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ANALYSIS AND FORECASTING OF UKRAINIAN AGRARIAN EXPORTS TO THE EU COUNTRIES

Purpose. *The purpose of the paper is to study the state, perspective directions of Ukrainian exports of agricultural products and the introduction of effective forecasting using the method of mathematical modeling of a continuous system of aperiodic components.*

Methodology / approach. *In the process of research, the fundamental provisions of modern economic science were used in relation to the groups of factors influencing the resulting indicators of export, foreign trade trends, methods of statistical analysis to assess the weight of factors influencing the resulting function, as well as modern mathematical methods for forecasting of agrarian exports were implemented.*

Results. *The application of the developed mathematical model and the algorithm based on it, allowed to study the situation with the export of Ukrainian agricultural products to the EU, to identify trends specific to individual countries and the EU market as a whole, to assess the opportunities and prospects of niche markets, expansion nomenclature of export goods. Prognoses were given both on the export prospects of individual goods, product groups, and on the volume of deliveries to the EU. The use of factor analysis for forecasting of export deliveries allowed us to assess the impact of each of the factors and limit their amount.*

Originality / scientific novelty. *For the first time, the method of mathematical modeling of a continuous system based on changes in its aperiodic components was used for efficient and relevant forecasting of agrarian export volumes. Even the stages of application of this method, in particular, the analysis and prognoses for individual items of the nomenclature of export goods, for individual countries – importers make it possible to represent the situation with agrarian exports more accurately and forecast future supplies.*

Practical value / importance. *The proposed mathematical approach for market analysis and forecasting of markets can be used by both market regulators and producers and exporters of agricultural products. These polynomial equations for analysis and prognostication for individual product groups can be directly used in practice.*

Key words: *foreign trade, agricultural products, Ukraine, EU, mathematical model, forecasting.*

Introduction and review of literature. Ukraine's foreign trade in agricultural products has passed through stages of serious crises in recent years and has undergone significant changes. The closure of the large-capacity Russian market as a result of the war required significant efforts by exporters to diversify exports, enter

new markets, including promising and capacious markets in the Middle East and China, open niche markets, and so on. Significant impetus to the export of domestic agricultural products was given by the signing of the «Association Agreement between Ukraine and the EU» (Heyets, 2014; 2016) and the granting of trade preferences for exports to the European Union. This impetus has different dimensions, and not only in the context of increasing trade and expanding the range of goods. Thus, the share of the European Union in the export of Ukrainian agricultural products by volume exceeds a quarter of all export supplies but is characterized by significant fluctuations, typical for goods that predominate in the export of Ukraine. The risks are increased by the predominant specialization of foreign trade in agricultural products, which, unfortunately, has been developed due to the distortion of the conditions of formation of Ukrainian agricultural exports – supplies of grain and oilseeds account for more than ¾ of total exports. Supply volumes are also affected by global crises, in particular the COVID-19 pandemic. The pandemic has made a negative impact, primarily on agricultural exports of fruits and vegetables around the world, which affected the trade of even such a powerful country as the United States. All these circumstances require the formation of an effective policy in all areas – production, storage, transportation, expansion of the range of goods, securing a strong foothold in foreign markets and so on. The criterion for the effectiveness of effective policy-making in this direction is the creation of certain trends and tendencies in foreign trade. This increases the need for a modern mathematical apparatus to obtain reliable and relevant predictions.

Such Ukrainian scientists as Heyets (2014; 2016), Dalevska (2012), Kvasha, Grigoriev (2016), Klyuchnik (2015), Melnyk (2010), Mesel-Veselyak (2010), Sabluk (2008) and others devoted their works to the study of the peculiarities of the export market of agriculture of Ukraine, its potential, opportunities, development trends. Their scientific achievements in the context of the formation of analytical methods for studying trends and tendencies of Ukrainian agro-export were used in the presented work to form a mathematical model. Hadzalo, Lupenko and Pugachev's (2016) methods of analysis of the market capacity of the countries-importers of the Ukrainian agricultural products made an especially valuable contribution. The main trends of the world food market, the role and place of Ukraine in it were studied by Absava (2009), Strashynska (2007), Kernasyuk (2019), Yatsenko, Nitsenko et al. (2019), Heldak et al. (2018), Kucher (2017) etc. Some research results as to the factors of regulatory influence on agro-markets by Yurchyshyn (2005), Lupenko and Gutorov (2018), Ryabokon and Novikova (2016), Shpykulyak (2010), Shpychak (2017), Pronko et al. (2020) were also used in this paper. Unfortunately, Ukrainian scientists paid little attention to modeling of foreign economic activity, prospects for expanding and improving the commodity structure of exports depending on the focus groups of importers, countries and regions, forecasting future periods (Romaneckas et al., 2019). The formation of analytical approaches in these areas received more attention from foreign scientists, some of whom used standard software products for complex economic analysis. In particular, the NARDL package is popular in its direct

use (Karamelikli and Korkmaz, 2016; Falco et al., 2020), or with some modifications and improvements (Khan et al., 2020; He et al., 2019). Sometimes this is due to the target setting. For example, big data made it difficult to study (Khan et al., 2020; Kirieieva et al., 2019) by time series. But the nonlinear method applied to the autoregression of the distributed lag made it possible to detect unexpected asymmetric results on model variables (Khan et al., 2020; Yatsenko, Yatsenko et al., 2019; Fenghe, 2020). SBM-DEA model (Dong et al., 2020) helped to identify implicit patterns in the data without prior processing, which allowed establishing the relationship between «positive» and «undesirable» data sets (Dong et al., 2020; Ma, 2020; Gao et al., 2020).

Analyzing the work of foreign scientists, we can find a certain regularity. Application of empirical-analytical approaches, for example, using elastic variables and GEASI model (Lusk et al., 2019), improved by Komer on the Cobb-Douglas approach of the Solow model (Edeme et al., 2016; Zamula et al., 2020), direct analysis of the connections between break-even and yield (Tun and Phyo, 2019), the method of comparative indicators of benefits (Seleka and Dlamini, 2020; Ostapenko et al., 2020) for the formation of export forecasts for countries with unfavorable starting conditions (which is interesting for Ukraine) (Bilan et al., 2017; Lavrysh, 2018), are changing to more complex models using linear splines, robust combination of constraints, etc. give more relevant results. For example, Bayesian modeling by the corrective approach of RMA (Liu and Ker, 2020), or GARCH modeling taking into account the change of parameters over time according to the Karali approach (Karali et al., 2019). That is, scientists move away from standard methods to the formation of analytical models and apply new approaches specialized for specific circumstances of foreign economic activity (Kravchenko et al., 2020; Ursul and Ursul, 2018). More often, the latest approaches to the formation of algorithms use some elements of time-tested approaches to simplify calculations, reduce time and computer resources, reduce sets of variables that affect the target functions, and so on (Awwad, 2018; Schonhart et al., 2009; Werner et al., 2019). The analysis of scientific works allows establishing that scientists look for and find new mathematical models for the forecast of export deliveries of agricultural products (Pyburn et al., 2016). This search allows identifying new mathematical approaches adapted to specific problems, circumstances and goals of modeling, which allows getting more relevant results.

The purpose of the article. The purpose of the paper is to study the state, perspective directions of Ukrainian exports of agricultural products and the introduction of effective forecasting using the method of mathematical modeling of a continuous system of aperiodic components.

Methodology. A mathematical model was developed to forecast the export of agricultural products. Forming the model was based on the fact that agro-export is a continuous system, a component of which is represented by individual product groups and markets of individual importing countries. As known, in a broad sense, the nature of the functional dependencies of exports in goods or in cash, other functional representations of exports by individual product groups and for individual

importing countries is aperiodic. During the analytical study it was found that the use of classical gravity model, in particular, in its logarithmic representation (Braha et al., 2017; Raišienė et al., 2019) had certain limitations on the accuracy and relevance of the results, especially for the dynamic aperiodic change of factors. But this approach was used by us as one of the elements of the model, in particular, to assess the importance of influencing factors and, accordingly, to reduce their number. The approach of Campa, Goldberg, Berman for modifications of Karamelikli was also partially used (Karamelikli and Korkmaz, 2016). The method of studying the export of niche goods by Zhang (2020) with elastic supply, cointegration relations by Ongan and Gocer (2020) and the method of estimating the dependence of agro-exports on currency exchange rate volatility (Kandilov, 2008) also turned out to be useful. Analysis of Ukrainian exports of agricultural products to the EU using the method (Melnikov et al., 2015; Ostapenko et al., 2020; Bazaluk et al., 2020) allowed establishing the results of regulatory measures, in particular, the agreement between the EU and Ukraine, to reduce the negative effects of this factor on export earnings (by 67 %).

The peculiarities inherent in these commodity groups are superimposed on foreign trade by individual commodity groups. But there should be common trends for this range of goods, which depend on the general trends of the world market of agricultural products, aggressive policy of Ukrainian agricultural management, joint action in foreign markets and so on. Obviously, the use of factor analysis to forecast Ukrainian agro-exports for such a large number of groups of differently directed factors of different weight and dependent on different groups of variables is impossible.

Therefore, for mathematical modeling of agro-exports, it is proposed to apply an approach that has not yet been used to predict economic trends in foreign markets. Some aspects of this approach are presented in scientific work (Melnikov et al., 2015; Zamula et al., 2020). This is the prediction of the motion vector of a continuous system, the component of which are successive attractors of the same type of aperiodic functional dependences of the first order on the response surface of the target function. Functional dependencies of individual export goods, obviously, can be represented by the same type of aperiodic functional dependencies of the first order.

An algorithm for constructing correlation matrices, motion vectors, and reaction vectors of continuous linearized systems using dispersion matrices and transposed matrices of their reactions is described in the scientific literature for stochastic variables that form stationary (in the general sense) functional dependencies. In this case, it is possible to consider this system as a multidimensional representation «input – output». This, in turn, allows using the approach of finding the scalar components of motion vectors and reaction vectors of continuous linearized systems by selecting on matrices representing these vectors, matrices splitting the output vector into scalar components by dividing the output matrix into separated matrices and finding correlation dependences input-output functions. Then the Lyapunov matrix equation

(or system of equations) can be applied to market indicators (so-called «colored noise»), which is known to differ from the so-called «white noise» by the strength and direction of individual indicators. As a subtask within the implementation of the proposed mathematical model there is a problem of studying the effectiveness of individual factors influencing the volume of exports of agricultural products.

The basic parameter for dynamic systems is time τ. Let us denote the vector of exogenous influence of a factor or group of factors – $\vec{w}(\tau)$. As pilot tests of the model have shown, short-term forecasts are more reliable. The error for annual forecasts is growing. The basic equation for finding the derivative of the state vector on the attractor $\vec{Y}(\tau)$ is (1) under conditions (2):

$$\frac{d\vec{Y}}{d\tau} = \vec{A}\vec{Y}(\tau) + \vec{B}\vec{w}(\tau) \quad (1)$$

$$\vec{Y}(\tau_1) = \vec{Y}_1; \vec{Z}(\tau) = \vec{C}\vec{Y}(\tau) : \varepsilon(\tau) = \vec{Z}(\tau_1) - \vec{Z}(\tau) \quad (2)$$

where $\vec{Z}(\tau)$ – output vector;

ε – deviation at the output;

$\vec{A}$, $\vec{B}$, $\vec{C}$ – state matrices, input and output parameters.

The appropriate condition is (3):

$$\vec{Y}(\tau) \in R^n, \varepsilon(\tau) \in R^m, \vec{A} \in R^{n \times m}, \vec{B} \in R^{n \times m}, \vec{C} \in R^{n \times m} \quad (3)$$

where R – known mathematical operator.

The scalar components of the output vector are the reactions of commodity markets by focus groups, the reactions of related industries in the markets, and so on. Output variance D_z will be a matrix and can be found in accordance with (1) – (3) by equation (4) (Melnikov et al, 2015):

$$\vec{D}_z(\tau) = M\{\vec{Z}(\tau)\vec{Z}^T(\tau)\} = M\{\vec{C}\vec{Y}(\tau)\vec{Y}^T(\tau)\vec{C}^T\} = \vec{C}\mathrm{M}\{\vec{Y}(\tau)\vec{Y}^T(\tau)\}\vec{C}^T \quad (4)$$

where M – in this case, a mathematical operator, which means a mathematical expectation.

As known, to find the mathematical expectation of a continuous stochastic variable, it is necessary to determine the density of its distribution, for which the nature of the functions is checked and it is found that they correspond to the normal distribution law.

Equation (4) indicates that it is possible to simplify the calculations greatly – to reduce the problem of finding the variance matrix using the Lyapunov equation if we present the system as an aggregate structure and a certain mathematical filter that will reveal a statistically significant so-called «colored» signal. The proposed approach, however, requires considerable time and computer resources, so at the first stage to model foreign economic relations a stationary gravity model and factor analysis were used, which, in addition to comparing the results, also limited the number of factors influencing agricultural exports for each item of agro-exports, by certain product groups (oilseeds, cereals, etc.), by importing countries and to individual markets as a whole.

As known, according to the gravity model, exports from the supplier country to the importing countries are considered to depend on the distance between them and their so-called «economic weight», which is taken as their GDP. Logarithmic

representation of the gravity model (5), more convenient for the formation of the algorithm:

$$ln\mathrm{T}_{ij} = ln \propto_k + \sum_1^z \propto_\mu * y_\mu + ln\vartheta \quad (5)$$

where i – index of the exporting country (Ukraine);

j – index of the importing country;

μ – impact factor index;

$\propto_\mu$ – weighing coefficient of the impact factor;

$\propto_k$ – free member of power dependence – the theoretical value of the annual turnover which does not depend on the identified impact factors;

T_{ij} – annual trade turnover between countries (exports plus imports);

y – parameter (GDP, GDP per capita, population, distance between countries, etc.);

ϑ – systematic deviation related, for example, to the shadow economy. The fact of the possibility of detecting such a systematic deviation and conducting its numerical evaluation in terms of forming an effective set of regulatory effects is a significant result of this mathematical representation.

Results and discussion. In order to assess the task facing the authors, we present some data sets that have been analyzed (see Table 1, Table 2, Table 3). This sample of data, which served as a basis for analytical research, is specially presented so as to be as representative as possible. Table 1 shows the total export volumes for all types of products.

Table 1

Volumes of exports of Ukrainian products by importing countries

No.	Importer	Import Value to the EU, thsd. EUR					
		2014	2015	2016	2017	2018	2019
1	2	3	4	5	6	7	8
1	Austria	530577	435555	446176	602282	547348	688789
2	Belgium	407033	322054	315327	443657	538490	601892
3	Bulgaria	530901	468454	409804	458296	477907	535002
4	Croatia	33119	29109	38268	23863	26802	35722
5	Cyprus	30183	30943	26865	41291	32189	29997
6	Czech Republic	780296	652906	635515	763459	857313	944231
7	Denmark	97847	90328	1072479	128839	189434	207064
8	Estonia	55738	45382	66674	90873	113908	104226
9	Finland	50802	32684	51681	66992	76400	34605
10	France	453879	484024	466999	409214	498911	597130
11	Germany	1338277	1343222	1421022	1740282	2047706	2242107
12	Greece	150272	166901	164353	183473	164749	186458
13	Hungary	1279691	1023412	1105307	1642785	1538360	1581546
14	Ireland	34155	46829	43211	38872	47245	84809
15	Italy	2209942	2087420	1984042	2476727	2623726	2501423
16	Latvia	112779	98653	110859	151848	165096	186989
17	Lithuania	239507	199364	201315	237741	245640	318728
18	Luxembourg	5190	4179	4922	7378	7436	9704
19	Malta	182	9150	2932	2080	7747	3409
20	Netherlands	786514	941226	899293	1527712	1509030	2102164

Continuation of table 1

1	2	3	4	5	6	7	8
21	Poland	1660	1518	1813025	2136483	2510432	2660691
22	Portugal	235671	264549	211744	246186	242448	265841
23	Romania	457886	560971	705181	807621	835776	930284
24	Slovakia	538748	456554	442873	611226	651981	543269
25	Slovenia	18552	21845	23489	43448	60138	73479
26	Spain	1151973	1112258	1091605	1281841	1340494	1574441
27	Sweden	50406	59170	70395	74953	70118	86008
28	United Kingdom	494082	340557	323298	452105	588407	677367
	EU28	13734578	12844593	13183430	16691533	18015235	19807382

Source: based on European Commission, 2020.

Table 2 shows the volume of exports of products that, along with cereals, form the basis of Ukrainian agro-export – sunflower oil. Table 3 presents data on exports of the type of Ukrainian agricultural products recognized among consumers, which can be attributed to niche export goods – honey.

As seen in the above tables, despite some fluctuations related to crop and non-crop years, the integrated export volume indicator for the European Union and the United Kingdom (abbreviated EU 28 in the tables) has a steady upward trend. Honey, like other goods subject to quotas, after reaching certain limits shows a certain stability in supply. However, some countries, especially those with small populations, such as Croatia and Cyprus, show some fluctuations in supply volumes. Larger fluctuations in the volume of supplies to certain countries show data on exports of one type of product (see Table 2). Despite the growth of the integrated index, the amplitude of its oscillations is more significant than in table 3.

Table 2

Exports of sunflower oil by importing countries

No.	Importer	Import Value to the EU, mln EUR					
		2014	2015	2016	2017	2018	2019
1	2	3	4	5	6	7	8
1	Austria	1.566	1.293	1.081	1.177	2.159	2.952
2	Belgium	4.0	10.759	-	-	0.407	5.673
3	Bulgaria	-	0.001	0.037	-	-	5.224
4	Croatia	-		0.017	-	-	-
5	Cyprus	1.434	3.839	5.955	2.184	-	2.362
6	Czech Republic	-	0.025	-	0.001	0.015	-
7	Denmark	-	-	-	0.033	0.000024	-
8	Estonia	-	0.034	0.036	0.036	0.004	0.0171
9	France	46.010	17.835	124.257	101.116	69.879	86.081
10	Germany	4.079	0.248	3. 609	0.725	7.707	24.054
11	Greece	6.024	8.154	9.260	8.517	5.639	7.375
12	Hungary	-	0.523	5. 126	0.691	-	-
13	Italy	108.922	128.862	225.704	233.315	200.619	255.328
14	Latvia	0.096	0.111	0.108	0.598	0.098	0.080
15	Lithuania	6.131	1.151	5.201	16.936	12.307	10.406
16	Malta	-	-	-	0.092	0.062	0.273

Continuation of table 2

1	2	3	4	5	6	7	8
17	Netherlands	101.091	128.168	224.822	152.619	100.718	384.896
18	Poland	9.191	6.523	9.275	20.968	24.298	13.875
19	Portugal	8.63	8.824	7.239	24.455	3.995	15.446
20	Romania	0.289	5.368	-	-	0.155	0.084
21	Slovakia	0.000053	0.024	-	0.000993	-	-
22	Spain	143.432	145.219	279.833	389.701	216.992	288.727
23	Sweden	-	-	0.019	-	-	-
24	United Kingdom	51.223	61.587	44.488	75.797	74.558	79.122
	EU 28	492.264	528.546	946.069	1028.964	719.615	1181.977

Source: based on European Commission, 2020.

Even more significant fluctuations show the volume of exports of honey to individual countries. Portugal, Netherlands, Croatia, Latvia for 2014, 2015 and, later, 2018, 2019 show zero deliveries. This emphasizes the thesis of aperiodicity in certain indicators, types of products, importing countries. And this requires a certain deviation from standard methods of forecasting and the use of methods that have shown their effectiveness for aperiodic functions.

Table 3

Volumes of honey exports by importing countries

No.	Importers	Import Value to the EU, EUR					
		2014	2015	2016	2017	2018	2019
1	Austria	733080	316557	651359	925487	732285	888950
2	Belgium	-	1094574	3123269	8818157	10825144	11603104
3	Bulgaria	685708	695014	1306862	1282697	672879	575068
4	Croatia	-	-	68002	88250	-	-
5	Czech Republic	491762	2051060	719232	1553920	1047569	1966984
6	Denmark	-	-	1457090	3142945	3069054	3017408
7	Estonia	-	-	50011	519315	463782	187205
8	France	1664271	4294484	4200725	8794470	9148613	10466923
9	Germany	13445637	15890952	20959405	20471510	16927141	18549059
10	Hungary	-	1863407	2250181	1761908	-	-
11	Italy	1,053,105	215504	1,645,000	2602129	2891561	1586482
12	Latvia	-	-	22,000	109990	-	-
13	Lithuania	567464	1319017	1113349	1264292	1005582	1225844
14	Netherlands	-	-	117450	39900	1017715	-
15	Poland	17340293	13114436	22323939	24155370	21952772	20858211
16	Portugal	-	-	-	383414	-	-
17	Romania	103923	179894	329549	749232	993558	12064
18	Slovakia	2815168	1666566	1197184	761453	733453	1296774
19	Slovenia	-	-	-	36950	106345	100090
20	Spain	970497	1912911	2828605	3567868	2926043	2356053
21	United Kingdom	-	50205	501564	851705	662445	863645
	EU28	39870908	44664581	64864781	81880964	75175950	75553864

Source: based on European Commission, 2020.

A significant number of impact factors were evaluated to obtain weighting coefficients. As an example, the results of the analysis of exports of agricultural

products to EU countries are given (see Table 4). This set of impact factors is a sample from a wider set. The factors are given in descending order of correlation coefficient. As known, a positive correlation coefficient indicates a direct relationship, a negative – an inverse. This suggests the presence of not always positive effects of export growth on factors belonging to the above-mentioned matrix of economic reactions (output matrix). As direct factor analysis shows, indicators of macroeconomic stability and development of financial markets will decrease. The resulting value of the coefficient of determination will be 0.787. The analysis shows that an increase in the actual population in the importing country by only 1 % will increase exports of Ukrainian agricultural products by 0.673 %. But in some EU countries, the official population is decreasing. This makes it possible to predict the reduction of Ukrainian agricultural products to the Baltic States, Romania and some other countries on the response surface. The geographical proximity of the importing country makes it possible to increase exports to 0.799 % by 1 % approximation.

Table 4

Results of correlation analysis of agricultural exports to EU countries

No.	Impact factor	Correlation coefficient	Significance level	Standard error
1	Geographical distance importer-exporter	0.799	0.01	0.259
2	GDP per capita	0.745	0.01	0.089
3	Population	0.673	0.01	0.686
4	Mutual direct investment	0.565	0.05	0.062
5	Market size	0.560	0.05	0.078
6	Gross domestic product	0.499	0.01	0.458
7	The presence of a common border	0.355	0.05	0.259
8	Macroeconomic stability	-0.440	0.01	0.342
9	Development of financial markets	-0.481	0.05	0.604

Source: calculated by the authors according to the State Statistics Service of Ukraine.

Increase in GDP per capita – up to 0.745 % by 1 %, etc. Since these factors are diverse, affect the formation of the attractor on the response surface in different ways, only their assessment by monitoring the situation will allow the formation of the forecast, using a merely gravity model with its appropriate correction. That is, the assessment using the gravity approach and factor analysis of the weight of the impact factors is one-time and over time the weight of the factors will change, and the forecast error will increase. That is why a new approach to forecasting was proposed.

The forecast calculations were made under a number of conditions, in particular, the positive decision of the European Commission to postpone for Ukraine the decision to limit the import of plants and oils from them, when growing the plants insecticides based on chlorpyrifos and chlorpyrifos-methyl were used. In Ukraine, agricultural producers treat 35–45 % of sunflower and rapeseed crops with insecticides containing these active substances. It is also taken into account that for some goods (fresh tomatoes, cucumbers, and zucchini) in the EU there is an input price.

Table 5 shows the results of the analysis of exports of Ukrainian agricultural products to those EU countries that are the largest importers. The total volume of exports to these countries in 2019 reached 11080.8 million EUR, which was 78.74 % of total agro-exports to the EU. Ukraine's agricultural products are supplied to all 28 EU countries, including the United Kingdom during the period under review. For each country, the dynamics of exports has some differences. Trends are different. Export volumes from year to year indicate the presence of certain fluctuations, sometimes differently directed for different countries. Some countries, in particular, Portugal, Croatia, and Cyprus in general show a certain stability of the market in the presence of fluctuations in export volumes.

Table 5

EU countries – the largest importers of Ukrainian agricultural products, mln EUR

Year	Germany	Growth, year / year, %	Italy	Growth, year / year, %	Netherlands	Growth, year / year, %	Poland	Growth, year / year, %	Spain	Growth, year / year, %
2014	1338.28	-	2209.94	-	786.51	-	1660.37	-	1151.97	-
2015	1343.22	0.37	2087.42	-5.57	941.23	19.56	1516.89	-9.50	1112.26	-3.47
2016	1421.02	5.80	1984.04	-4.90	899.29	-4.46	1813.02	19.50	1091.60	-1.79
2017	1740.28	22.44	2476.73	24.85	1527.71	69.86	2136.48	17.80	1281.84	17.42
2018	2047.71	17.40	2623.73	5.93	1509.03	-1.23	2510.43	17.50	1340.49	4.60
2019	2242.11	9.50	2501.42	-4.69	2102.16	39.29	2660.69	5.97	1574.44	17.37

Source: calculated by the author according to European Commission, 2020.

Some countries, in general, are characterized by a significant increase in supplies. In particular, for the countries listed in table 5 for the period 2015–2019 a significant average annual growth is characteristic. Among these countries, only Italy shows some market stabilization at ~ 2.5 billion EUR. But, for example, Germany ~ 11.1 %, the Netherlands ~ 24.6, Poland ~ 10.24, Spain ~ 6.83 %. The Swedish market shows a steady growth of 86008.781 thousand EUR for 2019 (22.86 %, 2019 to 2018); Cyprus, respectively 944230.984 thousand EUR (10.15 %); Austria 688789.11 thousand EUR (25.95 %); Belgium 601892.332 thousand EUR (11.77 %); Great Britain 677367.137 thousand EUR (15.14%) and some other countries.

Even at the level of analysis for each country, it is possible to indicate the presence of «white noise», the impact of which is greatly enhanced in the transition to the analysis of the EU market as a whole. The complexity of the study increases significantly with the transition to the level of analysis for individual product groups. As the analysis showed, the growth / decrease rates of Ukrainian agro-exports to the EU had significant fluctuations (see Fig. 1).

For comparison, the results of traditional data processing give a predictive equation (6):

$$y = 10.108\ln(x) - 2.4184 \quad (6)$$

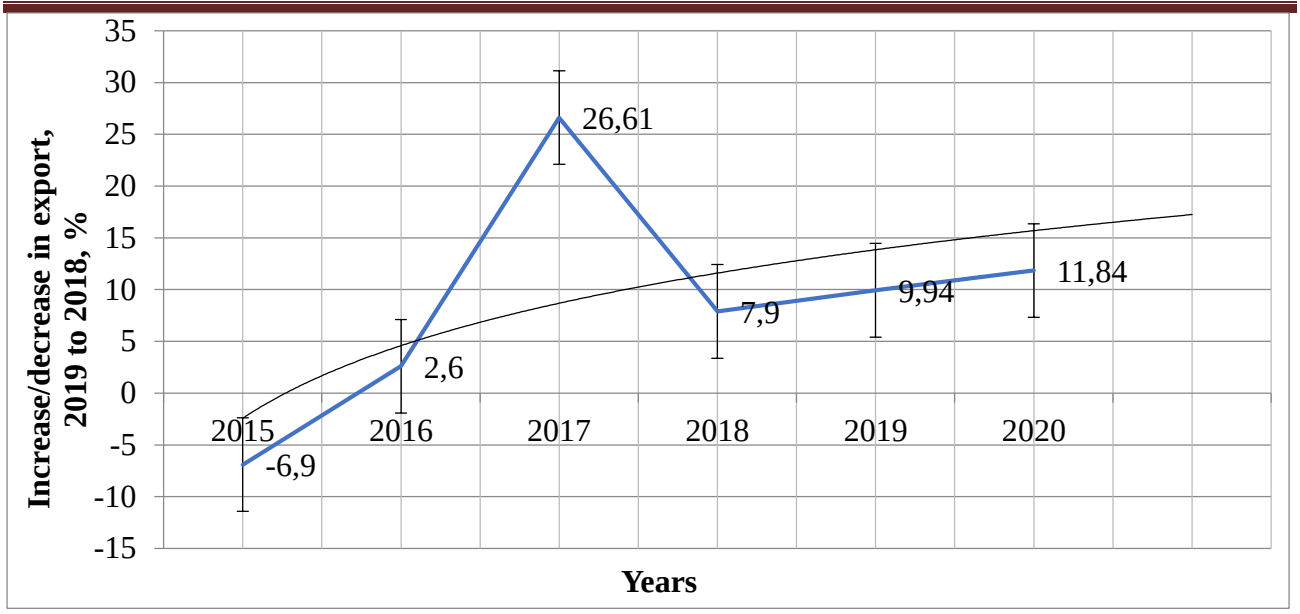

Fig. 1. Results of the analysis and forecast of growth rates / decrease of exports of agricultural products to the EU

Source: calculated by the author according to European Commission, 2020.

Unfortunately, the error bar (shown in Fig. 1) for the standard error is quite wide, so, obviously, the resulting equation needs to be corrected. The application of the developed mathematical model allows forming a polynomial equation (7) for forecasting the indicators of exports to the EU:

$$y = 0.0396x^4 - 0.7268x^3 + 4.772x^2 - 11.189x + 20.923 \quad (7)$$

This approach makes it possible to estimate the increase in 2020 to 2019 at 11.84 %. The results of the analysis and forecast of agricultural exports to the EU are shown in figure 2.

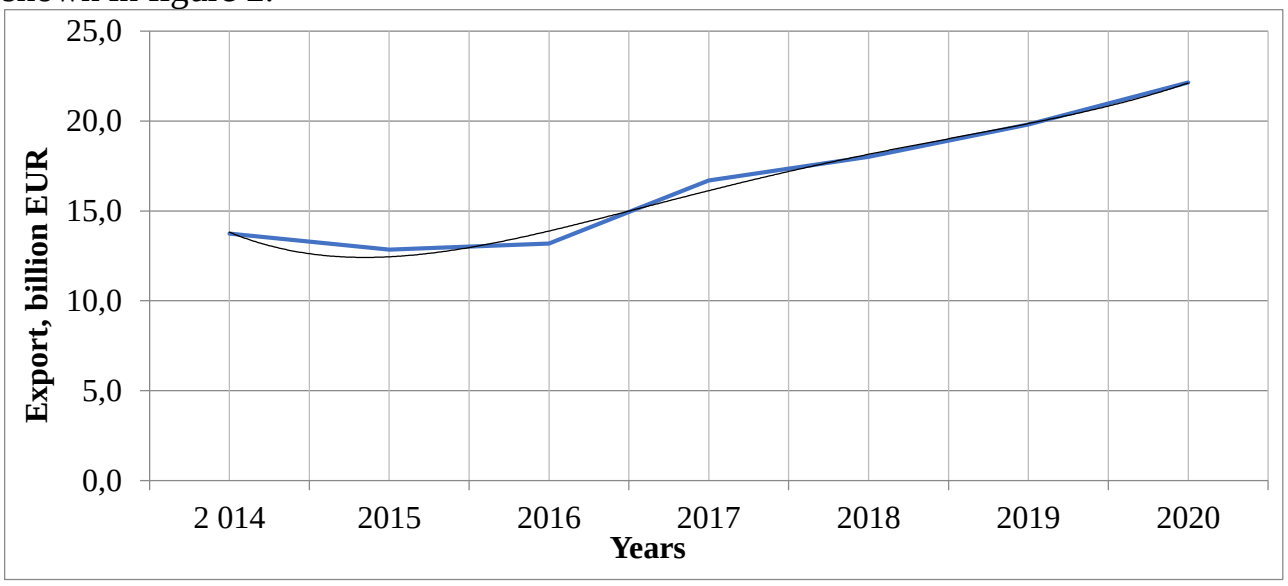

Fig. 2. Results of the analysis and forecast of volumes of export of agricultural products to the EU

Source: calculated by the author according to European Commission, 2020.

A detailed analysis was conducted to predict the impact of expanding the range of exports, in particular, niche goods. Some results of the analysis are given in

table 6. Forecasting using the gravity model showed expectations of a negative impact on export volumes, as there is a steady downward trend in GDP of Ukraine's important trading partners. For example, the annual growth rate of EU GDP, which in the first quarter of 2020 (compared to the first quarter of 2019) was -2.7 %, according to our forecast will worsen and in the first quarter of 2021 will be -2.75 %. EU GDP could reach 19.451 billion USD 19.100 billion USD for 2019. According to our forecasts, Ukraine's GDP for the first quarter of 2021 will give an absolute increase of 3.76 % (41.32 billion USD). GDP by type of economic activity, in particular, the position «Agriculture, forestry and fisheries» will give an absolute increase of 1.86 % (13 billion USD).

Table 6

Forecasting results for individual product items

No.	Product name (abbreviated)	Product code according to the EU classifier	Equation	Growth, 2020 / 2019, %
1	Garlic	07031019	$y = -11.111x^3 + 364.6x^2 – 496.29x + 902.29$	20.40
2	Feathers	05059000	$y = -48070x^2 + 343517x – 483942$	6.14
3	Sunflower oil	15121191	$y = -2E+07x^3 + 2E+08x^2 – 4E+08x + 9E+08$	4.99
4	Cucumbers	07031019	$y = -11.111x^3 + 364.6x^2 – 496.29x + 902.29$	11.20
5	Flowers	04072100	$y = -25576x^3 + 281402x^2 – 387845x + 2E+06$	20.85
6	Honey	04090000	$y = -196161x^5 + 4E+06x^4 – 4E+07x^3 + 1E+08x^2 – 2E+08x + 1E+08$	10.91
7	Soybeans	12019000	$y = 2E+06x^4 – 4E+07x^3 + 3E+08x^2 – 5E+08x + 7E+08$	3.02

Source: calculated by the author according to European Commission, 2020.

There is also a real reason to expect a decrease in exports of agricultural products given the weather and climatic conditions, which are projected to reduce the volume of commodity production in the agricultural sector.

Another negative factor affecting agro-exports is the quarantine restrictions of importing countries related to the COVID-19 pandemic, which primarily has hampered the supply of fresh fruits and vegetables.

On the other hand, according to surveys of producers, the situation with the COVID-19 pandemic can serve as an incentive to expand exports, as quarantine measures by the Ukrainian government have made it difficult to sell early fruits and vegetables in Ukraine and producers have begun to prepare new sales channels to prevent such risks in the future. This confirms the assertion of the different orientation and multidimensionality of groups of factors influencing the export of agricultural products. The analysis also confirms the point that the use of the gravity model to forecast exports as a whole does not provide relevant data.

Summarizing the comparison of different approaches to the formation of agro-export forecasts, first, it is necessary to assess the export prospects for each type of

product, and, secondly, to develop forecasts for regional markets (Middle East, EU, etc.) in terms of each importing countries of these regional markets. And, only having forecast data both on separate goods, and on separate countries, it is possible to forecast integral volumes of export on commodity groups and on regions on this basis. From the point of view of forecasting the export of agricultural products, indeed, 80 % of Ukrainian exports are a rather narrow commodity group - grain and oilseeds. Exports of these crops show steady growth. According to the analysis conducted in the first quarter of 2020, grain gives rise + 7.7 %, oilseeds + 8.8 %. This amount also includes the value of export deliveries of raw materials, which are classified as «residues and waste» – sunflower meal, the volume of exports to the EU of which is more than 2 million tons. In our opinion, the main factor that positively affects the export of these crops is the high yield last year. But, first, the volume of deliveries of 20 % for niche goods is a sufficient basis for the use of specialized analytical forecasting methods; secondly, the share of goods other than grain and oilseeds in exports, including even the processing of primary raw materials, tends to increase and its impact on total exports increases accordingly; thirdly, even if the current level of quotas and supply restrictions is maintained, an increase in the share of higher value-added products will lead to an increase in exports, although not in product, but in monetary terms. There is a positive trend towards an increase in the number of enterprises licensed to export their own products to the EU, moreover, products for the quality of which the EU has special requirements, in particular, livestock products. Production volumes for some goods and product groups have reached the limits of EU duty-free quotas. This applies not only to cereals and oilseeds (wheat, corn, barley) and products of their primary processing (including flour) but also plant products with a relatively high level of processing – processed starch, malt, gluten. From the livestock products with a relatively high level of processing, for which quotas are taken up, it should be mentioned butter, from poultry it is chicken, from horticulture – apple and grape juice.

The analysis shows that the current entry into the markets of importing countries with a niche range of goods is possible. Unfortunately, these attempts are not always successful.

The successful ones include a well-known example of honey exports and a lesser-known one – Ukrainian garlic. In order to forecast the garlic market, we conducted a detailed study of the export group 07 «Edible vegetables and certain roots and tubers» of the product 07032000 Garlic (product code – according to the EU classification). Quota conditions are duty-free delivery of 500 tons/year. Duty rate over quota is 9.6 + 120 EUR per 100 kg. 17 countries entered the markets with this product. Attempts to enter the markets of a number of countries with small trial batches, in particular, Romania and Slovenia, were unsuccessful. In some markets, in particular, Germany, the Netherlands failed to gain a foothold. Work with importers from Poland and the Baltic States turned out to be more successful. In other markets, the supply of garlic is characterized by significant fluctuations, which actually constitute the so-called «white noise», which complicates the forecast for the EU

market as a whole. Nevertheless, the chosen method allows forecasting for 2020/2021 the output value of imports (Import Value) of 740 thousand EUR. In the markets of some EU countries, this will be 120 thousand EUR for Poland, 110 thousand EUR for Estonia, Lithuania 170 thousand EUR for Lithuania and 230 thousand EUR for Latvia.

One of the significant advantages of Ukrainian agro-exports may be the occupation of a niche for supplies of organic products to the EU. Today, the European Commission confirmed the authority of seventeen internationally accredited organizations authorized to certify organic products in Ukraine. Other EU requirements for compliance with environmental norms and regulations also impose their restrictions on the uncontrolled use of mineral fertilizers, herbicides, etc. But this puts a high bar in ensuring European environmental standards in agricultural production. This factor, in our opinion, will be able to change the approach not only of Ukrainian agricultural producers but also of the population as a whole to compliance with environmental standards.

Conclusions. The results of the study revealed the following:

1. The algorithm using a mathematical model for predicting the motion vector of a continuous system, which consists of successive attractors of the same type of aperiodic functional dependences of the first order for individual exports, and individual importing countries on the response surface showed more relevant results compared to the gravity model.

2. Exports of agricultural products to European countries tend to grow and show the highest growth rates among other regions of the world. The high increase in exports to the EU was due to both the growth of physical volumes of supplies (in products) and favorable prices (in monetary terms).

3. Since 2017, there has been a tendency to increase the product range in the export of agricultural products. This increase is characterized by an increase in the penetration index to international markets for a larger number of product groups.

4. The main importers of Ukrainian agricultural products in the EU market are Spain, Poland, the Netherlands, Italy, Germany, Belgium and France. Exports to these countries account for more than 80 % of total exports to the EU. A significant part of agricultural exports to the EU are cereals and oilseeds, and products of their primary processing, together more than 80 % of the cost of supplies. But the share of niche goods and finished products is gradually increasing.

5. The forecasted tendency to expand the nomenclature of agro-exports with an increase in the share of both primary processing goods and goods with higher added value.

6. The relative share of intermediaries in entering foreign markets will decrease and the number of producers and associations of producers will increase. Vegetable and horticultural products will be exported with a shorter delivery leverage.

Taking into account the obtained practical experience of using the developed mathematical model, a promising direction of research is its improvement and the creation of a software product on its basis for use by the expert environment and

scientists. Research using the proposed mathematical model should be continued, primarily to study promising markets for Ukrainian agricultural products – the Middle East and China. Market research in North and South America is also relevant.

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