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Prediction of the number of domestic animals and birds in the conditions of the economic crisis

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Abstract

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The article analyzes the nonlinear regressions, on the basis of which the forecast of economic characteristic in the crisis period is made. Regression functions are obtained by solving the corresponding differential equations. It is shown on the example of the change in the number of animals in Ukraine and Russia for 1990–2017, what these changes may correspond to an exponential, logistic regression or their modifications. It is shown that in the crisis period, the dynamics of the decrease in the number of livestock corresponds to the modified exponential regression. It is suggested to find the two parameters of these regressions using the least squares method, the third parameter to be determined by the numerical method with the minimum average absolute percentage error (MAPE). At the exit of the crisis state, when the process of increasing the number of livestock begins, the dynamics corresponds to a modified logistic regression. Two logistic regression parameters were determined using the least squares method, the third and fourth parameters calculate by a numerical method from the condition of a minimum MAPE as a function of two variables. The theoretical findings obtained are in good agreement with the statistics corresponding to the dynamics of cows, pigs, sheep, goats and poultry in Ukraine for the period 1990–2017.

Keywords: prediction; exponential and logistic regressions; time series forecasting

Introduction

The global economic crisis which began since 2008 that gradually covered all sectors of the economy, led to a sharp decline in the main economic indicators of most countries of the world, subsequently causing a global recession of the economy. As a result, in recent years, the problem of forecasting indicators of time series in the context of a prolonged economic crisis is becoming increasingly important. The greatest accuracy of the forecast has a method based on linear and curvilinear regressions (Allen, 1994; Corraya, 2016; Elliott & Timmermann, 2016; Goldberger, 1964).

The regression analysis is based on the choice of the function that best approximates the statistical data corresponding to a given trend. Regression parameters are determined by the ordinary least squares method (OLS) (Goldberger, 1964). The algorithm for determining the parameters of the function obtained for linear regression (Goldberger, 1964). The quality of the approximation of statistical data is determined by the mean absolute percentage error (MAPE) (Guorfi et al., 2002)

$$MAPE = \frac{100\%}{n}\sum_{i=1}^{n}\left|\frac{E(t)_i}{K(t)_i}\right|, \quad (1)$$

where: $E(t) = K(t) - \overset{\frown}{K}(t)$, $K(t)$ is the statistical quantity, and $\overset{\frown}{K}(t)$ is the corresponding regression quantity.

If MAPE < 10%, then the quality of the approximation is considered high. When MAPE > 20%, it is necessary to proceed to the search for the corresponding curvilinear regression or averaging the oscillations of the parameter being studied (Billah et al., 2006; Clements & Hendry, 1998; Lin & Zhang, 2006; Tibshirani, 2014).

Curvilinear regressions can be divided into two groups. The first is curvilinear regressions, which can be converted to linear regression by logarithm of the function and the corresponding change of variables (Holt, 2004; Nepochatenko, 2012). The most used regressions of this type in economics are: power-law, exponential and hyperbolic regressions. The second regression group is non-linear in parameters (Bates & Watts, 1988; Ramos, 2013; Shehu, 2015). The most common: S-shaped Gompertz curve, logistic Pearl-Reed curve, Tornquist curve, Johnson curve. Two parameters of these regressions can be estimated using the OLS; the others are determined by numerical methods (Kucharavy & Guio, 2011; Nepochatenko, 2013; Wasserman, 2006).

For the study of crisis, the economy of Ukraine is a good model object, since the crisis in this country began much earlier, in 1991. Its beginning was due to a change in property rights during the collapse of the Soviet Union.

In this paper, as the object of the regression study, we chose animal husbandry of Ukraine. The analysis of changes in the number of livestock and poultry in general in farms of all categories was carried out for the period 1990–2017.

The choice of the regression function is based on solving the obtained differential equations. We have proposed, when determining the unknown parameters of curvilinear regressions by a numerical method, to use the minimum of the average absolute percentage error of approximation.

Based on the regressions obtained, a forecast was made of the number of livestock and poultry in Ukraine in 2025. To test the universality of the solutions obtained, a forecast of the number of cows in Russia was made.

The Research Methods

In the process of scientific research the method of regression analysis of statistical data, the method of numerical finding of the minimum of functions with one and two variables, and the solutions of the obtained differential equations were used.

Determination of the type of approximating functions

Let us consider which analytical function can correspond to the dynamics of reducing the livestock of agricultural animals and poultry during the crisis period, when the industry has a special need to attract investments and government support, without which most agricultural producers cannot have expanded animal reproduction. In this case, the change in the number of animals is a negative value, which is proportional to the previous quantity and the time change Δt

$$\Delta N = a_1 \cdot N \cdot \Delta t. \quad (2)$$

From (2) we obtain the differential equation:

$$dN = a_1 \cdot N \cdot dt, \quad (3)$$

whose solution is an exponential function:

$$N(t) = a_0 \cdot \exp(a_1 \cdot t) \quad (4)$$

where a_0 and a_1 are function parameters that do not change within the time series under investigation, the parameter $a_1 < 0$.

It should be noted that when determining the regression parameters (4) it is possible to obtain numbers with large degrees, so it is better to use the following regression:

$$N(t) = \exp(a_0 + a_1 \cdot t) \quad (5)$$

The parameters of the exponential regression are found by the method OLS, first converting (5) to linear regression:

$$ln(N(t)) = a_0 + a_1 \cdot t, \quad (6)$$

$$z = a_0 + a_1 \cdot t, \quad (7)$$

$$a_1 = (\overline{tz} - \overline{t} \cdot \overline{z})/(\overline{t^2} - \overline{t}^2);\ a_0 = \overline{z} - a_1\overline{t}, \quad (8)$$

where: $z = ln(N(t))$;

$$\overline{tz} = \frac{\sum_{i=1}^{n} tz}{n};\ \overline{t} = \frac{\sum_{i=1}^{n} t}{n};\ \overline{z} = \frac{\sum_{i=1}^{n} z}{n};\ \overline{t^2} = \frac{\sum_{i=1}^{n} t^2}{n};$$

n is the sampling size

The decreasing exponential regression (5) asymptotically approaches zero when $t \to \infty$, but sometimes the statistical data do not correspond to such an asymptote. In the latter case, we proposed to use a modified exponential regression

$$N_1(t,C) = \exp[a_0(C) + a_1(C) \cdot t] + C, \tag{9}$$

where C is the coefficient corresponding to the asymptotic value.

The parameters of the modified exponential regression $a_0(C)$ and $a_1(C)$ find the similar to (8), and the parameter C is found by a numerical method, from the minimum of the average absolute percentage error of approximation

$$MAPE(C) = \frac{100\%}{n}\sum_{i=1}^{n}\left|\frac{E(t,C)_i}{N_s(t)_i}\right|, \tag{10}$$

where $E(t,C) = N_s(t) - N(t,C)$ is the value difference between statistical and regression values of the number of animals.

For the case when the own financial resources of agricultural enterprises are sufficient to ensure expanded reproduction of livestock and poultry, the change in the number of animals ΔN is a positive value, which is also proportional to the previous number N and time change Δt

$$\Delta N = a_1 \cdot N \cdot \Delta t, \tag{11}$$

but the coefficient a_1 is not a constant over the study period, since the possible maximum quantity N_m is limited by the food supply, the conditions of housing and the sale of products. We assume that a_1 is proportion to the difference between the maximum and previous number of animals or poultry

$$a_1 = a_0 (N_m - N), \tag{12}$$

From (11), (12) we get:

$$\Delta N = a_0 \cdot (N_m - N) \cdot N \cdot \Delta t, \tag{13}$$

Equation (13) corresponds to the Bernoulli differential equation (Korn, 1968)

$$N' - a_0 \cdot N_m \cdot N = - a_0 \cdot N^2, \tag{14}$$

the solution of which is the logistic function of Pearl-Reed

$$N(t, N_m) = \frac{N_m}{1 + \exp(a_2 - a_3 \cdot t)} \tag{15}$$

where $a_2 = C_k \cdot N_m$; $a_3 = a_0 \cdot N_m$; C_k is the integration constant.

In order to determine the parameters of logistic regression from statistical data, it is necessary to convert (15) to linear regression

$$\frac{N_m}{N_s(t)} - 1 = \exp(a_2 - a_3 \cdot t), \tag{16}$$

$$Z(t, N_m) = a_2(N_m) - a_3(N_m) \cdot t, \tag{17}$$

The linear regression parameters (17) $a_2(N_m)$ and $a_3(N_m)$ find the OLS method similarly (8), the parameter N_m is determined by a numerical method from the condition of a minimum of the average absolute percentage approximation error:

$$MAPE(N_m) = \frac{100\%}{n}\sum_{i=1}^{n}\left|\frac{E(t, N_m)_i}{N_s(t)_i}\right|, \tag{18}$$

where $E(t, N_m) = N_s(t) - N(t, N_m)$, N_s is the statistical data.

The logistic decreasing regression asymptotically approaches zero when $t \to \infty$, but if the statistical data do not correspond to such an asymptote, then in this case we suggested using a modified logistic regression

$$N(t, N_m, C) = \frac{N_m}{1 + \exp(a_2(N_m, C) - a_3(N_m, C) \cdot t)} + C, \tag{19}$$

where C is the coefficient corresponding to the asymptotic value of the logistic regression.

The parameters of the modified logistic regression (19) $a_2(N_m, C)$ and $a_3(N_m, C)$ find the method of OLS similar to (7), the parameters N_m and C determined by a numerical method from the condition of a minimum of the average absolute percentage approximation error as a function of two variables:

$$MAPE(N_m, C) = \frac{100\%}{n}\sum_{i=1}^{n}\left|\frac{E(t, N_m, C)_i}{N_s(t)_i}\right|, \tag{20}$$

where $E(t, N_m, C) = N_s(t) - N(t, N_m, C)$.

Results and Discussion

Since 1990, in Ukraine, the number of cows has been decreasing every year (Figure 1). From our analysis, we have obtained that this time series since 1994 is well approximated by a modified exponential regression

$$N_1(t) = \exp(a_0 + a_1 \cdot t) + C_1, \tag{21}$$

where $a_0 = 193.463$; $a_1 = 0.096$; $C_1 = 1.276$; $MAPE = 2.24\%$

If there is no significant increase in funding for the expanded reproduction of the number of cows, then, according to the regression obtained, in 2025 the number of cows will amount $N_1(2025) = 1.62$ million, which is 5.17 times less than in 1990.

The number of pigs in Ukraine also decreased according to the exponential law from 1990 to 2008, with small fluctuations in numbers after 1996 (Figure 2). During this period, it corresponds to the modified exponential regression

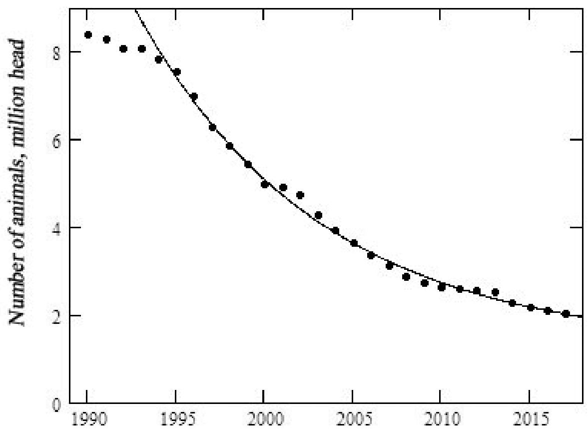

Fig. 1. Dynamics of change in the number of cows in Ukraine for 1990–2017
Source: The Statistical Yearbook "Agriculture of Ukraine" www.ukrstat.gov.ua

$$N_2(t) = \exp(a_3 + a_4 \cdot t) + C_2, \qquad (22)$$

where $a_3 = 247.205$; $a_4 = 0.23$; $C_2 = 4.372$; $MAPE = 5.06\%$

After 2008, there was a slight increase in the number of pigs, right up to 2013, and after that their numbers decreased linearly. If this trend continues, in 2025 the number of pigs will correspond to the results of the exponential regression $N_2(2025) = 4.57$ a million heads. .

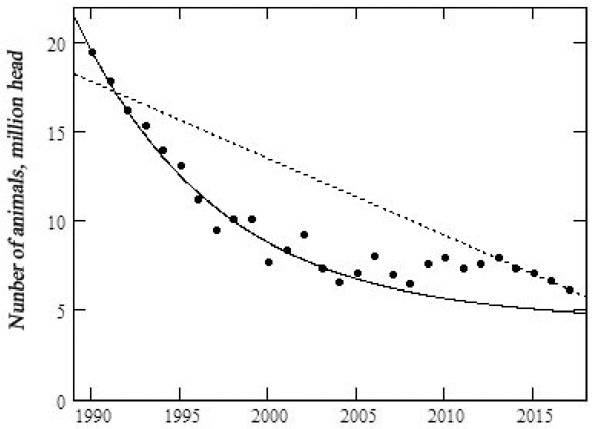

Fig. 2. Dynamics of changes in the number of pigs in Ukraine for 1990–2017
Source: The Statistical Yearbook "Agriculture of Ukraine" www.ukrstat.gov.ua

During the study period, the change in the livestock of sheep and goats in Ukraine corresponded to the modified logistic regression of Pearl-Reed (Figure 3):

$$N_3(t, N_m, C_3) = \frac{N_m}{1 + \exp(a_2(N_m, C_3) + a_3(N_m, C_3) \cdot t)} + C_3, \qquad (23)$$

where $a_2 = 621.858$; $a_3 = 0.312$; $N_m = 9.2$; $C_3 = 1.3093$; $MAPE = 16.5\%$

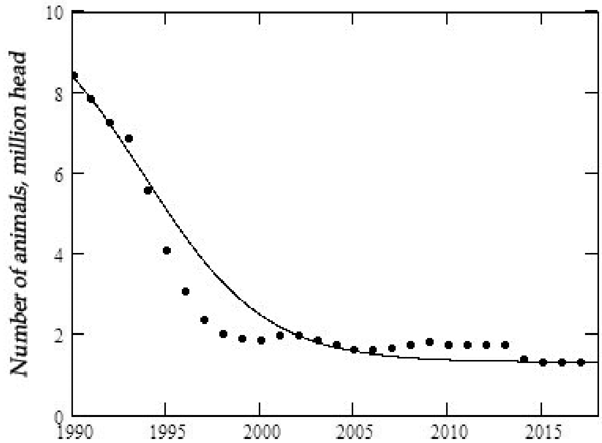

Fig. 3. Dynamics of change in the number of sheep and goats in Ukraine for 1990–2017
Source: The Statistical Yearbook "Agriculture of Ukraine" www.ukrstat.gov.ua

According to the results of research, if there is no significant change in the financing of this livestock industry, then in 2025 the total number of sheep and goats will remain at the level of 2016 $N_3(2025) = 1.31$ million heads.

The change in the number of poultry in Ukraine differed significantly from the number of domestic animals, at first it decreased, then increased (Figure 4). From 1991 to 1997, the number of poultry decreased by exponential law ($MAPE = 1.65\%$)

$$N_4(t) = \exp(a_5 + a_6 \cdot t), \qquad (24)$$

where $a_5 = 239.23$; $a_6 = 0.117$.

Since 1998, the number of poultry has increased annually, what explained by the significant amounts of state funding for this branch of animal husbandry, in particular - large poultry farms. During this period, the modified logistic regression of Pearl-Reed corresponded well with the change in the number of poultry.

$$N_5(t, N_m, C_4) = \frac{N_m}{1 + \exp(a_7(N_m) + a_8(N_m) \cdot t)} + C_4, \qquad (25)$$

where $a_7 = 194.167$; $a_8 = 0.096$; $N_m = 789.5$; $C_4 = 85.59$; $MAPE = 2.2\%$

Since 2014, the number of poultry has decreased due to the onset of the second stage of the crisis in Ukraine. Since the further trend has not been determined, the forecast of the number of birds is difficult.

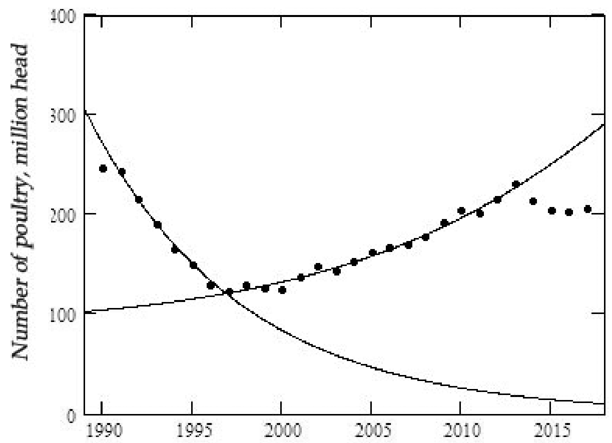

Fig. 4. Dynamics of changes in the number of poultry in Ukraine for 1990–2017
Source: The Statistical Yearbook "Agriculture of Ukraine" www.ukrstat.gov.ua

These regressions can also be used to predict the number of farm animals and birds in other countries, if there are stable trends in the agrarian sector. As an example, we apply the proposed regressions to analyze the dynamics of changes in the number of cows in Russia for the period 1990–2017.

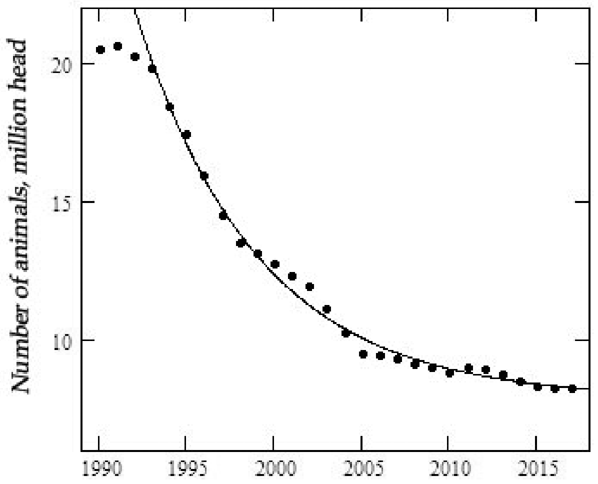

Fig. 5. Dynamics of change in the number of cows in the Russian Federation for 1990-2017
Source: The Statistical Yearbook "Agriculture of Ukraine" www.ukrstat.gov.ua

Since 1993, the number of livestock of cows corresponded to a modified exponential regression (Figure 5)

$$N_6(t) = \exp(a_0 + a_1 \cdot t) + C_5, \tag{26}$$

where $a_0 = 288.35$; $a_1 = -0.143$; $C_5 = 7.88$.

However, the relative decrease in the number of cows in the Russian Federation for 1993-2017 is 1.28 times less than in Ukraine.

According to the obtained regression, if in the near future there is be no increase in the volume of investments in the fixed capital of the industry, the number of livestock of cows in the Russian Federation will continue to decrease and in 2025 will reach the level of 7.99 million heads.

Conclusions

Thus, during a prolonged economic crisis in Ukraine, the dynamics of the number of livestock and poultry can be approximated by exponential, modified exponential or logistic and modified logistic regressions. From the obtained regressions one can make a forecast of the number of animals and birds for the subsequent years.

The main factor of overcoming the crisis in the agrarian sector is an increase in the profitability of agricultural producers by increasing purchase prices and government subsidies, modernizing production and increasing investments.

References

Allen, P. G. (1994). Economic forecasting in agriculture. *International Journal of Forecasting*, *10,* 81-135.

Bates, D. & Watts, D. (1988). Nonlinear regression and its applications. Wiley-Interscience.

Billah, B., King, M. L., Snyder, R. D. & Koehler, A. B. (2006). Exponential smoothing model selection for forecasting. *International Journal of Forecasting*, *22,* 239-247.

Clements, M. & Hendry, D. (1998). Forecasting economic processes. *International Journal of Forecasting, 14(1),* 111-131.

Corraya, A. D. & Corraya, S. (2016). Regression based price and yield prediction of agricultural crop. *International Journal of Computer Applications (0975 – 8887), 152(5),* 1-7.

Elliott, G. & Timmermann, A. (2016). Forecasting in economics and finance. *Annual Review of Economics, 8,* 81-110.

Goldberger, A. (1964). Econometric theory, New York. John Wiley & Sons.

Guorfi, L., Kohler, M., Krzyzak, A. & Walk, H. (2002). Distribution-free theory of nonparametric regression. Springer, New York.

Holt, C. (2004). Forecasting trends and seasonal by exponentially weighted averages. *International Journal of Forecasting, 20*, 5-13.

Korn, G. & Korn, **T.** (1968). Mathematical handbook. New York: McGraw-Hill.

Kucharavy, D. & Guio, R. (2011). Application of S-shaped curves. *Procedia Engineering, 9,* 559–572.

Lin, Y. & Zhang, H. H. (2006). Component selection and smoothing in multivariate nonparametric regression. *Annals of Statistics, 34(5),* 2272–2297.

Nepochatenko, **A. & Nepochatenko, V.** (2012). Correlation-regression analysis of changes in the number of machinery in agricultural enterprises of Ukraine for the period 2000-1010. *Ekonomika ta Upravlinnya APK, 7* (*93*), 98 – 101(Ukr).

Nepochatenko, **A. & Nepochatenko, V.** (2013). Economic and mathematical modeling of the value of the harvesting costs depending on the power of the combine harvester engine. *Ekonomika ta Upravlinnya APK, 11* (*106*), 130-136 (Ukr).

Ramos, R. (2013). Logistic function as a forecasting model: it's application to business and economics. *International Journal of Engineering and Applied Sciences, 2(3)*, 29-36.

Shehu, V. (2015). Logistic equation and its application as forecasting model of vegetables production in greenhouses in Albania. *Albanian J. Agric. Sci. 14 (3)***,** 228-235.

Tibshirani, R. J. (2014). Adaptive piecewise polynomial estimation via trend filtering. *Annals of Statistics, 42(1)*, 285–323.

Wasserman, L. (2006). All of nonparametric statistics. Springer, New York.

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