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STUDY ON THE PROFITABILITY OF AGRICULTURAL ENTERPRISES IN UKRAINE DURING THE RUSSIAN MILITARY INVASION OF UKRAINE

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Abstract. This paper examines the effectiveness of grouping agricultural enterprises according to the wheat harvested area and assesses their profitability. We have developed linear and non-linear regression equations to predict the income for said groups of enterprises. The methodology is designed for cases when future market prices are probabilistic in nature. With the help of the developed methodology, it is possible to calculate the necessary production volumes in the conditions of price fluctuations. We have used the Goldfeld–Quandt parametric test to test the model for heteroscedasticity. Calculations show that agricultural holdings are indeed inefficient, and preference should be given to enterprises with medium crop areas. Application of the Lagrange multipliers method when solving the problem of agricultural enterprise optimization makes it possible to increase profitability. The case of price risk, when future market prices are not deterministic, is considered. Therefore, it is necessary to be guided by two criteria when making managerial decisions: to maximize the expected total net income and to minimize the variance of the total net income.

Keywords: economic and mathematical models, heteroscedasticity, models of regression analysis, profitability, income, linear regression, nonlinear model, full-scale russian invasion of Ukraine.

INTRODUCTION

Wheat is one of the most important crops for food security worldwide. Growing wheat is also a source of income for the considerable part of Ukraine's population. Among the agricultural crops in Ukraine, wheat occupies more than half of the sown area. In the recent years, nation had entered the top ten major grain producing countries and became one of the world's leading exporters of wheat (Fig. 1). Moreover, wheat exports to Africa, Southeast Asia and the Western Hemisphere

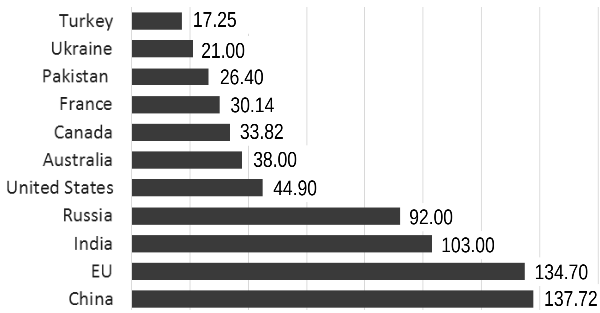

Fig. 1. Leading 10 wheat producers worldwide in 2022/2023 (in 1.000 metric tons)

were expected to increase in 2022/23. Unfortunately, as of May 2023 we can observe negative effects of war, as the economy exported 41.6 million tons of grain in the 2022/23 July-June season within the Black Sea Grain Initiative and overall wheat export is predicted to peak at 24 million tons. The negative trend is expected to remain, as the prognosis for the following period 2023/24 season stands at the threshold of 26 million tons [1].

A starting point in understanding the Ukraine's grain producing sector, is to analyse and group the enterprises by the size of the harvested area of wheat in 2021. In percentage terms, the ratio is as follows (Fig. 2). There are 24.016 wheat-growing enterprises in total. 61.6% of those are the small enterprises, in particular those with harvesting area of up to 100 hectares. Their aggregated volume of production is 1.986 thousand tons of wheat, which is accordingly 7.7% of the total volume of wheat production in Ukraine. There are only 123 enterprises with a total area of more than 3.000 hectares, the volume of production of which is 2.852.1 thousand tons, which is 11.1% of the total volume of wheat production in Ukraine [2].

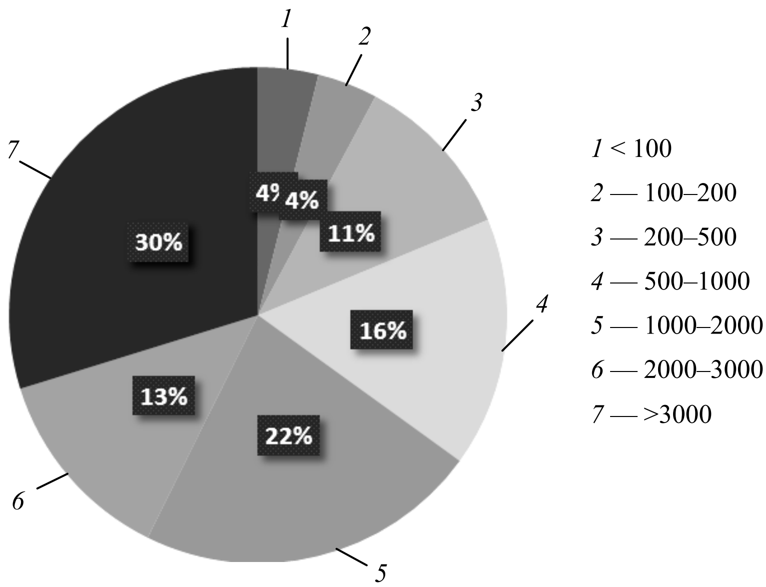

Fig. 2. Enterprises grouping by wheat production (thousand tons) in 2021
Source: Source: authors' elaboration on the data of [3]

The yield of wheat differs according to various groups of enterprises as follows: enterprises with an area of up to 100 hectares have a yield of 35 t/ha; with an area of 500-1000, respectively, 50.3 cwt/ha; for the enterprises with more than 3.000 hectares, the yield is 65.4 t/ha. By volume of harvested wheat to the total volume of production: enterprises with an area of up to 100 hectares collect 4%; with an area of 500–1000, respectively, 16.6%; with an area of 1000–2000 — 23.4%; with an area of 2.000–3.000 hectares — 12.8%; enterprises over 3.000 hectares 28.7%.

And the trend of overall wheat production in the previous years shows constant increase up to 2022 (Fig. 3), that is explained by the consequences of russian aggression towards Ukraine. As war escalates, under constant bombing and shelling, Ukrainian farmers are not able to harvest the grain. Moreover, fields, that are under russian occurrence are unreachable and inaccessible to them. Those crops, if being harvested at all, are at the disposal of occupiers and are being expropriated by them and consequently, their sale bypasses Ukraine. Hence, 25687.2 thousand tons of wheat were grown in 2021. Ukrainians consume about 20% of local wheat — the rest is being exported. That is, 20549.76 thousand tons were exported in 2021.

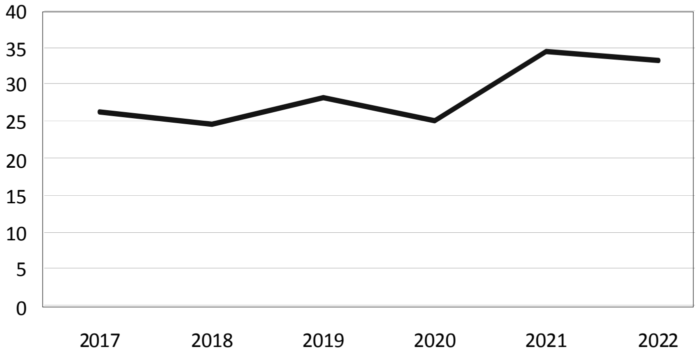

Fig. 3. Wheat harvest in Ukraine in previous years (1 cwt per hectare)
Source: authors' elaboration on the data of [4]

Due to the use of the higher-quality seeds, modern technology and plant protection products, this year, despite the war, farmers managed to harvest a quite proficient harvest. All this contributed to the increase in productivity. For the first time in 20 years, there was no drought in Ukraine. The best harvesting results were observed in Vinnytsia (6.7 million tons), Chernihiv (6.2 million tons), and Poltava regions (5.7 million tons) [4]. According to the groupings of agricultural producers, the productivity is as follows (Fig. 4): with an area of 100 hectares, as a percentage of the total 61%: with an area of 200–-500 hectares — 11.8%; with an area of 500–1000, respectively, 8%; with an area of 1000-2000 — 5.5%; with an area of 2.000–3.000 hectares — 1.6%; enterprises over 3.000 hectares 1.5%.

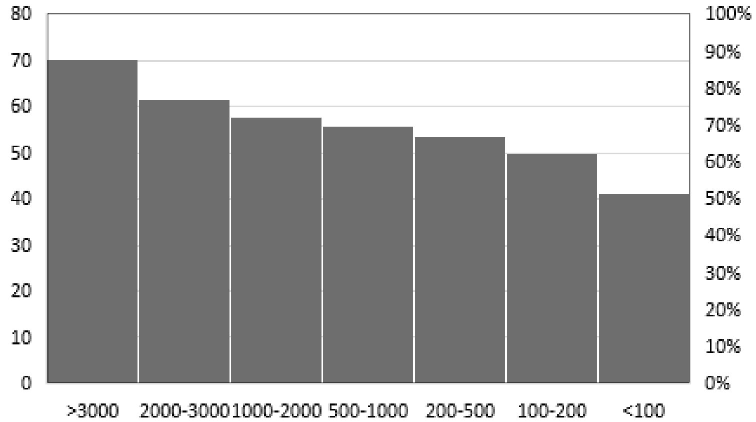

Fig. 4. Enterprises grouping by wheat yield in 2021 (centner per 1 hectare)
Source: authors' elaboration on the data of [3]

Compared to 2019, in 2022 the overall grain production trends were as follows: soybean harvest increased by 17; 40 million tons of corn were harvested; as well as 32 million tons of wheat (8 million tons more than in 2020). According to the press service of the Ukrainian Grain Association, the record wheat harvest guarantees the country's food security. By the end of 2021, all countries of the world expect to harvest a record 2.8 billion tons of grain, the Food and Agriculture Organization of the United Nations (FAO) predicts.

Exports of agricultural products, during the 11 months of the war, amounted to $24.4 billion, which is 22% higher than last year, according to customs data. Ukrainian products are mostly imported to China, India and the Netherlands [5]. For 2023, the National Bank of Ukraine (NBU) forecasts consumer inflation (December to December) at the level of 18.7% and an average annual rate of 20.3% (in 2022 it was 26.6% and 20.2%, respectively, in 2021 — 10% and 9.4%, in 2020 — 5% and 2.7%). According to NBU estimates, the average unemployment rate in Ukraine in 2023 will be 26.1% (in 2022 — 25.8%, in 2021 — 9.8%, in 2020 — 9.5%) [21].

Optimizing in the war time

Theoretical issues of land management were developed in the works of: Schluter G. [6, p. 747], who investigated the extent to which an increase in the minimum wage will affect food prices; Sánchez-Fung J. [7], who deals with the stability of macro indicators; Rasool H. [11, p. 87], who investigates the relationship between rural wages and food inflation; Dorward A. [12, p. 633], food safety specialist; as well as Sitikantha P. [10, p. 244], Bhattacharya R. [11, p.144], Duckett T. [12, p. 17], Bhattacharya R. [13, p. 146], Nwaolisa E. [17] Wilson I. [19, p. 505].

During the war, the problem of optimizing the groupings of agricultural producers is relevant both at the micro and macro level, since a significant part of the Ukraine's agrarian-industrial complex products is being exported. Moreover, agricultural production is characterized by seasonality. The manufacturer periodically builds up stocks of products that will possibly be sold in the future. The proposed methodology is designed for cases when the price of agricultural products is probabilistic. Its use will allow the owner of agricultural products to protect his economic interests to the maximum possible extent. The methods of substantiating management decisions in conditions of risk and uncertainty are to be considered from Taha H. [10].

Literature review. Models and metods

Since enterprises growing wheat have different areas, and accordingly will receive different income, it is advisable to monitor their income. To do this, to begin with, the variance of the residuals for different groups of enterprises was calculated, that is, it was checked for heteroskedasticity. The presence of heteroskedasticity causes a violation of the properties of model parameter estimates when calculating them using the least squares method. Therefore, it is always necessary to study this phenomenon and, if it exists, to use the generalized least squares method (Aitken's method) to estimate the model parameters. Here, in order to determine heteroskedasticity we have used the Goldfeld–Quandt parametric test.

In an econometric model that characterizes the dependence of consumption costs on income, the variance of the residuals may change for observations that belong to different groups of the population in terms of income.

We have developed a technique for optimizing the grouping of enterprises in wartime. Since future market prices are not deterministic, the decision must be guided by two criteria: maximizing expected total net income and minimizing the variance of total net income. The Lagrange method is used to solve the problem. The developed methodology is designed for the probabilistic nature of future market prices for products and makes it possible to take inflation into account.

Let us consider the method for optimizing the grouping of enterprises in the conditions of the price risk and price fluctuations, in a wartime. Since future market prices are not deterministic, the decision must be guided by two criteria: maximizing expected total net income and minimizing the variance of total net income. To solve the problem, the Lagrange method is used. Hence, using the Lagrange method we develop a methodise, designed for cases when the price of agricultural products has a probabilistic nature. We find the maximum income according to formula:

$$\bar{z}_{\max} = \sum_{t=1}^{T} (p_{t} - c_t) x_t ,$$

$\bar{z}_{\max}$ — maximum income; $p_{\bar{t}}$ — the sale price of a product unit at the given time t; c_t — costs associated with the storage of a product unit until the time $t = \overline{1,T}$; $\sigma(z)_{\min}$ — minimal dispersion; a — production volume; T — planning period. Then the maximum dispersion is:

$$\sigma(z)_{\max} = a\sigma_t^* .$$

Next, the worst values of the criterion indicators are calculated for a set of effective variants of the calendar plan:

$$\sigma(z)_{\min} = \frac{a}{\sqrt{\sum_{t=1}^{T} \frac{1}{\sigma_t^2}}} ;$$

$$\bar{z}_{\min} = \frac{a}{\sqrt{\sum_{t=1}^{T} \frac{1}{\sigma_t^2}}} \sum_{t=1}^{T} \frac{(\bar{p}_t - c_t)}{\sigma_t^2} .$$

Therefore, we calculate the range of variation of criterion indicators:

$$\bar{z}_{\min} \le \bar{z}_0 < \bar{z}_{\max} ; \ \sigma(z)_{\min} < \sigma_0 \le \sigma_{\max} .$$

The optimal calendar plan for the sale of stocks of agricultural products is determined. This plan $x^* = (x_1^*, \ldots, x_T^*)$ is computed by solving the convex programming problem, given that s — development criteria:

$$s \to \max ,$$

$$\sum_{t=1}^{T} (\bar{p}_t - c_t) x_t \ge \bar{z}_0 + s(\bar{z}_{\max} - \bar{z}_0) , \qquad (1)$$

$$\sum_{t=1} \sigma_t^2 x_t^2 \le \sigma_0^2 - s(\sigma_0^2 - \sigma^2(z)_{\min}), \qquad (2)$$

$$\sum_{t=1}^{T} x_t = a, \qquad (3)$$

$$x_t \geq 0,\ \ t = \overline{1, T}\ . \qquad (4)$$

It should be added that the optimal value s^* will show whether the acceptable levels of criterion indicators chosen by the product owner were true (at $s^* \geq 0$) or not (at $s^* < 0$).

MODELLING THE DEPENDENCE OF ENTERPRISE'S INCOME ON THE HARVESTED AREA

To build this model, the original data set, which includes 7 observations, is used. These data and calculations based on them are given in Table 1. Based on the nature of the relationship between the value of income of enterprises from the harvested area, it can be assumed that the variance of the residuals is not constant for each observation, that is, there may be a phenomenon of heteroscedasticity. Therefore, in order to choose the right method for estimating the parameters of the model, it is necessary to check whether heteroscedasticity is inherent in the given input data.

Table 1. Input data and calculations

Enterprises by area, thousand hectares	Volume of production, thousand centners	Crop yields, 1 centner per hectare	Production expenditures per ton, UAH	Price per ton including costs, UAH	Revenue, UAH billion
up to 100.00	1986.0	39.2	630.37	7299.63	14.498
10001–200.00	2010.3	45.2	539.21	7390.78	14.858
200.01–500.00	5044.5	47.0	508.08	7421.92	37.44
500.01–1000.00	6000.8	48.3	494.38	7435.62	44.62
1000.01–2000.00	5806.4	49.4	493.27	7436.73	43.181
2000.01–3000.00	1987.1	49.6	489.98	7440.02	14.785
over 3000.00	2852.1	49.1	464.14	7465.86	21.294

Source: authors' developments.

We consider the price per ton of wheat to be a constant value, which in 2022 is 7930 UAH. The cost of wheat production on one hectare of land is 22 thousand UAH. Thus, with an average yield of 5.37 centners/hectare (Fig. 4), the cost of 1 ton of production will be equal to 4.1 thousand UAH. At the selling price of wheat of 7931 UAH/ton, the profit per hectare will be 20 thousand UAH, which will provide the profitability of more than 90%. Data for the Goldfeld–Quandt parametric test is given in Table 2.

Table 2. Data for the Goldfeld–Quandt parametric test

Y	X	X^2	XY	$\hat{Y}$	$(Y-\hat{Y})$	$(Y-\hat{Y})^2$
14.498	1986	3944196	28793.028	13.57	0.928	0.861184
14.858	2010.3	4041306.09	29869.0374	13.74	1.118	1.249924
37.44	5044.5	25446980.25	188866.081	34.98	2.46	6.0516
44.62	6000.8	36009600.64	267755.696	41.67	2.95	8.7025
43.181	5806.4	33714280.96	250726.158	40.31	2.871	8.242641
14.785	1987.1	3948566.41	29379.2735	13.57	1.215	1.476225
21.294	2852.1	8134474.41	60732.6174	19.63	1.664	2.768896

Source: authors' developments.

Identification of variables: $Y = f(X,u)$, where Y — dependent variable (revenue); X — independent variable (area size); u — stochastic component.

Model specification:

$$Y = a_0 + a_1 X + u\ ,\ \ \hat{Y} = \hat{a}_0 + \hat{a}_1 X\ ,\ \ u = Y - \hat{Y}\ .$$

Using the Goldfeld–Kwandt algorithm, we determine the presence of heteroscedasticity. We find C observations that are in the middle of the population:

$$\frac{C}{n} = \frac{4}{15},\quad \frac{C}{7} = \frac{4}{15},\quad C = \frac{4*7}{15},\quad C \approx 2\ .$$

Then $n_1 = 3$, $n_2 = 3$= 3. Let us estimate an econometric model for the population n_1= 3. Let us quantitatively estimate the model parameters based on OLS:

$$\begin{cases} n\hat{a}_0 + \hat{a}_1 \sum x = \sum y, \\ \hat{a}_0 \sum x + \hat{a}_1 \sum x^2 = \sum xy. \end{cases}$$

For each model we find the sum of squares of residuals:

$$S_1 = u_1' u_1 = \sum (Y_1 - \hat{Y}_1)^2\ ,\ \ S_2 = u_2' u_2 = \sum (Y_2 - \hat{Y}_2)^2\ ,\ \ S_1 = 8.16,\ \ S_2 = 12.48.$$

Finding the criterion R:

$$R = \frac{S_1}{S_2};\ \ R = \frac{12.48}{8.16} = 1{,}53;\ \ F_{\text{tabl}} = 6.67\ .$$

Because of $R < F_{\text{tabl}}$ grouping of enterprises by the size of the harvested area of wheat heteroscedasticity is absent. If there is no heteroscedasticity, the least squares method can be applied (Table 2).

Calculating the coefficients of linear pairwise correlation (r_{xy}) and determination (R_1^2): $R_1^2 = r_{xy}^2 = 1^2 \approx 0.9999$.

Most often, in case of a system of linear equations, the linear method of least squares is used. For our case, the linear regression formula is obtained: $Y = 0.0075 * C_3 - 0.1215$. Using this formula, we can calculate exactly how much the income will increase when the area increases by one unit. In our case, an increase in area by 1 hectare will lead to an increase in income by 0.13 (billion UAH).

Further on, we find and analyse the power regression equation $\hat{y} = ax^b$, for the inputs x_i and y_i from Table 3.

Table 3. Additional values for calculating linear pairwise correlation (r_{xy}) and determination (R_1^2) coefficient

i	x_i	y_i	$\hat{y}_i$	$(x_i - (\bar{x}))$	$(x_i - (\bar{x}))^2$	$\exists_i$	$\exists_i^2$	A_i	***c***	$\Delta\exists_i^2$
1	1986	14.4	14.6	-1683.5	2834364.65	-0.188	0.035	0.001	–	–
2	2010.3	14.8	14.8	-1659.5	2754129.91	-0.007	0.0001	0.0005	0.1811	0.0328
3	5044.5	37.4	37.4	1374.9	1890467.86	-0.051	0.002	0.0014	0.0438	0.0019
4	6000.8	44.6	44.6	2331.2	5434693.25	-0.001	0	0	0.0496	0.0025
5	5806.4	43.1	43.1	2136.8	4566097.39	0.008	0.0001	0.0002	0.0105	0.0001
6	1987.1	14.7	14.6	-1682.4	280662.037	0.090	0.008	0.006	0.081	0.006
7	2852.1	21.2	21.1	-817.45	668236.18	–	0.068	0.028	–	0.047

Source: authors' developments.

Assessing the significance of regression and correlation parameters

In order to estimate the significance of regression and correlation parameters, let's find the average value $\bar{x} = 3669{,}56$; make a table of additional values, where $\varepsilon_i = y_i - \hat{y}_i$; $\varepsilon_i = y_i - \hat{y}_i$; $A_i = \left| \frac{y_i - \hat{y}_i}{y_i} \right|$.

The average approximation error (Table 3):

$$\overline{\mathrm{A}} = n \sum \frac{(y_i - \hat{y}_i)}{y_i} 100\% = 0{,}43\%,$$

F — Fisher criteria $F_{\text{tabl}} = 6.67$.

As it is known, the least squares method is a method of finding an approximate solution of an over determined system, which is used in regression analysis. The most commonly linear least squares method is used in the case of a system of linear equations. For our case, we obtain the linear regression formula: $Y = 0.0075 * C3 - 0.1215$.

Using this formula, we can calculate, how much income will increase with an increase in area per unit. In our case, an increase in area by 1 hectare will lead to an increase in income by 0.13(billion UAH).

Let us find and analyse the power regression equation $\hat{y} = ax^b$, for data x_i and y_i for Table 4.

Table 4. Auxiliary variables for calculating power regression

i	x_i	y_i	$\ln x_i$	$\ln^2 x_i$	$\ln y_i$	$\ln x_i \ln y_i$
1	1986	14.498	7.59	57.66	2.67	20.30
2	2010.3	14.858	7.61	57.84	2.69	20.52
3	5044.5	37.44	8.52	72.69	3.62	30.88
4	6000.8	44.62	8.69	75.68	3.79	33.04
5	5806.4	43.181	8.66	75.11	3.76	32.63
6	1987.1	14.785	7.59	57.67	2.69	20.45
7	2852.1	21.294	7.95	63.29	3.06	24.33
Total	25686.9	190.676	56.64	459.97	22.31	182.18

Source: authors' developments.

Let us calculate the coefficients a and b of the power regression equation by the known formulas:

$$b = \frac{n \sum (\ln x_i * \ln y_i) - \sum \ln x_i * \sum \ln y_i}{n \sum \ln^2 x_i - (\sum \ln x_i)} = \frac{7 * 182.19 - 56.64 * 22.31}{7 * 459.97 - 56.64^2} \approx 1.0064;$$

$$a = \exp\left(\frac{1}{n} \sum \ln y_i - \frac{b}{n} \sum \ln x_i\right) = \exp\left(\frac{1}{7} * 22.31 - \frac{1.0064}{7} * 55.64\right) \approx 0.007.$$

Nonlinear regression equation $\hat{Y} = 0{,}007 * x^{1{,}0064}$.

Let's compare the calculations with linear and power regression.

The data obtained by calculations, linear and power regression actually match. Thus, both relational models can be used.

Needless to say, that in order to create economic and mathematical models of agricultural enterprises in market conditions, it is necessary to take into account all factors, in particular: land resources, labour resources, fixed assets, movable assets, financial resources, information resources, costs. The combination of these indicators makes it possible to forecast income more accurately.

Thus, the study showed the efficiency of different groups of enterprises in terms of the size of the harvested area of wheat. Their profitability and income were estimated. Since the best results are obtained from enterprises with a harvested area of 200-2000 thousand hectares (Fig. 5), this is obviously the best option for an agricultural enterprise. Nevertheless, in a war time and respective post-war times, small businesses become more manoeuvrable and accessible to the population.

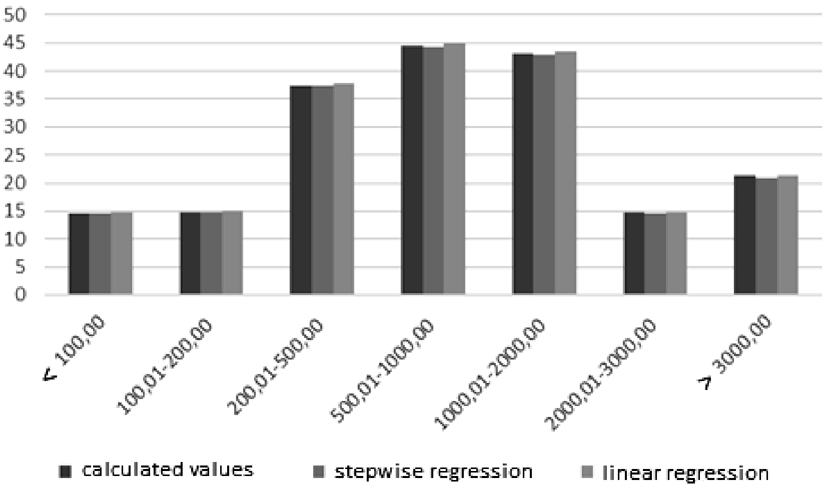

Fig. 5. Comparison of linear and power regression calculations
Source: authors' developments

General problem of conditional optimization

The general problem of conditional optimization with equality constraints is reduced to the problem of unconditional minimization using the Lagrange function, which is written in the form:

$$F(x_1,x_2,x_3,x_4,x_5,x_6,x_7,\lambda_1,\lambda_2) = f(x_1,x_2,x_3,x_4,x_5,x_6,x_7) -$$

$$-\lambda_1(u(x_1,x_2,x_3,x_4,x_5,x_6,x_7) - \lambda_2(u(x_1,x_2,x_3,x_4,x_5,x_6,x_7 - z_{\max})) .$$

An indispensable condition for using expression (2) is that the number of restrictions must be less than the number of variables. If this condition is not fulfilled, then there is no optimization problem, since the number of connections of variables exceeds their number. Thus, the task is reduced to finding the minimum of the function:

$$\frac{\partial F(x_j)\lambda_k}{\partial x_j} = 0 .$$

A necessary condition for the minimum of the function (2) is the equality of its gradient to zero, which leads to the system of equations. Consequently, solving this system of equations leads to finding unknown quantities.

The calculations were conducted in MathCAD, using the following formula for the maximum income:

$$(x_1, x_2, x_3, x_4, x_5, x_6, x_7, \lambda_1, \lambda_2) =$$

$$= 12800 \times 12 + 490 \times 22 + 80 \times 32 + 516 \times 42 + 566 \times 52 + 733 \times 62 + 2800 \times 72$$

variance:

$$u(x_1, x_2, x_3, x_4, x_5, x_6, x_7) =$$

$$= 7290 \times 1 + 7421 \times 2 + 7435 \times 3 + 7436 \times 5 + 7440 \times 6 + 7440 \times 6 + 7465 \times 7\,.$$

Solving the equation, we obtain optimal production volumes. We observe that there has been a shift towards enterprises with an area of 200.01-500.00 thousand hectares. Taking into account inflation, in order to achieve the received income, it is necessary to obtain the production volumes indicated in Table 5.

Table 5. Auxiliary variables for calculating power regression

N	Enterprises by area, thousand hectares	Volume of production, thousand centners	Price per ton incl. costs, UAH	Revenue, UAH billion	Standard price deviation, UAH σ	σ^2	Optimum production volumes	Optimum production volumes considering inflation
1	up to 100.00	1986.0	7299.63	14.498	–113.3	12838.5	920	1220
2	100.01–200.00	2010.3	7390.78	14.858	–22.2	490.9	2550	560
3	200.01–500.00	5044.5	7421.92	37.44	8.9	80.7	16500	18000
4	500.01–1000.00	6000.8	7435.62	44.62	22.7	514.5	2530	2800
5	1000.01–2000.00	5806.4	7436.73	43.181	23.8	566.1	1940	1940
6	2000.01–3000.00	1987.1	7440.02	14.785	27.1	733.5	1200	630
7	over 3000.00	2852.1	7465.86	21.294	52.9	2800.8	0.18	1

Source: authors' developments

Solving the system of partial differential equations (1)–(4), we obtain the optimal volumes of production, with the inflation taken into account. The results are shown in Table 5. We observe that there has been a shift towards enterprises with an area of 200.01–500.00 thousand hectares. That is, enterprises with an area of 200.000–500.000 hectares are the most efficient and provide the optimal volumes of wheat production. It becomes clear, considering this study, that enterprises with an area of 200–500, 500–1000 and 1000–2000 thousand hectares are efficient and competitive, and it is most expedient to develop precisely them.

The problem was solved using the Lagrange method and the probabilistic nature of prices was taken into account. The developed technique makes it possible to calculate the necessary volumes of production during the period of inflation. Calculations show that agricultural holdings are not efficient, and preference should be given to enterprises with average cultivated areas.

CONCLUSIONS

In a current paper we study the grouping of enterprises by the size of the harvested area of wheat. Wheat is one of the most important sources of income for the part of the population of Ukraine. Over the years, Ukraine has had agricultural land (71%), 78% of which is arable land; 97.2% of agricultural land is systematically used for economic purposes.

Here we examine the income of various groups of enterprises, using The Goldfeld–Quandt parametric test in order to determine heteroskedasticity.

Our analysis of yield, volume of production, income of each group of enterprises showed, that the best results are obtained by enterprises with an area of 200–2000 thousand hectares. Meaning, that large agricultural holdings proved to be not efficient, and preference should be given to enterprises with medium areas.

Since the phenomenon of heteroscedasticity was not detected, a linear regression formula was constructed using the method of least squares. For comparison, a power-law regression equation was found and analysed.

In order to predict the income for each group of enterprises by the size of the harvested area of wheat, we have developed equations of linear and nonlinear regression.

The scientific novelty of the work is that the equations of linear and nonlinear regression were developed to predict the income of each group of enterprises by the size of the harvested area of wheat. Application of the Lagrange method multipliers when solving the problem of optimization of agricultural enterprises makes it possible to increase profitability.

Developed models can be used to analyse the income and profitability of agricultural producers.

REFERENCES

1. M. Shahbandeh, "Global leading wheat producing countries 2022/2023," *Statista*. 2023, March 10. Available: https://www.statista.com/statistics/237912/global-top-wheat-producing-countries/
2. *Ministry of Agrarian Policy and Food of Ukraine*. [Official website]. 2022. Available: https://minagro.gov.ua/en
3. *FAOSTAT (2022). Statistical database of food and agriculture organization of the United Nations*. [Online]. Accessed on: March 15, 2022. Available: http://faostat.fao.org/faostat/
4. *Statistical Yearbook of Ukraine, 2021. State Statistics Service of Ukraine*. [Online]. Accessed on: February 2, 2022. Available: http://www.ukrstat.gov.ua
5. *Socio-economic characteristics of households in Ukraine 2021. State Statistics Service of Ukraine*. [Online]. Accessed on: February 2, 2022. Available: http://www.ukrstat.gov.ua
6. C. Lee, G. Schluter, and B. O'Roark, "How Much Would Increasing the Minimum Wage Affect Food Prices?" *Agriculture Information Bulletin*, vol. 3, p. 747, 2000. doi: 10.22004/ag.econ.33598.
7. J. Sánchez-Fung, "Institutions for macroeconomic stability: a review of Monetary policy in low financial development countries," *Macroeconomics and Finance in Emerging Market Economies*, vol. 15(1), 2022. Available: https://doi.org/10.1080/17520843.2022.2096913
8. I.S. Danilova and O.M. Hetmanets, "Method of determining the degree of freshness of snail meat by the photometric method (Patent of Ukraine No. 128984)," Ministry of Economic Development and Trade of Ukraine. 2018. Retrieved from https://sis.ukrpatent.org/uk/search/detail/237538/
9. V.V. Kasianchuk and N.M. Bohatko, "Method for determining degree of freshness of beef and pork meat (Patent of Ukraine No. 59032)," Ministry of Education and Science of Ukraine. 2003. Retrieved from https://uapatents. com/3-59032-sposib-viznachennya-stupenya-svizhosti-yalovichini-ta-svinini.html

10. H. Taha, *Operations Research: An Introduction Pearson*; 10th edition, 2016, 848 p.
11. H. Rasool and Md. Tarique, "Testing the link between Rural Wages and Food Inflation in India A Co-integration Approach," *IOSR 2 (IOSR-JBM)*, vol. 20(1), pp. 87–98, 2018. doi: 10.9790/487X-2001018798.
12. A. Dorward, "The short- and medium-term impacts of rises in staple food prices," *Food Security*, vol. 4, pp. 633–645, 2012. Available: https://doi.org/10.1007/s12571-012-0210-3
13. P. Sitikantha, M. Silu, and R. Soumyajit, "Inflation expectations of households: do they influence wage-price dynamics in India?" *Macroeconomics and Finance in Emerging Market Economies,* vol. 13(3), pp. 244–263, 2020. Available: https://doi.org/10.1080/17520843.2020.1720264
14. D.I. Babmindra, *Obtaining positive financial benefits as a way to get the agro-industrial complex out of the crisis*. Available: http://nbuv.gov.ua/UJRN /Zik_2013_2_6
15. P. Biber, T. Duckett, "Dynamic maps for long-term operation of mobile service robots," *Robotics: Science and Systems I*, June 8–11, pp. 17–24, 2005. Available: http://dx.doi.org/10.15607/RSS.2005.I.003
16. R. Bhattacharya, A.Sen Gupt, "Drivers and impact of food inflation in India," *Macroeconomics and Finance in Emerging Market Economies*, vol. 11(2), pp. 146–168, 2018. Available: https://doi.org/10.1080/17520843.2017.1351461
17. E. Nwaolisa, "Effects of Exchange Rate Fluctuations on the Balance of Payment in the Nigerian Economy. Approach," *IOSR Journal of Business and Management (IOSR-JBM)*, vol. 5(12), p. 7576–7583, 2017. Available: https://doi.org/10.18535/ ijsrm/v5i12.01
18. *United Nations Organization*. Available: http: //www.un.org/en/index.html
19. I. Wilson, "Strategic planning for the millennium: Resolving the dilemma," *Long rouge planning*, vol. 31, no. 4, pp. 507–551, Oxford etc., 2017. doi: 10.4236/ajibm.2017.74035.
20. A. Silva, A. Carrara, and N. Castro, "Inflation persistence for product groups in Brazil using the ARFIMA-GARCH model," *Macroeconomics and Finance in Emerging Market Economies*, vol. 15, issue 3, 2022. Available: https://doi.org/10.1080/ 17520843.2022.2080345
21. *Finbalance.* Available: https://finbalance.com.ua/news/nbu-serednorichna-inflyatsiya-v-2023-rotsi-bude-203
22. M. Usman, M.U. Rezekina, A. Baihaqi, and Srihandayani, "Analysis of export competitiveness of natural rubber from Indonesia and Thailand in the international market," *Scientific Journal of Accountancy, Management and Finance*, 1(4), pp. 220–230. doi: 10.33258/economit.v1i4.588.
23. I. Yuliadi, "A survey of agglomeration determinants in Indonesia," *Academic Journal of Interdisciplinary Studies*, 10(1), pp. 304–312, 2021. doi: 10.36941/ajis-2021-0026.
24. M. Dyadkova and G. Momchilov, *Constant market shares analysis beyond the intensive margin of external trade*. Bulgaria: Bulgarian National Bank, 2014.
25. E. Efendi et al., "Implementation of greedy algorithm for profit and cost analysis of swallow's nest processing dirty to finished products," *INFOKUM*, 10(02), pp. 849–858, 2022.

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ДОСЛІДЖЕННЯ РЕНТАБЕЛЬНОСТІ СІЛЬСЬКОГОСПОДАРСЬКИХ ПІДПРИЄМСТВ В УКРАЇНІ ПІД ЧАС ВІЙСЬКОВОГО ВТОРГНЕННЯ РОСІЇ В УКРАЇНУ / О.В. Цеслів, Т.А. Дунаєва, Ю.О. Єрешко, О.С. Цеслів

Анотація. Досліджено ефективність групування сільськогосподарських підприємств за розміром збиральної площі пшениці та дано оцінку їх прибутковості. Розроблено лінійні та нелінійні рівняння регресії для прогнозування доходу для зазначених груп підприємств. Методику розроблено для випадків, коли майбутні ринкові ціни мають імовірнісний характер. За допомогою розробленої методики можна розрахувати необхідні обсяги виробництва в умовах коливання цін. Використано параметричний тест Голдфельда–Квандта для перевірки моделі на гетероскедастичність. Розрахунки показують, що агрохолдинги насправді неефективні, і перевагу слід віддавати підприємствам із середніми посівними площами. Застосування методу множників Лагранжа для вирішення завдання оптимізації сільськогосподарських підприємств дає змогу підвищити рентабельність. Розглянуто випадок цінового ризику, коли майбутні ринкові ціни не є детермінованими. Тому під час прийняття управлінських рішень необхідно керуватися двома цілями-критеріями: максимізувати очікуваний сукупний чистий дохід і мінімізувати дисперсію сукупного чистого доходу.

Ключові слова: економіко-математичні моделі, гетероскедастичність, моделі регресійного аналізу, прибутковість, дохід, лінійна регресія, нелінійна модель, повномасштабне вторгнення росії в Україну.