\mathbf{4.87}-\mathbf{0.81}x_1+\mathbf{0.15}x_2-\mathbf{0.10}x_3-\mathbf{1.48}x_4$ | 0.455 | 319.9 |
| | less than 90 | A | $\mathbf{6.13}-\mathbf{0.98}x_1+\mathbf{0.21}x_2-0.15x_3-\mathbf{2.20}x_4$ | 0.332 | 190.3 |
| | | G | $\mathbf{5.38}-\mathbf{1.12}x_1+\mathbf{0.21}x_2-\mathbf{0.14}x_3-\mathbf{2.19}x_4$ | 0.464 | 331.8 |
| >110 km | 110 and above | A | $\mathbf{5.08}-\mathbf{1.00}x_1+\mathbf{0.16}x_2-\mathbf{0.12}x_3-\mathbf{1.90}x_4$ | 0.421 | 278.2 |
| | | G | $\mathbf{4.66}-\mathbf{0.74}x_1+\mathbf{0.14}x_2-\mathbf{0.09}x_3-\mathbf{1.33}x_4$ | 0.445 | 307.5 |
| | 90…110 | A | $\mathbf{6.03}-\mathbf{0.98}x_1+\mathbf{0.17}x_2-\mathbf{0.12}x_3-\mathbf{1.89}x_4$ | 0.417 | 274.1 |
| | | G | $\mathbf{4.88}-\mathbf{0.81}x_1+\mathbf{0.15}x_2-\mathbf{0.10}x_3-\mathbf{1.50}x_4$ | 0.458 | 323.3 |
| | less than 90 | A | $\mathbf{6.14}-\mathbf{0.88}x_1+\mathbf{0.25}x_2-0.19x_3-\mathbf{2.45}x_4$ | 0.261 | 135.9 |
| | | G | $\mathbf{5.36}-\mathbf{1.12}x_1+\mathbf{0.21}x_2-\mathbf{0.14}x_3-\mathbf{2.19}x_4$ | 0.450 | 326.0 |

Source: Authors' calculations.

Notes: [*] The average fertility rate of agricultural land in the Moscow region (weighted with areas) is 100.

Symbol ‘A’ denotes arable land, ‘G’ – grassland.

The variable x denotes normalized yields per hectare (average yield for a group is 1) for cereals, potatoes, vegetables and fodder, respectively. The parameters of land marginal product functions presented in bold are significant at $\alpha = 0.05$.

The fitted quadratic functions are characterized with $R^2$ within 0.642…0.823 for arable land and within 0.792…0.860 for grassland. Corresponding $F$ values are within 196.9…507.0 and 416.0…671.7, indicating very high confidence in the regression. For 2003, the estimated quadratic function of the common logarithm of the arable land marginal product (the case of medium distance and fertility) is

$$\mathbf{31.31}-\mathbf{22.15}x_1+\mathbf{2.08}x_2+0.29x_3-\mathbf{31.81}x_4+\mathbf{5.54}x_1^2-\mathbf{0.67}x_1x_2-0.02x_1x_3+\mathbf{9.73}x_1x_4-$$
$$-0.30x_2^2-0.01x_2x_3-\mathbf{0.63}x_2x_4+0.05x_3^2-0.17x_3x_4+\mathbf{9.83}x_4^2 \text{ (thousand roubles)}$$

and the common logarithm of the grassland marginal product (the same case) is

$$\mathbf{25.48}-\mathbf{17.42}x_1+\mathbf{1.48}x_2-0.02x_3-\mathbf{25.95}x_4+\mathbf{4.17}x_1^2-\mathbf{0.62}x_1x_2+0.15x_1x_3+\mathbf{7.85}x_1x_4+$$
$$+0.05x_2^2+0.06x^2x^3-\mathbf{0.84}x_2x_4-0.12x_3^2+0.03x_3x_4+\mathbf{8.12}x_4^2 \text{ (thousand roubles).}$$

For both functions, the significant estimates are typed in bold. The negative dependence of land marginal product on crop yields remains unchanged: The elasticities of the arable land marginal product on the variables are -4.67, 0.39, 0.44 and -7.41. The positive elasticities are not significant at $\alpha = 0.05$.

Table 2 presents the arable land marginal product values estimated by both parameterization approaches in comparison to the corresponding shadow prices obtained directly from the linear program in the case of mean yields. For one of the *q*-groups, the shadow price does not fit into the 95 % confidence interval of the estimate by the quadratic parameterization.

Since the quadratic form provides a narrower confidence interval and higher $F$ and $R^2$ compared to the linear form, the values obtained from the former are more trustworthy.

**Table 2: Arable land marginal product in 2003 at average crop productivity level, roubles per hectare**

| **Distance from Moscow** | **Rate of soil fertility*** | **By linear parametrization** | | | **By quadratic parametrization** | | | **By linear program** |
|---|---|---|---|---|---|---|---|---|
| | | **min** | **estimate** | **max** | **min** | **estimate** | **max** | |
| <60 km | 110 and above | 616 | **2255** | 8258 | 629 | **1309** | 2721 | 714 |
| | 90…110 | 494 | **1979** | 7919 | 504 | **1108** | 2438 | 567 |
| | less than 90 | 184 | **1222** | 8110 | 183 | **581** | 1845 | 197 |
| 60…110 km | 110 and above | 476 | **1998** | 8393 | 483 | **1096** | 2488 | 540 |
| | 90…110 | 416 | **1822** | 7981 | 422 | **986** | 2303 | 472 |
| | less than 90 | 110 | **1008** | 9268 | 107 | **442** | 1825 | 112 |
| >110 km | 110 and above | 342 | **1720** | 8646 | 345 | **886** | 2276 | 383 |
| | 90…110 | 321 | **1617** | 8153 | 323 | **833** | 2146 | 361 |
| | less than 90 | 43 | **750** | 13099 | 40 | **290** | 2121 | 34 |

Source: Authors' calculations.

Notes: * Average fertility rate of agricultural land in the Moscow region (weighted with areas) is 100.

Values in columns ‘min’ and ‘max’ are the boundaries of 95 % confidence intervals.

From Table 2 it can be concluded that in the statistical sense, the differences in the arable land marginal product of lands belonging to different location-fertility groups are insignificant in the majority of cases. But the decrease of this value with an increasing distance from Moscow or decreasing soil fertility conforms to theoretical expectations, which adds to the robustness of this approach.

Table 3 presents a comparison of the estimated agricultural land marginal product throughout years 2001-2003. The changes during this period have the same direction regardless of type of land or location-fertility class. The land marginal product in the Moscow region decreases, contrary to the hypothesis (a).

**Table 3: Marginal agricultural land product in the Moscow region from 2001-2003, roubles per hectare (by quadratic parameterization)**

| Distance from Moscow | Rate of soil fertility* | Type | 2001 | 2002 | 2003 | 2003 to 2001, % |
|---|---|---|---|---|---|---|
| <60 km | 110 and above | A | 5,395 | 2,132 | 1,309 | 24.3 |
| | | G | 920 | 391 | 308 | 33.5 |
| | 90…110 | A | 5,018 | 1,899 | 1,108 | 22.1 |
| | | G | 1,015 | 371 | 275 | 27.1 |
| | less than 90 | A | 4,166 | 1,370 | 581 | 13.9 |
| | | G | 496 | 96 | 73 | 14.7 |
| 60…110 km | 110 and above | A | 5,235 | 1,944 | 1,096 | 20.9 |
| | | G | 893 | 378 | 297 | 33.3 |
| | 90…110 | A | 4,913 | 1,791 | 986 | 20.1 |
| | | G | 991 | 358 | 263 | 26.5 |
| | less than 90 | A | 4,066 | 1,261 | 442 | 10.9 |
| | | G | 442 | 86 | 68 | 15.4 |
| >110 km | 110 and above | A | 5,064 | 1,763 | 886 | 17.5 |
| | | G | 866 | 358 | 275 | 31.8 |
| | 90…110 | A | 4,775 | 1,648 | 833 | 17.4 |
| | | G | 958 | 345 | 254 | 26.5 |
| | less than 90 | A | 3,970 | 1,161 | 290 | 7.3 |
| | | G | 423 | 82 | 65 | 15.4 |

Source: Authors' calculations.

Notes: * Average fertility rate of agricultural land in the Moscow region (weighted with areas) is 100.

Symbol ‘A’ denotes arable land, ‘G’ – grassland.

Another noticeable observation is that the expected dependence of land marginal product on distance from Moscow and on soil fertility is observed throughout the period of 2001-2003. The exception is the case of grassland in 2001, whose marginal product peaks at medium soil fertility.

The estimated land marginal product is low, characterizing the agricultural land in the Moscow region as hardly sufficient collateral. Osborne and Trueblood (2002) estimated shadow prices of agricultural land[3] in the Central economic district of Russia, to which the Moscow region belongs. Their result was $ 19.7 per hectare in 1995, declining to $ 11.9 per hectare in 1998. According to their estimations, 40 to 120 hectares had to be mortgaged in 1997 to buy a tractor

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[3] Since Osborne and Trueblood (2002) do not distinguish arable and low-intensity lands, their estimations should be attributed to the type of land that has the smallest marginal product. Hence, in our case they must be compared to grasslands.

(without accounting for transaction costs, which likely made the area of land to be mortgaged for buying a tractor raise to infinity). For the Moscow region, where relatively intensive suburban agriculture prevails, GATAULIN and SVETLOV (1995) found that the equilibrium price of grasslands used for hay production and pastures in 1994 were $ 170 and $ 213 per hectare, respectively.

Our results are $ 51.20 in 2001, declining to $ 28.6 in 2003 for a hectare of grassland[4] in the Moscow region. Despite the stabilization of Russian agriculture in terms of amount of production, there is no evidence that strengthening market institutions increases land price. As a consequence, agricultural land property remains unattractive and inefficiently allocated. This situation can be explained in accordance to the justification of the research hypothesis (c) formulated in Section 1. The agricultural production crisis in the 1990s caused many lands to lose value. Recovery has improved crop productivity[5]; but meanwhile, market capacity has grown slowly – resulting in decreasing land value.

## 6 CONCLUSIONS AND DISCUSSION

Research hypothesis (a) is clearly rejected by the results of our study, while hypothesis (c) is not rejected. As for hypothesis (b), the differences between land marginal products at different distances from Moscow are not significant in a statistical sense. However, a stable monotonic dependence suggests that in reality the factor of distance is influential, although its effect cannot be reliably proved by means of the applied methodology. This calls for its further improvement.

With respect to the research questions formulated in Section 1, the following can be concluded:

a) The methodology has proved its relevance to the aim of this study.

b) The marginal land product in the Moscow region from 2001 to 2003 is very low. Moreover, it displays a declining trend.

c) In this respect, for the purpose of making the land valuable there is a strong need for expanding markets and diversifying production, the precondition for which is increasing the population's incomes and, consequently, increasing payable demand.

The declining trend of the agricultural land marginal product signals that an effective land policy based on well-developed economic and political institutions is missing. Indeed, virtually valueless land hardly substantiates the

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[4] The case of medium fertility plots located between 60 and 110 km from Moscow.

[5] In the Moscow region, the yield per hectare in 2002, compared to that of 1996, was 112.1 % (cereals), 129.3 % (vegetables). Both displayed a relatively stable trend, except 1999, which was extremely unfavourable.

expectation that the costs of establishing land market and property institutions will be repaid, which in turn slows down institutional reforms in agriculture.

Prior to utilizing Europe's experience regarding land markets, the institutional development of regional agriculture should facilitate growth of the land marginal product. In particular, politicians' fears about foreign landlords accumulating land should be replaced with a policy aimed at attracting investors regardless of their citizenship. Large land areas should be temporarily taken out of agricultural use, both for ecological reasons and for changing the dynamics of the land marginal product. Temporary and reasonable protectionism on agricultural production markets can also be considered a tool that can help establish a truly functioning land market by increasing the demand of internal agricultural production.

Finally, a rural financing system that can perform efficiently in the absence of land mortgages should be established. This is a way to prevent a repetition of the dramatic failure of P. Stolypin's agrarian reform that took place a century ago and was substantially based on land mortgage schemes.

This study has highlighted many subjects that require improvement in the applied methodology. Considering the continuously-emerging "agro-holdings" (RYLKO and JOLLY, 2005), the supply and demand of land outside the Moscow region is an important factor influencing the agricultural land marginal product inside the region. This leads to the idea of a mathematical model that would be able to consider data about external supply and demand. However, the problem here is in obtaining such data.

With regard to the utility function, a recent study by SVETLOV (2005) does not support the hypothesis about the profit-maximizing behavior of Moscow region corporate farms. Furthermore, the depreciation costs only roughly approximate the capital recovery costs. To capture the long-term preferences precisely, a propensity to invest should also be taken into account. Although we attempt to control the effects of unobserved preferences of farm management by assumption 7 in Section 2, there is a need for a more precise utility function to make estimations more truthful.

For parameterization purposes, we vary only crop yields. Varying output prices as well could enrich the analysis. However, this would introduce additional degrees of freedom into the regression equations. To conclude about the pros and cons of varying the prices, a further research agenda is proposed.

Despite the arguments in favor of the chosen representation of technologies (see Section 3), the data envelopment representation is also worth trying. Joint verification of the models would strengthen the conclusiveness of the study.

The model presented in this study allows infeasible solutions when testing. Such solutions provide incomparable shadow prices that are excluded from the parameterization procedures. However, the conditions leading to unfeasibility are quite realistic and can provide valuable data for the parameterization. In this respect, a formulation of the model disabling unfeasibility would improve the methodology.

Finally, the present version of the methodology excludes from consideration a large area of agricultural lands, namely that area occupied by household plots. The reason for this imperfection is the absence of necessary data at our disposal. It is very likely that household land is not marginal and therefore does not affect the obtained values; however, this is a hypothesis that needs further testing.

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