DEVELOPMENT OF A MULTI-FACTOR MATHEMATICAL MODEL TO EVALUATE THE EFFICIENCY OF AGRICULTURAL LAND USE

Natalya O. Gordeeva

PhD in Physics and Mathematics, Associate Professor, Belgorod State National Research University (Stary Oskol branch) 18 Solnechny mkn., Stary Oskol, 309502, Russia e-mail: gordeeva@bsu.edu.ru

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Abstract

The article discusses the development process and the possibility of multifactor model use to model the cadastral value of agricultural land on the example of the Belgorod region. The structure of a multifactor model is proposed and they performed the quantitative analysis of factors affecting the cadastral value of agricultural lands.

Key words:

Introduction

The choice of research trend is justified by the relevance of the issues of land use efficiency improvement at the regional level and their importance in food security provision within the region. Most of the territory of the Belgorod region is occupied by agricultural lands, the area of which amounted to 2088.3 thousand ha (76.9%) on January 1, 2019. The issues of agricultural land efficient use are relevant in the context of existing development strategies of the region.

Prediction of land use effectiveness is necessary to identify the hidden reserves of its increase, justifying a complex of agrotechnical, organizational and other measures aimed at the maximum amount of production and soil fertility increase.

Most scientists believe that it is the efficiency of land use that determines the efficiency of agricultural production as a whole. For example, V.A. Dobrynin (Dobrynin et al., 1993) considers the economic efficiency of agricultural production as the efficiency of land use, the level of farming on it.

Mathematical modeling based on the methods of factor and regression analysis can be considered as one of the promising approaches to agricultural land use efficiency evaluation.

Formulation of the problem

The purpose of this study was to develop a methodology that ensures the development of a multivariate regression model for agricultural land use, taking into account regional characteristics.

Agricultural production efficiency is a multi-factor category. During the model development, we assume that the regularity of the simulated process develops under the influence of a number of factors. In this case the generalized form of the mathematical model can be represented by the following equation:

$y_t = f(\alpha, x_t) + \varepsilon_t$, (1)

where $f(\alpha, x_t)$ is the functional expressing the form and structure of the relationships between the levels of the variables y_t and x_{it} at time instants t=1, 2,..., T (or on the intervals (t, t+1)); $\mathbf{x}_t$ = (x_{1t}, x_{2t},..., x_{nt}) – the vector of independent variable (factor) values at time t; α=(α_0, α_1,..., α_n) – the vector of model parameters; the parameter α_i expresses the degree of the factor x_i influence on the variable y over the entire considered interval (1, T); α0 is the model constant; ε_t – the random error of the model at time t.

The factors x_i , i=1, 2,..., n, are called independent, emphasizing their independence of the variable y in the sense of the y inverse effect absence on x_i. In this regard, the factors x_i are often called exogenous (external) variables, and the variable y is called the endogenous (internal) variable of the model.

The optimal composition of the factors included in the econometric model is one of the main conditions for its quality, understood both as the correspondence between the model form and the theoretical concept, expressing the content of the relationships between the considered variables, and as the accuracy of the prediction in the considered time interval t = 1, 2, ..., T of the variable y_t observed values by the equation $f(\alpha, x_t)$.

To select the most preferred composition of independent factors among a number of alternative options, we will use the a priori approach. The a priori approach involves the study of the nature and strength of the relationships between the variables in question, according to which they include in the model the factors that are most significant on the dependent variable y_t by their “direct” influence. And, on the contrary, the factors are excluded from the model if they are either insignificant in terms of their influence strength on the variable y_t, or their strong influence on it can be interpreted as induced by interconnections with other exogenous variables.

The influence of factors on the dependent variable is confirmed by quantitative characteristics, the most important of which is their paired linear correlation coefficient r_{yx}. The logic of the pair correlation coefficient use in the selection of significant factors is as follows. If the value $|r_{yxi}|$ is large enough, i.e.

$$|r_{xy_i}| > \rho 1 ,$$

where ρ1 is a certain empirical boundary (ρ1≈0,5-0,6 for this study), then we can talk about the presence of a significant linear relationship between the variables y and x_i or about a sufficiently strong effect of x_i on y. The greater the absolute value of the pair correlation coefficient, the stronger this influence.

MAIN PART

According to most agricultural scientists (Gataulina, 1999; Dobrynin, 2000; Zinchenko, 2002; Kovalenko, 2019; Tyapkina, 1980), the economic efficiency of land use in agriculture is determined by a system of indicators, the most important (direct) of which are the indicators calculated by production results and land resource comparison. In turn, the direct indicators, most fully reflecting the efficiency of land use, are divided into natural and value ones.

It is advisable to use the gross output of plant growing and animal husbandry ss the natural indicators of land use, the composition of which must include all the crops grown on the land, including main and by-products, waste used, postharvest, repeated, and intermediate crops.

Given the features of agricultural production in the Belgorod region, the following set of indicators is proposed:

Designation	Indicator	Measurement unit
X1	Agricultural products	Million rubles
X2	Gross regional product (per capita)	rubles
X3	Gross harvest of grain and leguminous crops	Thousand tons
X4	Gross harvest of root crops	Thousand tons
X5	Gross harvest of potatoes	Thousand tons
X6	Gross harvest of sunflower	Thousand tons
X7	Gross harvest of sugar beet	Thousand tons
X8	Productivity of grain and leguminous plants (from the harvested area)	Centners per hectare
X9	Potato yield (from the harvested area)	Centners per hectare
X10	The yield of fodder root crops (from the harvested area)	Centners per hectare
X11	Sunflower yield (from the harvested area)	Centners per hectare
X12	Sugar beet yield (from the harvested area)	Centners per hectare
X13	Crop area	Thousand hectares
X14	Livestock and poultry	Thousand animals
X15	Livestock and poultry produced in live weight (per year)	Thousand tons
X16	Potato consumption (per capita)	kilogram
X17	Consumption of milk and dairy products (per capita)	kilogram
X18	Meat and meat products consumption (per capita)	kilogram
X19	Consumption of bread products (per capita)	kilogram

Table 1: The composition of the multifactor model indicators

Thus, 19 factors entered the model at the first stage. As a general indicator of land use efficiency, an average level of agricultural land cadastral value (rubles/ha) is proposed, which reflects the value of land for various intended uses. Economic measures involve the use of such cost indicators as cadastral valuation of land with the aim of a farming system optimal selection by land users that provides rental income and preserves the land quality.

The initial data for the model development and study were the data of the Federal State Statistics Service (https://fedstat.ru), the National Report on the State and Use of Lands by the Cadastral Chamber of the Rosreestr in the Belgorod Region for 2000-2018.

To assess the significance of the indicators, the matrix of pair correlation coefficients was compiled, which measures the tightness of the relationship between each factor and the effective sign and with each other.

The result of the paired linear correlation coefficient calculation for the model presented in table 1 is shown in table 2.

Factor	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10
Linear correlation coefficient	0,876	0,866	0,706	-0,6698	-0,3007	0,760	0,314	0,749	0,499	0,152
Factor	X11	X12	X13	X14	X15	X16	X17	X18	X19	
Linear correlation coefficient	0,793	0,616	0,400	0,730	0,806	-0,436	0,493	0,670	0,434	

Table 2: The result of the paired linear correlation coefficient calculation for the indicator Y and X_i

At the next stage, insignificant factors with the lowest value | ryxi | are removed from the model, and thus, a new version of the model with a reduced number of factors is developed. Note that there are several insignificant factors in the model - X5, X7, X10, X13, X16, X19, the value of the pair correlation coefficient of which makes 0.15 - 0.44. However, all of them should not be deleted at the same time. It is possible that the insignificance of some of them is conditioned by the influence of the “worst” of insignificant factors, and these factors will turn out to be significant during the next calculation step. In this regard, the indicator with the lowest coefficient of pair correlation - X10 is first excluded from the model and a new matrix of pair correlation coefficients is developed.

The factor selection process will be considered completed when all the factors remained in the model are significant. Correlation analysis showed that such factors as the yield of fodder root crops (X10), gross harvest of potatoes (X5), gross harvest of sugar beets (X7), sown area of crops (X13), potato consumption (per capita) (X16), bread product consumption (per capita) (X19) are insignificant in their “direct” influence on the dependent variable yt..

Thus, after the correlation analysis, we can talk about the presence of a significant linear relationship between y and the factors X1, X2, X3, X4, X6, X8, X9, X11, X12, X14, X15, X17, X18.

The regression model will be expressed by the following mathematical equation relating the variables included in the model:

Yt = -2856,9 +0,1225*X1 - 0,0025*X2 + 3*X3 + 10,46*X4+18,99*X6 - 161,37*X8- 34,01*X9 – 99,45*X11-18,44*X12 – 0,012*X14 - 17,85*X15 – 19,20*X17 + 29,26*X18 (2)

If the obtained version of the model meets the criteria of its quality, then they justified conclusion on the advisability of its use in the course of further research and the model development process can be considered completed as a whole.

The quality of the constructed regression model was evaluated in the following areas:

- checking the quality of the regression equation;
- checking the significance of the regression equation;
- the analysis of the model parameter statistical significance;
- verification of the premise fulfillment of the least squares method.

In the general case, the “quality” of the econometric model is evaluated by two groups of characteristics. The first group will include the indicators, and criteria expressing the “degree” of the developed model conformity to the basic laws of the process described by it. The second group is represented by the indicators and criteria, assessing the approximation accuracy of the observed values of the process Yt to a greater extent.

A group of criteria, more aimed at approximation accuracy degree determination by the functional f(a, xt) of the observed values of the dependent variable yt, is formed by the coefficient of multiple correlation R, the coefficient of determination R2, and the Fisher criterion F widely used in statistics and econometrics (Devore, Jay, 1995).

In the constructed model, the multiple correlation coefficient R = 0.97 and the coefficient of determination R2 = 0.942 are close to unity. The calculated value of the Fisher test is F = 49.9 with the significance of 0.0066. All this indicates the adequacy of the linear model (2). A rather significant share (94.2%) of the total variation of the dependent variable yt is conditioned by the variation of the variable xi factor.

Conclusion

Based on the developed model, it is possible to develop forecast indicators of land use effectiveness and feasibility in the Belgorod region.

Being convinced of the model adequacy, we consider the most significant factors.

With an increase in agricultural production (X1) by 10%, the average cadastral value of agricultural land will be changed by 30%. With the gross harvest of grain and leguminous crops (X3) increase by 10%, the average cadastral value of agricultural land will be changed by 10%. With the gross yield of sunflower (X6) increase by 10%, the generalizing indicator will be changed by 8%. With potato productivity increase (calculated per harvested area) (X9) by 10%, the generalizing indicator will be changed by 4.2%, but upward. With meat and meat products (per capita) (X18) consumption increase by 10%, the general indicator will be changed by 2.8%.

A correct predictive assessment will ensure optimal planning and use of land in the future.

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