

Economies of Scale and Provision of Technological Efficiency in Agricultural Complexes

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Abstract. The article sets forth a generalized understanding of economies of scale in agrarian production as a complex integrative phenomenon, implemented in a unity of three components – the intra-branch scale effect in agrarian production, the quality effect, the number of enterprises and the effect of their average scale production. The author's translogarithmic model of economies of scale and the approach to its optimization have been proposed. Specific, potential determinants of the high cost of agricultural products based on the assessment of trends in economies of scale and the level of technological efficiency in the specialized Crimean production units have been established. A parametric analysis of the economies of scale in the model of factor-resource potential has been constructed in the framework of the boundary stochastic function of agrarian production in order to ensure an adequate level of technological efficiency. The ways of increasing of the branch effectiveness and technological efficiency of the agrarian formations of Crimea have been proposed.

1. Introduction

Improvement of technological and allocative efficiency of agriculture is a priority strategic direction of socio-economic development, and the growth of profitability and efficiency of agricultural production is the most important tactical task. A generalization of methodological approaches to the study of the economic efficiency of agricultural production in the Crimea and its sub-sectors in terms of the concept of Farrell's efficiency (1957) allows us to estimate the return on the consumed resource potential of each Crimean enterprise taken. In this context, it is necessary to find out how much production can be increased without attracting new resources. At the same time, to establish to what extent low production efficiency is associated with the non-optimality of the used set of resources, and to what extent it is the result of the use of non-optimal technologies.

The purpose of this article is to focus on identification and quantitative analysis of economies of scale, to reveal the existing large-scale effects for Crimean agrarian formations in general, and viticulture sub-sector in particular, to consider the differences in the efficiency of their resources used, as well as to justify the parametric models that reflect the level of scale production and technological efficiency.

According to this issue, the generalized essential characteristics of the categories of economies of scale and efficiency of agricultural production have been summarized; have been revealed the

principles of concentration, intensification and specialization in the context of the content of performance parameters; the reasons of the low technological and allocative production efficiency in Crimea have been disclosed.

2. Relevance and statement of the problem

Historically, the issues of returns to scale and production's technological efficiency have attracted much attention of agrarian economists because of the wide range of observed area sizes [1, 2, 3, 4,5,6]. They have found that large farms with highly qualified personnel are usually more technologically efficient and allocative, but factors that affect changes in returns to scale have not been identified. It has also been found that larger farms give lower returns on capital investment than small ones.

A conceptual understanding of economies of scale presupposes the variability of understanding of the category of economies of scale and is embodied in the form of measuring a number of performance parameters of an individual enterprise in the industry: gross output (intra-branch scale effect) and changes in output in the analyzed industry (branch scale effect). The last parameter is measured by the dynamics of the unit cost of production and reveals the reason for the occurrence of a positive or negative scale effect.

The essential characteristic of our approach to the study of economies of scale, to the formation of an empirical assessment of the technological efficiency of production is to explain the paradox: agricultural enterprises that use the same resources produce different volumes of products, reach different levels of profitability and have different direction in changing of the contribution to profitability. This situation has been theoretically proven by the neoclassicists in DEA-analysis models and boundary production capabilities and shows the need for parametric calculation of relatively new categories: technological, allocative and overall economic efficiency [7, 8, 9]. Our approach to assessing the effectiveness of agricultural production involves the consideration of economic efficiency as a product of technological efficiency and resource allocation efficiency. Assessment of technological efficiency must be carried out from two perspectives. Firstly, from the point of view of input-oriented analysis, which reflects how much resource costs the enterprise is able to reduce for a given level of capacity and volume of production, and secondly, from the position of output-oriented analysis, which reflects how much output the enterprise can increase without involving new resources in production [10]. The universality of this method lies in the fact that it allows us to identify factors of production influencing the economic efficiency and determine promising areas for the development of enterprises, and the ratio of the values and parameters of the intra-industry scale effect allows us to determine the nature of the economies of scale dominant in the sector [11].

3. The main results of the study

Due to the fact that economies of scale reflect the relationship between output and costs, we have analyzed these values for the period of 2014-2018 in relation to the profile, specialized formations of the viticulture sub-sector of the agricultural sector in the Crimea. For the same period, we have analyzed the dynamics of the area under the vineyard and the gross crop yield of grapes, have established basic indices of changes in the volume of consumed resources, gross output, average size of labor costs and cost of sales. The empirical distance functions proved to be most convenient for study of the scale and measure of technological efficiency of multi-output and multi-input technologies [11, 12].

Input distance function $D^\pi(x, y, t)$ identifies the smallest input vector x needed to create the output vector y , determined by the parameter of the set (y, t) , taking into account the output time vector t . The input-output function with several outputs, taking into account deviations from the boundar, is formally defined as follows [14]:

$$D^\pi(X, Y, t) = \max\{\rho: \rho > 0, (x / \rho) \in L(y, t)\}, \quad (1)$$

where: ρ is a scalar, $L(Y, t)$ is the set of input vectors, $X(x_1, \dots, x_N) \in R_+^N$, which in year t can create an output vector $Y(y_1, \dots, y_M) \in R_+^M$.

We assume that the input distance function developed by C. J. Morrison-Paul and R. Nehring [13]

and generalized by B. Larue [11] can be approximated by using the translogarithmic production function by specialized agrarian enterprises. They have more flexible capabilities in approximating production technologies and have the advantage of economizing on scale for different levels of activity. Taking parameter (x_3) as the normalizing input production factor with parameters i (index of enterprises) and t (time period) and taking into account its intrinsically empirical specification, we combined system of equations (1) as a standard stochastic production function [11, 15]:

$$\begin{aligned}
 -\log x_{3it} = & \alpha_0 + \sum_{\eta \neq 3}^N \alpha_{\eta} \log x_{\eta it}^* + \frac{1}{2} \sum_{\eta \neq 3}^N \sum_{k \neq 3}^N \alpha_{\eta k} \log x_{\eta} \log x_{k it}^* + \sum_{m=1}^M \beta_m \log y_{mit} + \\
 & + \frac{1}{2} \sum_{m=1}^M \sum_{l=1}^M \beta_{ml} \log y_{mit} \log y_{lit} + \sum_{m=1}^M \sum_{\eta \neq 3}^N \gamma_{m\eta} \log y_{m\eta} \log x_{\eta it}^* + \sum_{\eta=1}^N \delta_{tx\eta} t \log x_{\eta it}^* + \\
 & + \sum_{m=1}^M \delta_{ty_m} t \log y_{mit} + \sum_{s=2}^{\pi} \tau_{\eta} C_s + \sum_{r=1}^B \sum_{\eta=1}^N \omega_m R_r \log x_{\eta it} + \sum_{r=1}^B \sum_{\eta=1}^N K_{rm} R_r \log y_{mit} + \omega_1 t + \\
 & + \omega_2 t^2 + \vartheta_{it} + \mu_{it}
 \end{aligned} \tag{2}$$

where: $x_{it}^* = x_{it}/x_{3it} \forall, i, t$; ϑ_{it} is a random statistical error; $\mu_{it} = \mu_i e^{-(tT)}$ is the private term defined by the parameter $\log D_{it}^{\pi}(X_i, Y_i) = \mu_{it} \geq 0$; $D_{it}^{\pi}(X_i, Y_i) \geq 1$ is the value of the input distance function of the desired i -th enterprise, using the initial factor vector x_i and creating the output product vector (y_i) in year t .

Our theoretical and empirical justification of economies of scale for all agrarian formations of the Crimea correspond to the conclusions made earlier by P. Morrison-Paul [13] and B. Larue [11] regarding the level of error (ϑ_{it}) without taking into account the distribution factor of random variables ($N, 0, \delta_{\vartheta}^2$). The criterion μ_{it} correlates with the component of the equations of C.A.K. Lovell, S. Richardson, P. Travers and L. Wood [4].

As a research object, large-scale enterprises of the viticulture and wine-making sub-sector of the Crimean agro-industrial complex were selected for the period of 2014-2018. More than 70% of the Crimea's vineyards are concentrated in six Crimean regions: in the zone of the city of Sevastopol, Bakhchisaray, Kirovsky, Saki, Simferopol regions and in the city of Sudak [7, 15].

The impact of the (positive / negative) effect of economies of scale and losses is explained by measures of concentration, specialization (table 1) and production intensification and is quantitatively justified by parametric growth or reduction of production [7, 11].

Table 1. Economic efficiency of specialization in the production of grapes in the Crimea, in average for 2014–2018.

Indicators	Specialization, %				Total
	I	II	III	IV	
	to 20	21-40	41-60	over 60	
Number of households in the group	8	5	4	7.0	24
Average level of specialization, %	4.1	29	45	85.0	45
Crop yield, t/ha	5,4	9.8	20.4	49.8	28.8
Profit (loss) per 1 ha of vineyards, rub.	-2052	-1477.44	1751.04	7397.46	-122.78
Profitability (loss ratio), %	-60.3	-18.7	21.8	185.2	x

According to the table's data the logarithmic equation can be calculated reflecting the trend of the impact of the level of specialization (x) on the level of profitability (y). The bond equation is defined as: $y = 153.14 \log x - 89.669$, $R^2 = 0.7335$. The resulting equation shows that in the Crimean viticulture there are significant reserves for increasing the production efficiency due to the deepening of production specialization. Thus, enterprises of the IV group of specialization compared with the enterprises of the I group significantly increased the economic efficiency of grape production (the

level of profitability is 240% higher). With a 100% level of production specialization, profitability will be 281% [7, 11].

In order to establish the importance of influence of intensification on the growth of grape yield, we used a system of synthetic indicators of the cost level per 1 ha (Figure 1) and calculated a translogarithmic function that reflects the dependence of grape yield (y) on the level of production costs per 1 ha (x) [7, 16]:

$$y = 18,236\log x - 4,6308 \quad R^2 = 0,814 \quad (3)$$

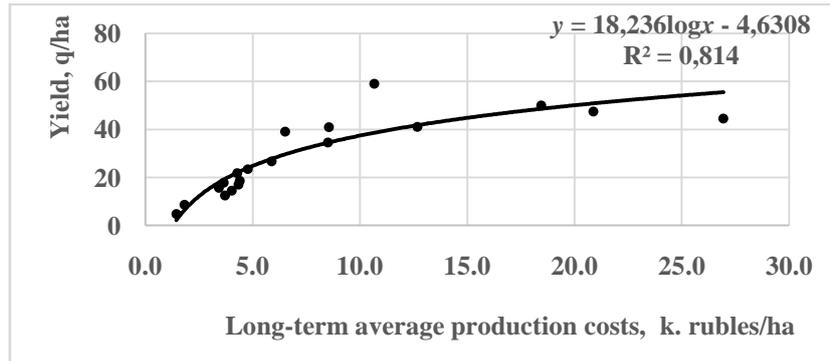


Figure 1. The dependence of crop yield on production costs per 1 ha in 2014–2018.

The parameters of the translogarithmic equation (3) show that an increase in long-term average production costs to 4.63 thousand rubles/ha (crop yield increases to 18.24 kg/ha) will ensure a reduction in the cost of each marginal quintal’s product, and an increase in production costs by 1 ha over 14.63 thousand rubles/ha, considering the increase influence of other factors and the effect of the law of decreasing of productivity, provides a rise in the cost of production of each additional quintal of grapes.

Specialization of production inevitably leads to its concentration (table 2). Grape production is cost-effective in enterprises with a vineyard area of more than 500 hectares. They also have the highest crop yield of grapes (8.0 t/ha). In terms of productivity, the western piedmont-seaside zone occupies the second place among all regions after the Saki region, with a crop yield of 5.0 t/ha.

Table 2. The effect of concentration of grape plantations in agricultural enterprises of the Crimea on the economic efficiency of grape production, in average for 2014–2018.

Indicators	Group of farms by area of fruiting vineyards			Total
	I – up to 500	II – 500-1000	III – Over 1000	
Number of farms	13	7	4	24
Area of vineyards, total, ha	127	683	1278	455
incl. fruiting area, ha	119.5	581	1069	423.0
Crop yield, t/ha	6.3	26.3	37.2	28.8
Profit (loss) per 1 ha of vineyards, rub.	-2028.06	2746.26	6161.81	-122.78
Level of profitability (loss ratio), %	-54.2	67	158.1	x

Dynamics of gross production and crop yield in the main grape Crimean zones has a cyclic translogarithmic form (Figure 2), indicating a sharp decline in production associated with on-farm and market reasons as well as with the effects of periodicity of fruiting. Even with a high level of specialization, a lean year put many winegrowers in a difficult situation.

An important point is the establishment of an optimal structure of production resources that ensures a minimum level of production costs and leads to an increase in technological efficiency, calculated by the DEA method as the ratio between economic and allocative efficiency (table 3) [7, 11]. High

economic efficiency is determined by allocative efficiency. So, the enterprises of Simferopol district and the city of Sudak, having a high level of management (> 80%), good conditions for viticulture, are unable to ensure on-farm profitability due to expensive technologies and inability to establish the optimal combination of resources. By solving this problem, they will increase their income by 45%. And the enterprises of Yalta, due to a significant level of allocative efficiency, have the highest indicator of economic efficiency [7, 9, 11]. By solving problems with technological efficiency, they will be able to increase production in average by 15%. From the above data, we can calculate equations reflecting the trends of influence:

– the level of allocative efficiency on the economic efficiency of production:

$$y = 0.0126x^2 + 0.2421x + 1.6543 \text{ with } R^2 = 0.8908 \tag{4}$$

– the level of economic efficiency on the economic production efficiency:

$$y = 0.0168x^2 + 0.0178x + 1.0329 \text{ at } R^2 = 0.9293 \tag{5}$$

– the level of technological efficiency on economic production efficiency:

$$y = 0.0377x^2 + 0.3009x + 0.3533 \text{ at } R^2 = 0.8064 \tag{6}$$

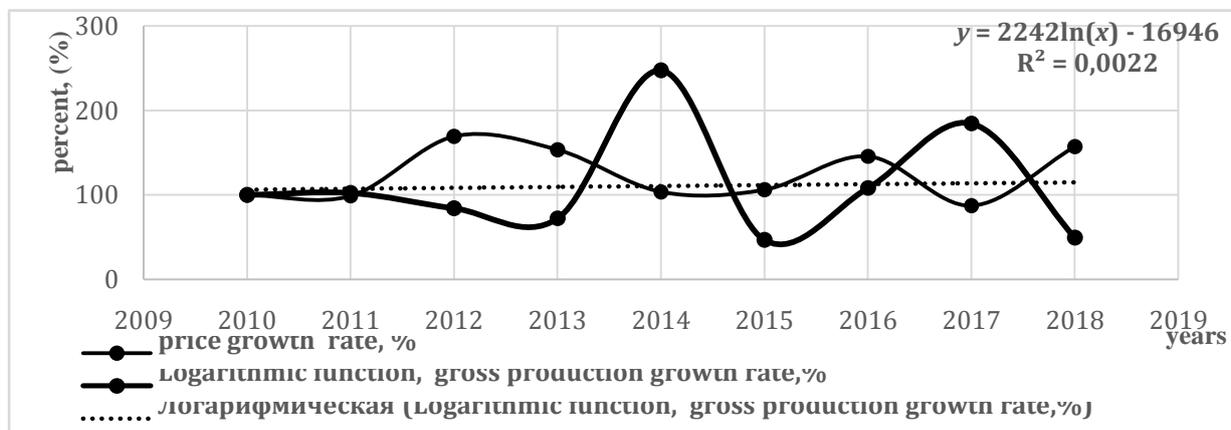


Figure 2. Comparable dynamics of changes in the growth rate of production and the market price of grapes in the Crimea in 2010–2018.

Table 3. Efficiency indicators of grape production according to the DEA method and the level of profitability of production in 2014-2018.

Administrative region	Technological efficiency	Allocative efficiency	Economic efficiency	Level of production profitability, %
Yalta	0.857	1.167	1.0	133.5
Alushta	0.803	1.117	0.897	109.5
Sevastopol	1,000	0.904	0.904	78.4
Bakhchisaray	0.938	0.787	0.738	34.4
Simferopol	0.815	0.510	0.416	-2, 7
Kirovsky	0.595	0.652	0.388	-9.3

Dependency equations (4, 5, 6) confirm that the greatest influence on the economic efficiency have cost and structure of consumed resources. Thus, a change in allocative efficiency by 1 percentage point will lead to an increase in economic efficiency by 0.97 percentage points, and a similar change in technological efficiency – only by 0.4 percentage points. Moreover, the low coefficient of determination (0.5) of equation (4) confirms the influence on the efficiency of other factors: the high cost of resources, the situation on the grape market, etc. [17, 18, 19, 20].

4. Conclusion

To identify growth points for agricultural production, it is necessary to modify the parameters for calculating efficiency, introducing relatively new categories: technological, allocative and general economic efficiency, and considering economic efficiency as a product of technological efficiency and resource allocation efficiency. Evaluation of the efficiency of agricultural production on the example of profile, specialized formations of the viticulture sub-sector of the Crimean agro-industrial complex allowed us to show that the scale effect manifests itself through the interconnection of output and long-term costs. The application of the standard stochastic production function made it possible to establish that in viticulture, due to the deepening of specialization and concentration of production, there are significant prospects for obtaining positive economies of scale. At enterprises with a specialization level above 60% and concentration of more than 1000 ha, in average a crop yield of 50 c/ha and 7379.46 thousand rubles profit can be obtained. The profitability level in average will be 150%, and with a specialization level of 100%, it will reach 260%.

Improvement of technological and allocative efficiency as a result of economies of scale is achieved by reducing of production costs. However, an increase in the long-term average production costs to 4.63 thousand rubles/ha ensures a reduction in the cost of each marginal quintal's production, and an increase in production costs per 1 ha which exceeds 14.63 thousand rubles will provide a rise in the cost of production per unit of output [6, 7, 20]. The next important factor in economies of scale and improving of technological and allocative efficiency is the solution of problems of limited resources by improving the equipping of the production process with resource potential. So, the ratio of capital to the number of workers for technologically efficient enterprises is by 18.8% higher than that of less efficient.

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