CHAPTER 1
CURRENT TRENDS IN ECONOMIC DEVELOPMENT

MODELING THE IMPACT OF ECONOMIC INDICATORS ON FOOD SECURITY

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Abstract*. The article considers the methods of economic modeling to ensure the security and sustainability of the food supply system. It is justified that this allows to ensure the complementarity of the activities of different entities and to create an appropriate basis for the development of the industry as a whole. It is proved that the quality of the formation of such a base largely depends on the quality of the selected indicators and their compliance with the factors of success in ensuring food security. An integrated approach to the study of food security is applied, its properties, principles and elements as a complex multi-level system structure are disclosed. It is proved that a systematic approach, as a direction of scientific methodology, should be used to study food security problems, since they are complex and non-standard. It is established that theoretical and methodological approaches to the study of food security should be based on two general scientific approaches such as systemic and integrated. The main parametric criteria level of food security of the country as whole and individual regions is defined. The assessment of agricultural production using the tools of economic-mathematical descriptive modeling is evaluated. At the methodological level, nine components of food security have been identified as a complex system that affect food security. Using the Statgraphics XVII Centurion statistical data analysis software package, a multi-factor model is constructed, the presence and type of relationship between independent variables is verified and established. It is established that due to forecasting agricultural production, linear models are often used. A predictive multi-factorial regression model of the relationship of food security components is built. An ANOVA analysis has been carried out, a hypothesis has been proved on the correlation between changes in agricultural production and household incomes, consumption of bread and bread products, meat and meat products and budget expenditures of the Ministry of Agrarian Policy and Food. The article outlines the benefits of using the methods of economic modeling.*

Keywords*: economic modeling, food production, food security, forecasting production, national economy.*

JEL Classification: C52, E19, F52, Q19

Formulas: 3; fig.: 1; tabl.:4; bibl.: 19

Introduction. The development of long-term forecasts for the development of agro-industrial production should become a permanent and extremely important area of activity of the Government of Ukraine. Overcoming the consequences of long-term decline in food production and consumption of basic foodstuffs, achieving expanded reproduction and functioning of agricultural producers in a market economy requires the formulation and implementation of large-scale and multifaceted tasks of socio-economic development. The process of harmonizing the parameters of agricultural policy, planning and forecasting economic growth is becoming increasingly complex. Therefore, an effective tool for achieving long-term priorities and goals of state development should be modeling the main activities.

The importance of analysis and forecasting of resource, technological and financial constraints and barriers in the conditions of uncertainty of long-term prospects increases. All this determines the relevance of the study of this issue and the need to improve and develop methods and model tools in the development of long-term forecasts, possible alternatives and scenarios in agriculture.

Recently, the construction of such systems is based on a cognitive approach that combines formalized scientific knowledge with the experience of experts and the creative potential of decision makers. Given the complexity of studying the problem of food security of the national economy, it is advisable to proceed to a qualitative analysis of the interrelated factors that affect the development of production and overall welfare.

Literature review. For a long time in different countries of the world experience of development of models of the analysis of an economic situation and scenario forecasting of economic dynamics was accumulated. Such tool systems typically include pre-processing and short-, medium- and long-term forecasting models.

The peculiarity of econometric models is that the evaluation of their parameters is carried out using statistical methods, which allows the use of standard hypothesis testing procedures to verify the correctness of the model specification in accordance with the normality of the distribution. In addition, for qualitative modeling it is necessary to have information about the data of all values of input variables for a long period of time [1, p. 110].

In order for the solution of the problem of determining the parameters of the model to exist and be unique, a number of constraints must be met that combine the number of equations and their form with the number of endogenous variables in the model [2].

Therefore, there are many works in which new methods are proposed or existing ones are improved [3]. Thus, most modern long-term macroeconomic econometric models have three key blocks of equations: equilibrium conditions, description of expectations, and description of the transition of the model to a new equilibrium when changing parameters [4-7].

The methodology of cognitive modeling, designed for analysis and decision making in difficult to predict situations, was proposed by Axelrod R. [8]. Later this question was developed in the works of Roberts FS. [9], and Simplicial Analysis and the Chains of Connection method of the cognitive map have been examined in detail by such well-known researchers as Atkin R. and Casti JL. [10].

Analysis of domestic developments in cognitive modeling shows that the vast majority of scientific papers are related to the development of theoretical research based on foreign methods of evaluating complex systems using dialogic management decision-making systems [11-16].

A prominent contribution to the development of these methods was made by the prominent Ukrainian mathematician Mykhailo Ostrogradsky, who in the middle of the XIX century formulated the basic ideas of statistical control over the quality of production [17, p. 5].

Therefore, the use of modeling in research on food security and the choice of the optimal development scenario is an extremely important task that requires the use of appropriate theoretical and methodological approaches and methods for solving problems of complex systems under uncertainty.

Aims. Investigate the methods of economic modeling of complex economic systems to ensure food security of the national economy.

Methods. The main research methods were scientific abstraction, logical generalization, graphic, economic and cognitive modeling for identification the impact of economic indicators on food security, visual reflection the system of food production for future periods and for the development of a food production model.

Results. Among the models directly related to agricultural production, the key is the model of forecasting production and its efficiency. In modern conditions, ensuring high efficiency of economic research requires not only original highly effective solutions, but also the development of various models of economic relations in almost all areas of production, processing and sale of agricultural products, including related areas [18].

Basic data analysis procedures are most often implemented using modern computer technology. At the same time, researchers either build calculation algorithms themselves and write appropriate computer programs, or use existing software.

Successful solution of food security problems as a complex socio-economic system also involves multidimensional statistical analysis using special mathematical packages. To conduct such research, we use the statistical analysis program Statgraphics XVII Centurion. The statistical package provides many opportunities for in-depth, visual analysis of data from socio-economic systems, which are described by various features measured on metric and non-metric scales.

The task of the study of food security as a complex system using multidimensional statistical analysis is to verify the presence and type of relationship between independent variables chi (predictors, factors), the values of which may vary and have a predetermined error, and the dependent variable (response) z.

Our analysis of components and their importance in ensuring food security as a complex system (19) allowed us to identify those indicators that have the greatest impact on its level. These include:

ProdAgro – production of agricultural products, per person per year, kg;

IP – disposable income per capita per year, UAH;

CBread – consumption of bread products, per person per year, kg;

CMilk – consumption of milk and dairy products, per person per year, kg;

CMeat – consumption of meat and meat products, per person per year, kg;

TaxF – tax freedom, %;

InvF – investment freedom, %;

BusF – business freedom, %;

Budget – budget expenditures under KPKV 2800000 of the Ministry of Agrarian Policy and Food of Ukraine, in % of all expenditures.

Thus, it is possible to formulate a hypothetical model consisting of factors (predictors), which, according to our assumptions, significantly affect the studied characteristics of the food security system.

Let us test our assumption using the Multiple Variable Analysis capabilities for the selected eight predictors (IP, CBread, CMilk, CMeat, TaxF, InvF, BusF, Budget) and the main variable ProdAgro (Table 1).

Table 1. Matrix of correlation coefficients for all variables

	ProdAgro	IP	CBread	CMilk	CMeat	TaxF	InvF	BusF	Budget
ProdAgro		0,9396	-0,8389	-0,3830	0,6873	0,3414	-0,4492	0,5180	-0,7738
		(19)	(19)	(19)	(19)	(19)	(19)	(19)	(19)
		0,0000	**0,0000**	0,1056	**0,0011**	0,1525	0,0537	**0,0231**	**0,0001**
IP	0,9396		-0,9195	-0,5190	0,7496	0,4135	-0,4976	0,4060	-0,7787
	(19)		(19)	(19)	(19)	(19)	(19)	(19)	(19)
	0,0000		**0,0000**	**0,0228**	**0,0002**	0,0785	**0,0302**	0,0845	**0,0001**
CBread	-0,8389	-0,9195		0,4519	-0,8996	-0,5675	0,7185	-0,1402	0,7556
	(19)	(19)		(19)	(19)	(19)	(19)	(19)	(19)
	0,0000	**0,0000**		0,0521	**0,0000**	**0,0113**	**0,0005**	0,5669	**0,0002**
CMilk	-0,3830	-0,5190	0,4519		-0,2431	0,2281	-0,0668	-0,2497	0,3732
	(19)	(19)	(19)		(19)	(19)	(19)	(19)	(19)
	0,1056	**0,0228**	0,0521		0,3160	0,3476	0,7859	0,3026	0,1155
CMeat	0,6873	0,7496	-0,8996	-0,2431		0,6490	-0,8148	-0,1632	-0,6531
	(19)	(19)	(19)	(19)		(19)	(19)	(19)	(19)
	0,0011	**0,0002**	**0,0000**	0,3160		**0,0026**	**0,0000**	0,5043	**0,0024**
TaxF	0,3414	0,4135	-0,5675	0,2281	0,6490		-0,6227	-0,2938	-0,2318
	(19)	(19)	(19)	(19)	(19)		(19)	(19)	(19)
	0,1525	0,0785	**0,0113**	0,3476	**0,0026**		**0,0044**	0,2221	0,3395
InvF	-0,4492	-0,4976	0,7185	-0,0668	-0,8148	-0,6227		0,1579	0,5461
	(19)	(19)	(19)	(19)	(19)	(19)		(19)	(19)
	0,0537	**0,0302**	**0,0005**	0,7859	**0,0000**	**0,0044**		0,5186	**0,0156**
BusF	0,5180	0,4060	-0,1402	-0,2497	-0,1632	-0,2938	0,1579		-0,3129
	(19)	(19)	(19)	(19)	(19)	(19)	(19)		(19)
	0,0231	0,0845	0,5669	0,3026	0,5043	0,2221	0,5186		0,1921
Budget	-0,7738	-0,7787	0,7556	0,3732	-0,6531	-0,2318	0,5461	-0,3129	
	(19)	(19)	(19)	(19)	(19)	(19)	(19)	(19)	
	0,0001	**0,0001**	**0,0002**	0,1155	**0,0024**	0,3395	**0,0156**	0,1921	

Source: author's development

In the table 1 calculated Pearson instantaneous correlation coefficients between each pair of variables. These coefficients range from -1 to +1 and measure the strength of the linear relationship between variables. The number of pairs of data values used to calculate each coefficient is indicated in parentheses. Then comes the value of P-value (third number), which checks the statistical significance of the calculated correlations. If the P-value is lower than 0.05, it indicates statistically significant non-zero correlations with a probability of 95.0%.

In our investigation, the values of P-value below 0.05 have the following pairs of variables:

ProdAgro and CMilk – 0.1056; correlation coefficient – -0.3830;

ProdAgro and TaxF – 0.1525; correlation coefficient – +0.3414;

ProdAgro and InvF – 0, 0537; the correlation coefficient is -0.4492.

In addition, there is a weak relationship between other pairs of variables:

IP and BusF – P-value <0.05 and is 0.0845;

CBread and BusF – P-value <0.05 and is 0.5669;

CMilk and BusF – P-value <0.05 and is 0.3026;

CMeat and BusF – P-value <0.05 and is 0.5043;

TaxF and BusF – P-value <0.05 and is 0.2221;

InvF and BusF – P-value <0.05 and is 0.5186;

Budget and BusF – P-value <0.05 and is 0.1921.

Given the P-value and the low correlation coefficient, which indicates a weak relationship between pairs of variables (less than 50%) with a probability of 95%, these variables can be further discarded for a reliable statistical analysis.

Construct a matrix of estimation correlation coefficients with four variables that remained after the preliminary analysis to check the statistical significance of the calculated correlations, and the main variable ProdAgro (Table 2).

Table 2. Correlation matrix for selected variables

	ProdAgro	IP	CBread	CMeat	Budget
ProdAgro		0,9396	-0,8389	0,6873	-0,7738
		(19)	(19)	(19)	(19)
		0,0000	**0,0000**	**0,0011**	**0,0001**
IP	0,9396		-0,9195	0,7496	-0,7787
	(19)		(19)	(19)	(19)
	0,0000		**0,0000**	**0,0002**	**0,0001**
CBread	-0,8389	-0,9195		-0,8996	0,7556
	(19)	(19)		(19)	(19)
	0,0000	**0,0000**		**0,0000**	**0,0002**
CMeat	0,6873	0,7496	-0,8996		-0,6531
	(19)	(19)	(19)		(19)
	0,0011	**0,0002**	**0,0000**		**0,0024**
Budget	-0,7738	-0,7787	0,7556	-0,6531	
	(19)	(19)	(19)	(19)	
	0,0001	**0,0001**	**0,0002**	**0,0024**	

Source: author's development

The calculated new instantaneous correlation coefficients of Pearson between each pair of variables indicate a fairly close relationship between agricultural production per capita per year (ProdAgro) and household income per capita per year (IP) – density + 93.96% , as well as with the consumption of bread and bread products per person per year (CBread) – density -83.89.

The average density of communication found by us between the pairs of agricultural production per capita per year (ProdAgro) and budget expenditures for KPKV 2800000 of the Ministry of Agrarian Policy and Food of Ukraine – -77.38%, as well as the consumption of meat and meat products per person per year (CMeat) – density 68.73%.

The "+" sign of the correlation coefficient indicates a direct relationship between the pairs, and the sign "-" – the inverse.

The value of P-value for all pairs of variables is lower than 0.05, which indicates the statistical significance of the calculated correlations with a probability of 95.0%.

To check the normality of statistical data, we analyze two most important indicators: standardized asymmetry and standardized excess, which can be used to determine whether the studied variables meet the conditions of normal distribution. If the values of the statistical data are outside the range from -2 to +2, it indicates a significant deviation from the norm, that is the distribution is not normal. In this case, many performed statistical operations on such data are not reliable (Table 3).

Table 3. Summary Statistics

	ProdAgro	*IP*	*CBread*	*CMeat*	*Budget*
Count	19	19	19	19	19
Average	3492,28	19148,6	114,437	45,8526	2,97368
Median	2219,6	14373,0	111,7	50,6	2,9
Standard deviation	2149,4	16020,3	10,0103	8,48386	1,7779
Coeff. of variation	61,5471%	83,6629%	8,74743%	18,5025%	59,7879%
Minimum	1584,0	1760,6	99,5	31,1	0,3
Maximum	8659,7	58442,0	131,2	56,1	6,6
Range	7075,7	56681,4	31,7	25,0	6,3
Lower quartile	1909,0	5704,1	108,4	38,5	1,4
Upper quartile	5595,0	26782,0	124,5	52,0	4,5
Interquartile range	3686,0	21077,9	16,1	13,5	3,1
Stnd. skewness	1,74928	1,8275	0,247099	-1,14769	0,460764
Stnd. kurtosis	-0,161368	0,494483	-1,02321	-1,07164	-0,71542

Source: author's development

As can be seen from the table. 3, standardized asymmetry (Stnd. Skewness) and standardized excess (Stnd. Kurtosis) outside the range -2 to +2 do not go beyond all analyzed variables. This indicates their compliance with the normal distribution and the reliability of the following statistical actions.

Based on the results of the analysis of statistical significance and compliance of the selected variables with the normal distribution, we can assume that the general model of growth of agricultural production per capita (ProdAgro) from our selected four independent variables can be represented as a system of equations:

$$ProdAgro = f(IP, CBread, CMeat, Budget) \qquad (1);$$

$$ProdAgro = \varepsilon + C_1 \times IP + C_2 \times CBread + C_3 \times CMeat + C_4 \times Budget \qquad (2);$$

where ε – magnitude of random deviations; C (1,2,… n) – regression coefficients of independent variables.

To test our assumption about the possible type of dependence of Y on X1,2… n, we construct a multifactor regression model of the growth of agricultural production per capita per year (ProdAgro). This model makes it possible to predict one variable taking into account the values of several other variables (Table 4).

Table 4. Multiple Regression – ProdAgro

Dependent variable: ProdAgro				
Method: Ordinary Least Squares				
Number of observations: 19				
		Standard	*T*	
Parameter	*Estimate*	*Error*	*Statistic*	*P-Value*
CONSTANT	-8056,65	11921,8	-0,675789	0,5102
IP	0,143847	0,0350285	4,10657	**0,0011**
CBread	70,6093	80,5691	0,876382	0,3956
CMeat	25,1778	56,5214	0,445455	0,6628
Budget	-148,068	169,727	-0,87239	0,3977

Analysis of Variance					
Source	*Sum of Squares*	*Df*	*Mean Square*	*F-Ratio*	*P-Value*
Model	7,4395E7	4	1,85988E7	29,71	**0,0000**
Residual	8,76317E6	14	625941,		
Total (Corr.)	8,31582E7	18			

R-squared = **89,462** percent	Mean absolute error = **518,076**
R-squared (adjusted for d.f.) = **86,4512** percent	Durbin-Watson statistic = 0,993526 (P=**0,0007**)
Standard Error of Est. = **791,164**	Lag 1 residual autocorrelation = 0,472683

Source: author's development

The parameters of the model were estimated using the least squares method, because according to our preliminary calculations, the variable Y (ProdAgro) corresponds to the normal distribution.

The initial data of table. 4 show the results of the selection of a multifactor linear regression model to describe the relationship of ProdAgro with four independent variables. The equation of the model is as follows:

$$ProdAgro = -8056,65 + 0,143847 \times IP + 70,6093 \times CBread + 25,1778 \times CMeat - 148,068 \times Budget \qquad (3);$$

The value of P-value in the ANOVA table is less than 0.05 and equal to 0.0000, so we can conclude that there is a statistically significant relationship between the studied variables with a probability of 95.0%.

The R-Squared indicator shows that in this form our model explains the change in agricultural production per capita per year (ProdAgro) by 89.46%, which is a high value.

The adjusted R-Squared, which is more suitable for comparing models with different numbers of independent variables, is 86.45%, which is also quite a high value for our model. The standard estimate error shows a standard deviation of the residuals of 791,164.

The average value of the balances shows the average absolute error (MAE), which is equal to 518,076.

Durbin-Watson statistics (P-value = 0.0007 <0.05) from the verification of residues show that with a probability of 95.0% there is a significant correlation based on the sequence in which they occur in the model.

Discussion. Based on the data of the multifactor regression model (Table 4), construct a forecast schedule of agricultural production per person per year (ProdAgro) (Fig. 1).

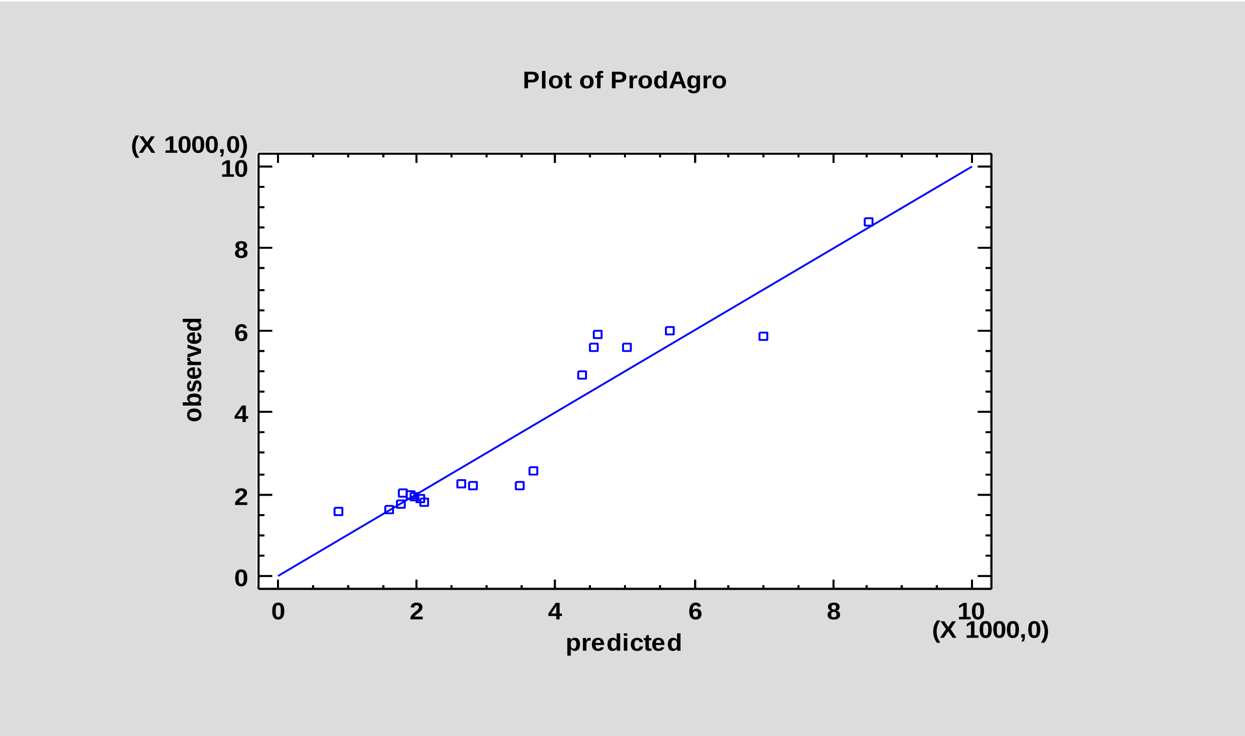

Figure 1. Forecast of agricultural production

Source: author's development

According to this graph, we can conclude about the relatively high quality of the ProdAgro model. This is evidenced by the predicted values of ProdAgro in comparison with the values predicted by our chosen model – the closer the values (marks) are near the diagonal line, the better the model for predicting the studied variables.

Conclusion. Thus, the results of investigation can lead to a number of important conclusions.

1. In determining whether the model can be simplified to the form of a linear equation of dependence between only two variables ProdAgro and IP, it should be guided by the fact that the largest value of P-value for the studied independent variables 0.0000 belongs to IP. Since the value of P-value <0.05, the statistical significance of the variable is achieved at a confidence level of 95.0%. As a result, it is not advisable to discard other variables from the studied model, because the deviation from the values of the coefficients of the best model is quite small.

2. According to the results calculated in table 1 Pearson's instantaneous correlation coefficients from the selected eight predictor factors (IP, CBread, CMilk, CMeat, TaxF, InvF, BusF, Budget) four variables were discarded due to the low level of correlation coefficients (less than 50%). Among the four variables that were left (IP, CBread, CMeat, Budget), the correlation coefficients ranged from 68.73% to 93.96% when all variables corresponded to the normal distribution of standardized asymmetry and standardized excess.

3. The lack of heteroscedasticity of the selected model according to Durbin-Watson statistics indicates that the analyzed residues are random variables and the application of the proposed model is appropriate.

4. Testing the model for adequacy according to the ANOVA method (Table 4) showed that the selected model according to R-Squared, Adjusted R-Squared, MAE, Fisher's statistics (F-Ratio), the value of P-value is adequate and different combinations of variables of the proposed model with four independent variables are quite suitable for forecasting ProdAgro.

Thus, our model is statistically significant and has high rates of multifactor statistical analysis. The forecast model of growth of agricultural production ProdAgro with four independent variables is confirmed (formula 3).

The model built by us in the form of such an equation explains 89.46% of the change in agricultural production per capita per year.

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