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Econometric modelling of the agricultural sector sustainable development

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SUMMARY

Using the Cobb-Douglas production function, econometric analysis with eco-socio-economic factors has shown that economic growth in agriculture is associated with improved quantitative and qualitative characteristics of labour potential, growing capital investment and reducing pollutant emissions. Estimation of the elasticity coefficients of the constructed Cobb-Douglas function (the sum exceeds 1) justifies that the economic development of agriculture mainly contains the features of a large-scale economy: modern level of science and technology provides advantageous expanding production to increase output. The constructed models allow to forecast assessment of the development of the agricultural sector's components and can be used to develop the basic directions of the state agricultural policy to manage the formation and use of resource potential.

Introduction

Sustainable development of the agricultural sector not only guarantees food security as one of the components of general economic security of the state but also provides economic growth, rural development, stimulates the progress of other industries through a multiplier effect. The agricultural sector of Ukraine demonstrates positive dynamics due to the significant natural and human potential, as well as favourable climatic conditions. The agricultural sector combines social, production, and environmental functions, sectoral and territorial aspects: the basic agricultural sector which generates the rural environment with the appropriate resource base (spatial, natural, and labour).

Method

In the analysis, general-scientific methods (analysis and synthesis, induction and deduction) and special methods of phenomena and processes analysis (abstraction, econometric and econometric-mathematical modelling) have been used.

Results

For conducting an empirical study of the agricultural sector of the economy and the construction of the production function, the relationship between the basic production resources (labour, capital, intellectual assets and emissions of pollutants) and output was used. In a market economy, the main indicator of the degree of development of the industry is gross value added, which reflects the possibility of expanding production. In this case, gross value added and gross output of agriculture are considered performance indicators.

The model considered in the work uses the data of the annual reports of the State Statistics Service of Ukraine (2020): gross output of agriculture *Y(T)*, the amount of fixed capital *K(T)*, the number of employees in agriculture *L(T)* and pollutant emissions *E(T)*; indicators of the integral coefficient of intellectual assets *I(T)*.

There is conducted a study of the Cobb-Douglas production function, which considers the gross output of agriculture Ukraine a performance indicator (*Y(T)* is the gross output of agriculture, in constant prices of 2010) (Table 1).

Table 1 *Statistics for calculations of the production function (Y(T) is the gross output)*

T, year	*Y(T)*, mln UAH	*K(T)*, mln UAH	*L(T)*, thous persons	*I(T)*	*E(T)*, thous t	$y_1=\ln Y$	$x_1=\ln K$	$x_2=\ln L$	$x_3=\ln I$	$x_4=\ln E$
2008	101451	16682	3322,1	0,5399	7210,3	11,5	9,7	8,1	-0,6	8,9
2009	96274	9295	3152,2	0,5120	6442,9	11,5	9,1	8,1	-0,7	8,8
2010	90792	11311	3115,6	0,6479	6678,0	11,4	9,3	8,0	-0,4	8,8
2011	117111	17981	3410,3	0,5566	6877,3	11,7	9,8	8,1	-0,6	8,8
2012	110072	18564	3506,7	0,6072	6821,1	11,6	9,8	8,2	-0,5	8,8
2013	133683	18175	3389	0,5956	6719,8	11,8	9,8	8,1	-0,5	8,8
2014	139058	18388	3091,4	0,5793	5346,2	11,8	9,8	8,0	-0,5	8,6
2015	131919	29310	2870,6	0,5031	4521,3	11,8	10,3	8,0	-0,7	8,4
2016	145119	49660	2866,5	0,5093	4498,1	11,9	10,8	8,0	-0,7	8,4
2017	140535	63401	2860,7	0,4632	3879,1	11,9	11,1	8,0	-0,8	8,3
2018	158307	65059	2937,6	0,4363	3866,7	12,0	11,1	8,0	-0,8	8,3

After performing the calculations using the method of least squares, the desired Cobb-Douglas production function takes the following form:

$$Y = 341K^{0,08353}L^{1,70970}I^{0,32224}E^{-0,98789} \quad (2)$$

The multiple correlation coefficient is *R*=0.892, the standard approximation error is 0.107. Fisher's F-criterion calculated is 9.26 – this is greater than Fisher's F-criterion tabular (99% confidence, reliability), which is 8.45. This gives a 99% probability that the found Cobb-Douglas production function (2) corresponds to the initial data of the problem. Therefore, the constructed production function has satisfactory statistical characteristics (Table 2). The value of the multiple correlation coefficient indicates that the variation in the volume of gross output by 89.2% depends on the fluctuations of the factors included in the equation and depends by 10.8% on the factors that are not taken into account. Coefficient of determination R^2 has a satisfactory value (0.796), the variance of the output *Y(T)* is due to the regression of the selected levers of influence (*K, L, I, E*) by 79.6 %.

Table 2 *Regression analysis parameters for Y(T) (gross output)*

Multiple correlation coefficient *R*	0.892
Coefficient of determination R^2	0.796
Standard approximation error	0.107
Fisher's F-criterion calculated F_{calc}	9.26
Fisher's F-criterion tabular F_{tab}	8.45
Number of observations	11

Based on the actual values of gross output and their calculated values, a graphical model of the results of the Cobb-Douglas production function approximation is obtained (Figure 1). In addition to the multiple correlation coefficient, the high degree of accuracy of the regression equation is evidenced by a slight deviation of the calculated values from the actual ones.

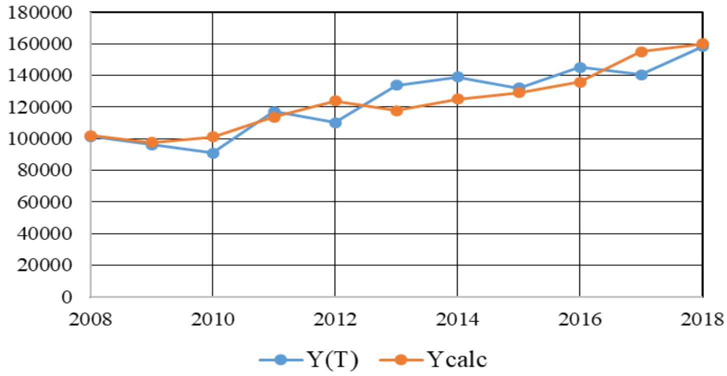

Figure 1 *Results of the approximation of the Cobb-Douglas production function for gross output*

Thus, in equation (2) the elasticity coefficients a_2 = 1.70970 and a_4 = -0.98789 reflect the influence of factors on performance. Because of a_2 far exceeds 1, the main role in the growth of agricultural production is played by the number of the employed persons. In the case of an increase in the number of employees in agriculture by 1%, an increase in gross output of agriculture by 1.70970% should be expected. The elasticity coefficient a_4 is negative; therefore, the quantity and quality of labour are influenced by environmental factors, namely – pollutant emissions deteriorate the quality of life of the rural population and have a negative impact on crop yields. The sum $(a_1 + a_2 + a_3 + a_4) = 1{,}13 > 1$ shows the increasing effect of the economies of scale (value $f(x_i)$ increases more than value x_i), the growth of production outpaces the increase in cost factors, with the expansion of production, the average cost of resources per unit of output decreases.

The significant deviation of the elasticity coefficients (2) from 1 can be explained by the fact that other factors, such as political, social and administrative, can have an impact on the situational variable.

The statistics shown in Table 3 were used to calculate the Cobb-Douglas production function with the performance indicator "gross value added". Correlation and regression analysis is used to determine and verify the parameters of the production function. The approximation of well-known power functions in the Cobb-Douglas production function helps mitigate mistakes and close in on real values.

After calculations using linear regression analysis by the method of least squares, the values of the coefficients of the Cobb-Douglas production function are determined. The production function obtained takes the form:

$$Y = 422388 K^{0,34474} L^{2,63344} I^{1,60806} E^{-2,86638} \quad (3)$$

Table 3 *Statistics for calculations of the production function (Y(T) is the gross value added)*

T, year	*Y(T)*, mln UAH	*K(T)*, mln UAH	*L(T)*, thous persons	*I(T)*	*E(T)*, thous t	y_1=ln*Y*	x_1=ln*K*	x_2=ln*L*	x_3=ln*I*	x_4=ln*E*
2008	65148	16682	3322,1	0,5	7210,3	11,1	9,7	8,1	-0,6	8,9
2009	65758	9295	3152,2	0,5	6442,9	11,1	9,1	8,1	-0,7	8,8
2010	82948	11311	3115,6	0,6	6678,0	11,3	9,3	8,0	-0,4	8,8
2011	109961	17981	3410,3	0,6	6877,3	11,6	9,8	8,1	-0,6	8,8
2012	113245	18564	3506,7	0,6	6821,1	11,6	9,8	8,2	-0,5	8,8
2013	132354	18175	3389	0,6	6719,8	11,8	9,8	8,1	-0,5	8,8
2014	161145	18388	3091,4	0,6	5346,2	12,0	9,8	8,0	-0,5	8,6
2015	239806	29310	2870,6	0,5	4521,3	12,4	10,3	8,0	-0,7	8,4
2016	279701	49660	2866,5	0,5	4498,1	12,5	10,8	8,0	-0,7	8,4
2017	303949	63401	2860,7	0,5	3879,1	12,6	11,1	8,0	-0,8	8,3
2018	360757	65059	2937,6	0,4	3866,7	12,8	11,1	8,0	-0,8	8,3

To assess the calculated production function (3), the parameters of regression analysis are studied. The multiple correlation coefficient is R = 0.983, the standard approximation error is 0.148. Fisher's F-criterion calculated is 46.71 and is greater than Fisher's F-criterion tabular (99% confidence, reliability), which is 8.45 (Table 4). Therefore, the regression equation obtained can be considered significant. This means that with a 99% probability the found Cobb-Douglas production function (1) corresponds to the initial data of the problem.

Table 4 *Regression analysis parameters for Y(T) (gross value added)*

Multiple correlation coefficient *R*	0.983
Coefficient of determination R^2	0.966
Standard approximation error	0.148
Fisher's F-criterion calculated F_{calc}	46.71
Fisher's F-criterion tabular F_{tab}	8.45
Number of observations	11

Thus, the constructed production function has reliable statistical characteristics. The value of the multiple correlation coefficient indicates a high close relationship between the performance indicator and the selected factors, the variation of gross value added by 98.3% depends on the fluctuations of the factors included in the equation and only 1.7% depends on factors that are not taken into account. The value of the coefficient of determination R^2 (0.966) is quite close to 1, so the regression model is successful, and the relationship between the resulting indicator of the production function and the input factors is strong. Variance of the output *Y(T)* is due to the regression of the selected levers of influence *(K, L, I, E)* by 96.6 %. This confirms that the model takes into account the most important factors. In addition to the multiple correlation coefficient, the adequacy of the equation is evidenced by the small value of the average approximation error, which characterizes the average relative deviation between the actual and theoretical values based on the equation constructed (Figure 2). Thus, equation (3) meets all the requirements and can be used for economic analysis.

The analysis shows that the growth of quantitative and qualitative indicators of labour potential of the agricultural sector has a direct impact on the growth of gross value added of agricultural products, as there is a direct relationship between them.

The economic analysis of the Cobb-Douglas production function can be performed on the basis of elasticity coefficients that reflect the nature of the influence of factors on performance. For example, the elasticity coefficient a_1 = 0.34474 (3) shows the elasticity of agricultural production relative to capital investment with a constant number of employed persons in rural areas, the integral coefficient of intellectual assets and pollutant emissions. If capital investment increases by 1%, the gross value added of agriculture should be expected to grow by 0.34474%. The elasticity coefficient a_2 = 2.63344 (3) indicates the output elasticity relative to the number of employed persons in rural areas with

constant capital investment, the integral coefficient of intellectual assets and pollutant emissions, i.e., with an increase in the number of employed persons in rural areas in agriculture by 1% gross value added of agriculture should increase by 2.63344%. The elasticity coefficient a_3 = 1.60806 (7) reflects the elasticity of production relative to the integral coefficient of intellectual assets with a constant amount of capital investment, the number of employed persons in rural areas and the number of pollutant emissions, i.e., if the integral coefficient of intellectual assets increases by 1%, an increase in gross value added by 1.60806% should be expected. The elasticity coefficient a_4 = -2.86638 (7) shows the elasticity of production relative to pollutant emissions with constant capital investment, employed persons in rural areas and the integral coefficient of intellectual assets, i.e., with an increase in pollutant emissions by 1%, reduction of agricultural output by 2.86638% should be expected. The value of the technological coefficient $a0$ obtained (422388) is much more than 1. We can justify a significant impact of technical progress on the growth of gross value added in agriculture.
This means that the increase in gross value added is, firstly, due to an increase in the number of employees ($a_2 > a_1$); secondly, this is possible due to improving the quality characteristics of labour potential ($a_3 > a_1$). This type of economic growth cannot be called labour-saving; according to Solow, the transition to a model of the production function with scientific and technological progress requires qualitative changes in production processes, improving the efficiency of labour resources and productivity.

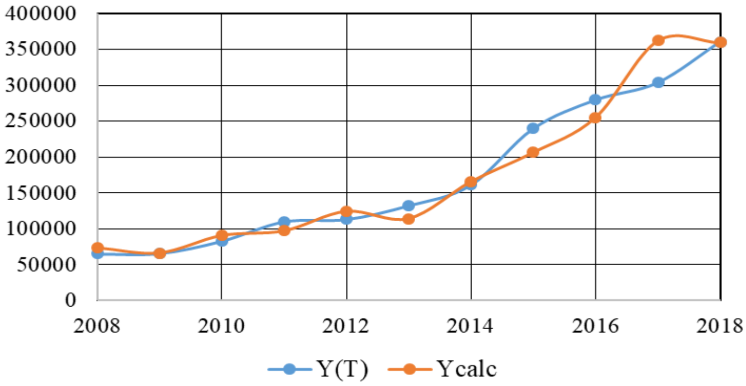

Figure 2 *Results of the approximation of the Cobb-Douglas production function for gross value added*

Thus, the most significant in the economic growth of agricultural production are quantitative and qualitative indicators of labour potential: the number of employed persons (L) and the integral coefficient of intellectual assets (I), while the capital factor is less influential. This reveals the need to update the issue of priority of development of labour potential of the agricultural sector.
Aggregate influence of factors $(a_1 + a_2 + a_3 + a_4)$ exceeds 1: $(a_1 + a_2 + a_3 + a_4) = 1{,}72 > 1$. This indicates the positive strength of their influence; the resulting production function describes the growing economy (Pshenychnykova, 2017) within the endogenous model of growth. The economic development of agriculture mainly has the characteristics of a large-scale economy: at the current level of science and technology, it is advantageous to expand production for increasing output.

Conclusions

Modelling how the resource factors act on output using the method of construction and calculation of parameters of the production function allows to predict the sustainable development of agricultural production under quantitative and qualitative changes in the use of labour and capital, as well as environmental factors. Further research ensures obtaining a dynamic multi-factor model of sustainable development of the agricultural sector and determining the main mechanisms of influence on the levers of economic growth.