SYNCHRONIZATION OF CYCLES AND CRISES IN THE AGRI-FOOD SECTORS OF UKRAINE

СИНХРОНІЗАЦІЯ ЦИКЛІВ ТА КРИЗ В АГРОПРОДОВОЛЬЧОМУ СЕКТОРІ УКРАЇНИ

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The article studies the presence of cyclicality in the development of sectors of the agri-food sector: agriculture and food industry. Development models of sectors of the agri-food sector were built using the LOG-modeling technique. The rates of approaching the crisis state, the critical period and the amplitude of cyclical fluctuations in the development of agricultural and food industries were determined. To determine the synchronicity of the cyclical development of the sectors of the agri-food sector and their subsectors, a correlation and regression analysis was applied taking into account the time lag. The synchronicity of the development of such branches of the food industry as the production of meat and meat products, the processing and canning of vegetables and fruits, the production of oil and animal fats and the production of beverages was established using the cross-correlation coefficients. The synchronicity of the development cycles of animal husbandry and meat products industry was established.
Key words: *cyclical development, crisis, LPPL modeling, synchronicity, agri-food sector.*

В статье проведены исследования наличия цикличности в развитии секторов агропродовольственного сектора: сельского хозяйства и пищевой промышленности. Построены модели развития секторов агропродовольственного сектора с использованием приема LOG-моделирования. Определены темпы приближения к кризисному состоянию, критический период и амплитуда циклических колебаний развития отраслей сельского хозяйства и отраслей пищевой промышленности. Для определения синхронности циклического развития секторов агропродовольственного сектора и их подсекторов был применен корреляционно-регрессионный анализ с учетом временного лага. Установлена с помощью коэффициентов кросскореляции синхронность развития таких отраслей пищевой промышленности, как производство мяса и мясных продуктов, переработка и консервирование овощей и фруктов, производство масла и животных жиров и производство напитков. Установлена синхронность циклов развития животноводства и отрасли производства мяса и мясных продуктов.
Ключевые слова: *цикличность развития, кризисное состояние, LPPL моделирования, синхронность, агропродовольственный сектор.*

В статті проведено дослідження наявність циклічності у розвитку секторів агропродовольчого сектору: сільському господарстві та харчовій промисловості. Побудовані моделі розвитку секторів агропродовольчого сектору з використанням прийому LOG-моделювання. Були розроблені LPPL-моделі розвитку галузей сільського господарства та галузей харчової промисловості. Визначені швидкість наближення до кризового стану, критичний період та амплітуда циклічних коливань для всіх підгалузей агропродовольчого сектору України. Встановлені галузі, які за досліджуваний період пройшли пік кризи. Для визначення синхронності циклічного розвитку секторів агропродовольчого сектору та підсекторів сільського господарства та харчової промисловості був використаний апарат кореляційно-регресійного аналізу з урахуванням часового лагу. Доведено, що найбільші флуктуації відбуваються у ті періоди, коли спостерігається певна синхронізація циклів. Встановлена за допомогою коефіцієнті кроскореляції синхронність розвитку таких галузей харчової промисловості, як виробництво м'яса та м'ясних продуктів, перероблення та консервування овочів та фруктів, виробництво олії та тваринних жирів та виробництво напоїв. Існує синхронізація циклів розвитку тваринництва та галузі виробництва м'яса та м'ясних продуктів, але повністю відсутня синхронність з галуззю виробництва молочних продуктів. Встановлено, що найвища синхронізація між більшістю галузей харчової промисловості та рослинництвом досягається з лагом у 6 років. Дослідження циклічності розвитку певних галузей агропродовольчого сектору, передбачення кризових періодів розвитку економіки, їх тривалості та глибини є передумовою для розробки антициклічних програм та застосування заходів державної підтримки розвитку. Питання оптимізації заходів державного регулювання залишається важливим відповідно до умов розвитку економічної системи, визначення періодів посилення регуляторної функції держави в певні періоди економічного розвитку.
Ключові слова: *циклічність розвитку, кризовий стан, LPPL моделювання, синхронність, агропродовольчий сектор.*

Introduction. In determining the prospects for economic development, one should take into account the inevitability of cyclical fluctuations in economic dynamics, the frequency of crisis phases of medium and long-term cycles.

Anticipation of crisis periods in the development of the economy, their duration and depth, allows to develop a complex of preventive counter-cyclical measures (programs). The problem of counter-cyclical programs, developed by the Governments of different countries at different time periods, is their focus on the separate solution of current problems or a separate sector of economy (real, financial) or a separate industry (production sector, agriculture). None of the programs considers the comprehensive impact of monetary, fiscal, and other policies on economic development. The issue of optimization of state regulation measures in accordance with the conditions of economic system development, determination of periods of strengthening of the regulatory function of the state in certain periods of economic development and legislative support of the principles of state support remains important. The mechanism of state regulation and state support must be harmoniously combined, which gives it additional sustainability, increases the efficiency of the system and, in certain conditions, produces a synergistic effect. Therefore, the first step in the improvement of the counter-cyclical development program of the country should be to predict the cyclicality of its development, taking into account the peculiarities of the cyclical mechanism of each component of the national economy (production sector, agriculture, etc.).

Identification of synchrony in the development of national economy sectors at certain periods of time provides information on improving economic indicators of the country's development at the expense of endogenous factors, which is a prerequisite for adjusting the state regulation in the direction of restraining rapid development and vice versa.

Literature review. One of the most difficult issues of today is forecasting the cyclicality of economic development. There are a number of methodological techniques that are used to predict fluctuations in the economic system and to establish the moment of bifurcation in the system. Among the methods of crisis forecasting, the following approaches can be distinguished: expert methods, methods based on mathematical models and using a system of leading indicators [1].

Mathematical models are mostly developed for the medium and long-term forecasting of changes in the system under the influence of internal and external factors. Such methods include predictive extrapolation methods, feature selection method, matrix methods, optimal planning and modeling, economic and statistical models, simulation models, network models, linear programming, inter-industry balance method, correlation and regression method, economic analysis method, program-target method, etc.

Often, when developing mathematical models of the dynamics of complex systems, methods of simulation are used in conjunction with the running of all the elements of the system during the process of joint functioning. The development of mathematical models requires the establishment of a list of significant factors that influence the process and the relationship between them. An important point is to use the most reliable source information to develop forecasts.

The use of a system of leading indicators is based on the use of a system of indicators, trends of which serve as signals for the manifestation of a crisis situation in the system. Leading indicators should not be reduced to a single comprehensive indicator, and crisis forecasting should be made on a set of indicators. E. Baranov points out: "There is no ideal indicator for crisis prediction, and conclusions should be drawn on the basis of a summary of all indicators. An ideal indicator will emerge only when we have a better understanding of how the economy works" [2].

An important point is the selection of indicators for crisis forecasting, depending on the type of crisis itself. To predict the currency crisis, signals are such indicators as the reduction of international reserves to a dangerous level, an increase in foreign debt to a dangerous level, a change in stock quotes, etc. [3, p. 7–8].

Studies have shown that the use of models that are built on a significant number of indicators (anywhere from up to 20 indicators) does not lead to a more reliable predictive assessment than models that use 5-6 indicators [4, 5]. The IMF researchers use a model with 5 variables to predict the threat of a currency crisis: the degree of overvaluation of the real exchange rate, the size of the current account deficit relative to GDP, the growth rate of exports, the growth rate of reserves and the ratio of short-term external debt [3, p. 9]. The first four indicators characterize the increase in tension between external and internal tasks, which leads to the collapse of the currency. The fifth indicator shows the vulnerability of the economy in the event of a sudden change in the direction of capital flows. Empirical work on early warning systems is a comparative innovation. It remains a significant problem to identify events that may trigger a crisis, to which a range of economic, political and psychological factors are involved [6].

A large group of global projections for the future of the world economy and the economies of individual countries is the development of Western governments (The US Central Intelligence Agency, National Intelligence Council (NIC), North Atlantic Alliance (NATO)) and non-governmental organizations (the UN, Center "Startfor", the Berlin Center for Future Research), etc., as well as research from some US institutes and universities (SRI International, Harvard University, Princeton University, etc.).

A significant contribution to the development of the methodology for forecasting cycles and crises was made by the Association "Forecasts and Cycles", the International N.D. Kondratiev Foundation, the Institute of Economic Forecasting of RAS [7, p. 25; 8–9]. The methodology for forecasting cycles and crises is based on the theory of cycles and crises. Among the main provisions there are the following: 1) Any socio-economic system develops cyclically, consistently passing through the phases of birth, formation, distribution (diffusion), stable development (maturity), crisis and relict state; 2) Crises are an inevitable phase of the cycle. The following stages of crisis development and exit can be distinguished: latent (latent accumulation of elements and precursors of crisis), landslide (sharp manifestation of negative parameters of crisis), depressive (accumulation of preconditions for crisis exit) and final (recovery, system recovery, achievement and exceedance to the crisis level in the new structure); 3) Systems dynamics is polycyclic. Cycles of different durations are superimposed on each other, mutually affecting each other. The inevitable interaction of cycles in different spheres is in the dynamics of adjacent systems. Cycle interaction takes three forms: resonant (enhances the amplitude of oscillations in cycle phases), damping (which reduces the amplitude of oscillations, softens the severity of the crisis phase) and deforming (which interrupts the normal cycle, for example); 4) Cyclical dynamics is insurmountable. Therefore, counter-cyclical programs, calls for crisis-free development are futile.

Correct forecasting of future structural changes in economic systems can be performed by methods of dynamic modeling of economic origin on the basis of a system of nonlinear, complex, differential equations that take into account not only the time factor but also many feedbacks and structural changes in their calculations [10]. Such dynamic models with a high degree of probability predict the speed and acceleration of changes in the parameters of the system (economic dynamics), as a result of the effects of various internal controls and predicted external influences on it. The resulting forecasts model not only "smooth" processes, but also future sudden crises that create an avalanche of economic catastrophes [11–16].

A sine wave of the form $Y = A \cdot sin\ (b_0 \cdot x + b_1)$, where A – is the amplitude of the sine wave, b_0 – is the oscillation frequency, b_1 – is the initial phase of oscillation, is the most widespread used to predict the cyclicality of the development of the system. Modification of the sine wave to predict cyclic processes $Y = a_0 + a1 \cdot x + a_2 \cdot sin\ (a_3 \cdot x) \cdot (x - 1)$ was proposed in the work of V. Uzun and T. Platonov [17]: It should be noted that the authors consider the dynamics of system development as a linear trend with a cyclic component. The issue of pre-determining parameter a3 and using it in the model as a constant is quite debatable. A Fourier series has been widely used by methods of analytical alignment of series with cyclic component: $Y = a_0 + \sum (a_i \cdot cos(k \cdot t) + b_1 \cdot sin(k \cdot t)$ where k – is the harmonic index of the series. The modification of the Fourier function was used in the works of I. Sokolov, I. Tarapatov, O. Borysenko, O. Oliinyk, and other scientists [18]. However, each model proposed has discussion points related either to the determination of the cycle length or to the use of constant coefficient values in the models defined previously.

Purpose. In today's economic environment, countries need to track the development of the global economic system, with all the fluctuations inherent in it, in order to achieve sustainable economic growth. The economic system develops cyclically and is affected by both endogenous and exogenous factors. The greatest fluctuations occur during the periods when there is a certain synchronization of cycles: industrial, agricultural, etc. The purpose of the study is to determine the cyclicality of development in the agri-food sector of Ukraine and to determine the points of synchronization of cycles of sub-sectors of the agri-food sector. Research into the cyclical development of certain agri-food sectors is a prerequisite for the development of counter-cyclical programs and government support for development.

Results. The modern economic and mathematical apparatus of LPPL-modeling, which belong to the category of LOG-models, was used to describe the dynamics of development of branches of the agri-food sector of Ukraine taking into account the cyclical nature [19–22]. The model is widely used to describe scenarios of endogenous financial market crashes. The developers of the model have suggested that during the speculative bubble, the nominal index increases by a power law with log-periodic oscillations. The end of the crash is the culmination of the so-called Log-Periodic Power Law (LPPL). A distinctive feature of the equation is the rapid acceleration of change in the price of an asset or index as t approaches to oscillations with decreasing amplitude. The most likely time in the event of a crash occurs when $t = tc$, and for $t \geq tc$ the equation goes beyond the complex number. This allows us to identify clear signatures of almost critical behavior before a crash. The hypothesis is that the collapse in the financial markets is a slow increase in the range of correlation between individual traders, leading to global cooperative behavior, which leads to the collapse of the stock market at one critical moment.

The use of LPPL-models is justified by the advantages such as the ability to select a model that reflects the trend of system development, with the establishment of the moment of system failure; the ability to determine in advance the critical state of the system associated with endogenous factors; determine the rate of growth of system indicators; determine the amplitude and frequency of oscillations of the system indicators. The use of LPPL-models for economic sectors is possible in order to determine their synchronous / asynchronous approach to the critical period, which leads to a crisis in the whole system due to the influence of endogenous factors. The calculation of periods, frequencies and amplitudes of oscillations, resonance in the development of individual sectors gives clear signals about the real moments of time of influence through state measures for the development of both individual sectors and the economy as a whole. These data make it possible to switch levers of influence from one sector to another in a timely manner, as well as to make decisions on strengthening or weakening state regulation in certain periods of economic development.

This approach was tested using the example of the agri-food sectors. It allows to determine the tendencies of development of the branches of the food industry, agriculture; critical time for the systems under study; the exponential growth rate and the amplitude of the oscillations.

Such a model has been used to build models for the development of food and agriculture [19]

$$y(t) = A + B \cdot (t_c - t)^z \cdot (1 + C \cdot \cos(w \cdot \ln(t_c - t) + \phi),$$

where A – is the numerical value of the indicator at a critical time for the system, A> 0;

B – is a numerical factor, B <0;

t_c – is the critical time for the system, $t_c > t$;

w – is the coefficient characterizing the amplitude of the model oscillations, the cycle frequency;

z – is the value that determines the exponential growth of the model, z > 0;

φ – is the initial phase of oscillation.

Indicators for the development of agri-food sectors at comparable prices were used to build models: for the food industry from 2001 to 2017 [23], for agriculture - from 1991 to 2017 [24]. Production volumes of food and agriculture are examined without the influence of inflation. On the basis of the initial information and mathematical apparatus, LPPL-models of development of sectors of the agri-food sector of Ukraine have been constructed.

Table 1 shows the models of food industry development.

Figure 1 graphically shows the dynamics of production volumes of the food industry by LPPL-models.

As it can be seen from Figure 1, the largest share in the production of food, beverages and tobacco is the production of oil and animal fats. However, according to the data, this industry reached its peak in the cycle of 2013-2014 and has a clear tendency to further decline.

Industries such as beverage and tobacco production have a clear wavy development trend with a maximum for tobacco production in 2007, and for beverage production in 2009–2010. The tobacco development curve indicates the onset of the 2017 crisis.

Similar trends are observed in the production of meat and meat products and in the processing and preserving of vegetables and fruits: a growing trend with a slower growth rate.

Other industries show slight fluctuations near their mid-range. An exception is the bread and bakery industry, which has an upward trend throughout almost the entire study period.

Table 1 shows the values of the statistical indicator – the correlation coefficient – for each model. Almost all metrics exceed 0.9, indicating a strong correlation between argument and function.

Table 2 summarizes the main characteristics of LPPL models for the development of the food industry: exponential growth rate, cycle frequency, initial oscillation phase, and critical period for the system.

The exponential growth factor is the highest (1.92) in the development model of the meat and meat products industry. This indicates that the speed of approaching the critical state is greatest in this area.

Table 1

Models of development of food industry sectors

The food industry sectors / models of development	Correlation coefficient
Production of food, beverages and tobacco products (in general)	
$y(t)=648705{,}5-22345{,}7\cdot(2018-t)^{1{,}65}\cdot(1+1{,}06\cdot\cos(0{,}76\cdot\ln(2018-t)+1{,}61)$,	0.974
1. Food production (total across all sectors)	
$y(t)=494096{,}97-4179{,}3\cdot(2018-t)^{1{,}72}\cdot(1+1{,}28\cdot\cos(1{,}08\cdot\ln(2018-t)+1{,}2)$,	0.956
-production of meat and meat products	
$y(t)=79474{,}77-8619{,}7\cdot(2018-t)^{1{,}92}\cdot(1+1{,}09\cdot\cos(0{,}036\cdot\ln(2018-t)+3{,}51)$,	0.969
-processing and preserving of vegetables and fruits	
$y(t)=21823{,}87-1651{,}15\cdot(2018-t)^{1{,}57}\cdot(1+1{,}07\cdot\cos(0{,}62\cdot\ln(2018-t)+1{,}97)$,	0.924
-production of oil and animal fats	
$y(t)=189997{,}27-42230{,}3\cdot(2018-t)^{0{,}62}\cdot(1+1{,}39\cdot\cos(0{,}81\cdot\ln(2018-t)+2{,}07)$,	0.954
-production of dairy products and ice cream	
$y(t)=45674{,}83-1261{,}9\cdot(2016{,}36-t)^{1{,}04}\cdot(1+1{,}06\cdot\cos(1{,}56\cdot\ln(2016{,}36-t)-0{,}33)$,	0.624
-production of flour and cereals, starch products	
$y(t)=29626{,}43-991{,}6\cdot(2018-t)^{1{,}28}\cdot(1+1{,}23\cdot\cos(0{,}88\cdot\ln(2018-t)+1{,}37)$,	0.862
-production of bread and bakery products	
$y(t)=29399{,}82-673{,}1\cdot(2018-t)^{1{,}01}\cdot(1+3{,}21\cdot\cos(1{,}29\cdot\ln(2018-t)+0{,}436)$,	0.981
2. Production of beverages	
$y(t)=68703{,}79-3237{,}6\cdot(2018-t)^{0{,}98}\cdot(1+1{,}17\cdot\cos(2{,}12\cdot\ln(2018-t)-1{,}45)$,	0.981
3. Production of tobacco products	
$y(t)=69796{,}27-804{,}7\cdot(2016{,}97-t)^{1{,}34}\cdot(1+1{,}8\cdot\cos(1{,}34\cdot\ln(2016{,}97-t)-3{,}13)$.	0.968

Source: built by the author based on her own calculations according to [23]

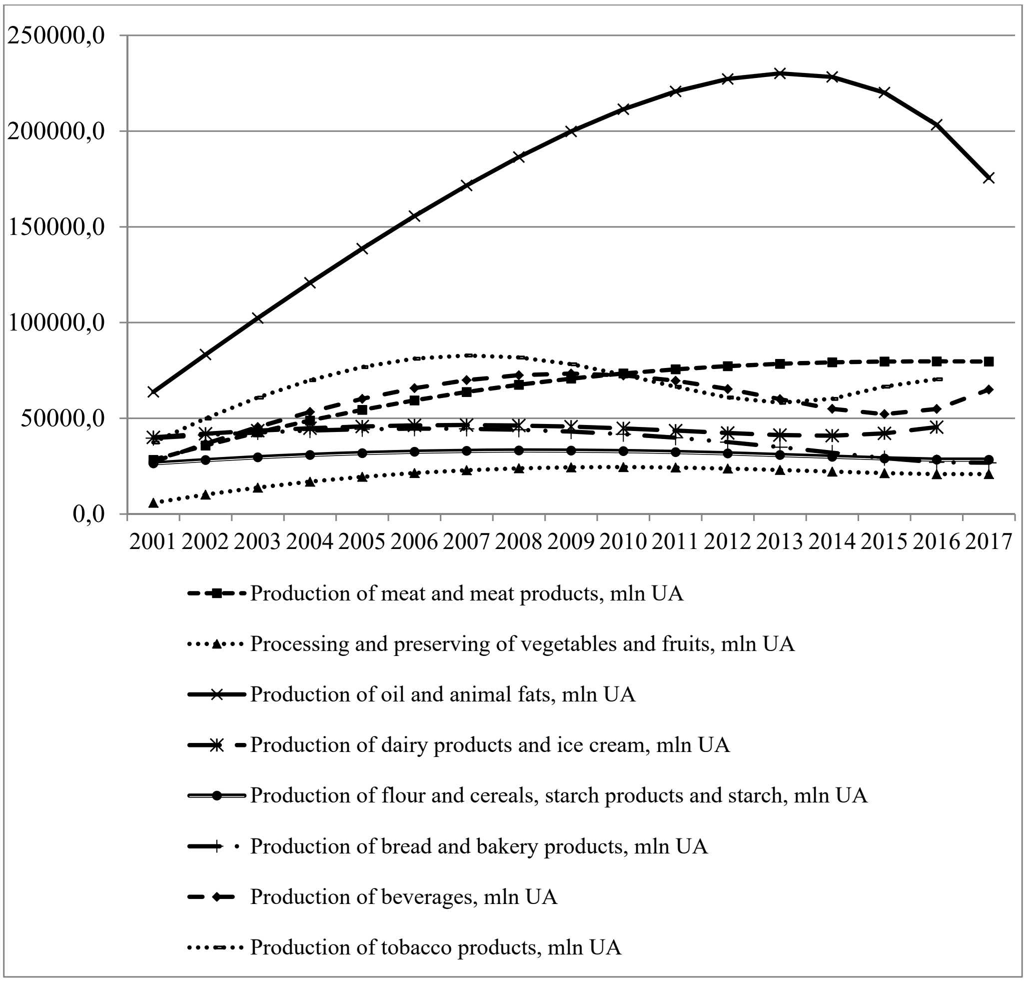

Figure 1. Dynamics of change in the production of food by industry, beverages and tobacco by LPPL-models

Source: author-based [23]

Table 2

The main characteristics of LPPL-models of development of food industry sectors

Object of study	Indicator			
	Exponential growth rate	Cycle frequency	Initial phase of oscillation	Critical period for the system
	z	*w*	*ϕ*	t_c
Production of food, beverages and tobacco products	1.64	0.76	1.61	for 2018
Production of meat and meat products	1.92	0.04	3.51	for 2018
Processing and preserving of vegetables and fruits	1.57	0.62	1.98	for 2018
Production of oil and animal fats	0.62	0.81	2.07	for 2018
Production of dairy products and ice cream	1.04	1.56	-0.33	2016.36
Production of flour and cereals, starch products and starch	1.28	0.88	1.37	for 2018
Production of bread and bakery products	1.01	1.29	0.44	for 2018
Production of beverages	0.98	2.11	-1.45	for 2018
Production of tobacco products	1.34	2.83	-3.13	2016.97

Source: calculated by the author

The lowest performance in the production of oil and animal fats, which indicates a critical state in the near future, it does not threaten. In the food, beverage and tobacco industries, this ratio is 1.64. The amplitude of oscillations is the largest according to models in the beverage industries (2.11) and tobacco (2.83). The smallest amplitude in the field of meat and meat products (0.04), indicating that there is almost no fluctuation. The critical period for the food industry under study between 2001 and 2017 is defined for only two sectors: dairy and ice cream production (2016) and tobacco production (2017). Other industries have either undergone a critical period between 1991 and 2001, or a critical period beyond 2018.

The synchronization of cycles is determined by the cross-correlation coefficients with a certain shift in time (time lag). The correlation coefficients with time lag L = 0, 1, 2,…, 6 are determined for the food industry.

The study of the synchronization of cycles of development of the food industry provides additional opportunities for the development of strategic programs for the development of the agri-food sector of the economy. At certain times when the cycles of the food processing industries are synchronized, which leads to an increase in the overall indicators of the agri-food sector development, the government's efforts to support certain sectors at the expense of budget funds directly may be reduced. In addition, reorientation of government support to other sectors that require additional investment can be made.

Studies show that the synchronization of the development of the canning, oil and fat and beverage industries affects the overall volume of food production without a delay in interaction. Asynchrony in the development cycles of 2–3 years is observed in the industries of products of the flour and cereals industry, dairy products and ice cream, tobacco products with a general development cycle of the food industry. The greatest asynchrony is observed in the field of bread and bakery products. The reasons for this asynchrony should be sought in the study of the development of agriculture, as a major supplier of raw materials for food businesses.

Table 4 shows the agricultural industry development models based on data from 1991–2017.

Figure 2 shows the dynamics of agricultural output by LPPL-models graphically.

The dynamics of the development of the sectors is based on the indicators of the gross output of the agricultural sectors at comparable prices for the period from 1991 to 2017. As it can be seen from Figure 2, the largest share in the gross agricultural output is attributable to crop production, the development of which almost fully reflects the dynamics of agricultural development as a whole. The difficult period of agricultural development dates from 1991 to 2000. It was 2000 that was the turning point – the moment of crisis. The ascending phase of the plant-growing industry lasted from 2000 to 2016.

Animal husbandry, although it had certain prerequisites for development, was unfortunately unable to reach the vector of the upward phase of development.

Table 4 shows the values of the statistic – the correlation coefficient – for each model, which exceeds 0.9, indicates the high strength of the correlation between argument and function.

Table 3

Cross-correlation coefficients of production indices of food industry

Time lag between the total production of food, beverages and tobacco products and a specific food industry sectors	**L=0**	**L=1**	**L=2**	**L=3**	**L=4**	**L=5**	**L=6**
Production of meat and meat products	0.790	0.636	0.360	-0.079	-0.533	-0.807	-0.924
Processing and preserving of vegetables and fruits	0.996	0.934	0.729	0.291	-0.260	-0.652	-0.853
Production of oil and animal fats	0.823	0.644	0.327	-0.139	-0.592	-0.845	-0.943
Production of dairy products and ice cream	0.290	0.522	0.808	0.940	0.743	0.258	-0.289
Production of flour and cereals, starch products and starch	0.652	0.830	0.923	0.700	0.122	-0.427	-0.753
Production of bread and bakery products	-0.064	0.155	0.445	0.744	0.844	0.667	0.283
Production of beverages	0.917	0.968	0.892	0.527	-0.085	-0.580	-0.840
Production of tobacco products	0.588	0.770	0.952	0.956	0.608	0.068	-0.428

Source: calculated by the author

Table 4

Models of development of agricultural sectors

The of agricultural sectors / models of development	**Correlation coefficient**
Gross production of agriculture	
$y(t) = 252293{,}31 - 43{,}4 \cdot (2018 - t)^{2{,}15} \cdot (1 - 10{,}87 \cdot \cos(1{,}03 \cdot \ln(2018 - t) + 1{,}38).$	0.963
1. Gross crop production	
$y(t) = 179182{,}3 - 2052{,}1 \cdot (2018 - t)^{1{,}12} \cdot (1 + 1{,}17 \cdot \cos(1{,}99 \cdot \ln(2018 - t) + 1{,}54).$	0.95
2. Gross livestock production	
$y(t) = 70891{,}51 - 1{,}11 \cdot (2018 - t)^{3{,}39} \cdot (1 - 2{,}7 \cdot \cos(1{,}25 \cdot \ln(2018 - t) + 9{,}85).$	0.987

Source: built by the author based on her own calculations according to [24]

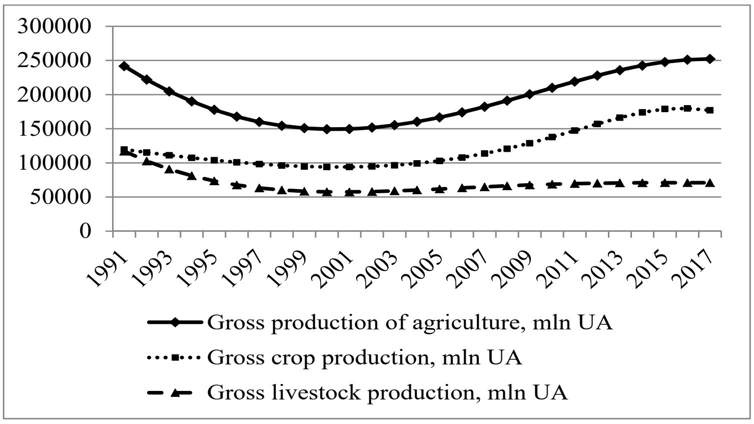

Figure 2. Dynamics of agricultural production change (LPPL models)

Source: author-based [24]

Table 5 summarizes the main charac-teristics of LPPL-models for agricultural development.

The coefficient of exponential growth is of the highest importance (3.39) in the animal husbandry industry development model. This indicates that it is in this area that there is a permanent crisis. The lowest value of the indicator (1.12) is in the field of crop production, which indicates a rather slow approach to the critical state. It should be noted that the overall exponential growth rate in agriculture exceeds that in food, beverage and tobacco.

The amplitude of oscillations is the largest according to the models in the field of crop production (1.99). The critical period for the agricultural sectors under study is beyond 2018.

The study of synchronization of cycles of plant and animal husbandry with agriculture showed that there is a complete asynchrony of the development of livestock and crop production.

It is advisable to study the synchronicity of the development of the food industry with the development of plant and animal husbandry. The impact of state regulatory instruments on the development of agri-cultural sectors makes it possible to adjust the indicators of food industry development and achieve the desired food security indicators of the country.

Tables 6 and 7 show the cross-correlation indica-tors between the food and time sectors, respectively.

A strong correlation with lag at 6 years is observed between the crop and the industries of processing and canning of vegetables and fruits, beverage production and production of flour and cereals. As regards the production of oil and animal fats, the correlation between crop development and oil production is extremely high, regardless of the time lag.

There is no correlation between the development of crop production and the production of bread and bakery products.

There is a strong correlation between livestock development and the production of meat and meat products (more than 0.9). The trend in the livestock industry is fully consistent with the trend in the meat and meat products industry.

Table 5

The main characteristics of LPPL-models of development of agriculture

Object of study	Indicator			
	Exponential growth rate	Cycle frequency	Initial phase of oscillation	Critical period for the system
	z	w	ϕ	t_c
Gross production of agriculture	2.15	1.03	1.38	for 2018
Gross crop production	1.12	1.99	1.54	for 2018
Gross livestock production	3.39	1.,25	9.85	for 2018

Source: calculated by the author

Table 6

Cross-correlation coefficients of food production and crop production

Time lag between the total crop production and a specific food industry sectors	L=0	L=1	L=2	L=3	L=4	L=5	L=6
Processing and preserving of vegetables and fruits	0.518	0.623	0.730	0.824	0.897	0.947	0.978
Production of oil and animal fats	0.813	0.919	0.967	0.988	0.994	0.993	0.986
Production of flour and cereals, starch products and starch	-0.347	-0.153	0.097	0.376	0.629	0.814	0.924
Production of bread and bakery products	-0.895	-0.831	-0.760	-0.672	-0.547	-0.352	-0.034
Production of beverages	0.,155	0.217	0.382	0.591	0.778	0.904	0.971
Production of tobacco products	-0.202	-0.196	-0.160	-0.054	0.144	0.408	0.678

Source: calculated by the author

Table 7

Cross-correlation coefficients of food production and livestock production

Time lag between the total livestock production and a specific food industry sectors	L=0	L=1	L=2	L=3	L=4	L=5	L=6
Production of meat and meat products	0.993	0.998	0.997	0.991	0.983	0.973	0.961
Production of oil and animal fats	0.946	0.991	0.995	0.985	0.969	0.953	0.937
Production of dairy products and ice cream	-0.215	-0.204	-0.186	-0.050	0.160	0.436	0.722

Source: calculated by the author

There is no correlation between livestock development and dairy and ice cream production.

Conclusions. Research into Ukraine's agri-food sector development indicators has shown that most of the food industries have already reached their peak in the 2000 to 2017 interval and have begun a slow creep into the crisis.

For the dairy, ice cream and tobacco industries, the crisis period came in 2016 and 2017, respectively, as evidenced by the actual statistics on the status of these industries. The most rapid creep in the crisis in the meat and meat products industry, which corresponds to the critical permanent state of development of the livestock industry. There is a noticeable synchronization of the development of such industries as the production of meat and meat products, processing and preserving of vegetables and fruits, production of oil and animal fats and production of beverages. Dairy, ice cream and tobacco products are asynchronous to these industries with a shift in time, but synchronous to one another. Agriculture has a faster pace of approaching the crisis than the food industry, driven by negative trends in the livestock industry.

A study of synchronicity between the food and agriculture sectors has shown that:

1) there is a synchronization of livestock development cycles with the meat and meat products industry, but no synchronicity with the dairy industry. This testifies to the expediency of directing state regulation in the development of dairy farming;

2) there is a fairly high correlation between crop development and oil production and the processing of fruit and vegetable canning;

3) the greatest synchronization between most branches of the food industry and crop production is reached with a lag of 6 years.

The conducted researches allow to optimize approaches to application of the measures of the state regulation with the purpose of restraint or revival of economic development.

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