https://doi.org/10.26565/2786-4995-2026-2-11
UDC: 339.56(477:4-6EU):330.4

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Probabilistic-automatic modeling of the balance sheet of foreign trade of Ukraine with EU countries in terms of goods

Abstract. Ukraine carries out intensive trade in goods with EU countries. This is facilitated by a convenient geographical location, an extensive road network and other factors.

Problem statement. For planning the activities of enterprises, searching for external partners, as well as for forming the state's foreign trade policy, it is advisable to analyze and forecast trade indicators, including by building simulation models.

Unresolved aspects. Given the gap in the use of probabilistic-automatic modeling in the field of studying Ukraine's foreign trade with 27 EU countries both in general and in terms of countries, this article is designed to fill it.

Purpose of the article. The purpose of the article is to build a probabilistic-automatic model of the dynamics of the balance of export-import operations between Ukraine and EU countries in terms of goods.

Main material. The article defines the initial parameters of the model; forms a graph of connections between automatons; determines the structure of the alphabet matrix of the system; builds a system of functions of automatons' outputs; a table of conditional functionals-transitions was formed; a vector of initial states of automatons was determined as actual data on foreign trade in goods between Ukraine and 27 EU countries in 2024; a system of distribution of independent random variables was constructed; simulation runs of the model were conducted using the Microsoft Excel program.

Conclusions. It is predicted that the balance sheet of Ukraine's foreign trade with EU countries in terms of goods in 2025–2027 will be negative, that is, imports will exceed exports, but this difference will decrease annually.

Keywords: *export of goods, import of goods, simulation model, forecasting of dynamics, random variables.*

Formulas: 0; fig.: 2, tabl.: 4, bibl.: 12.

JEL F 17

For citation: Totska Olesia. Probabilistic-automatic modeling of the balance sheet of foreign trade of Ukraine with EU countries in terms of goods. Financial and Credit Systems: Prospects for Development. №2(21) 2026. P. 144-153. https://doi.org/10.26565/2786-4995-2026-2-11

Introduction. Ukraine carries out intensive trade in goods with EU countries, especially in the agricultural sector. This is facilitated by a convenient geographical location, an extensive road network, large crop yields and other factors. Although the state of war in which the state has been since 2022 makes certain adjustments to foreign trade, domestic exporters and foreign importers are quickly adapting to changes. For planning the activities of enterprises, searching for external partners, as well as for forming the state's foreign trade policy, it is advisable to analyze and forecast trade indicators, including by building simulation models.

Literature review. When studying Ukraine's foreign trade, domestic and foreign scientists built and analyzed various models: E. Horska *et al.* (2019) – a multiple linear econometric model of the interdependence of economic and demographic indicators of regions of Ukraine (including exports of goods per capita) [2]; E. Horska *et al.* (2023) – a one-way fixed effects model for analyzing export dynamics in Ukraine [3]; L. Nagyova *et al.* (2018) – a logarithmic linear model of export development from Ukraine to the Visegrad Group countries [6]; O. Totska (2022) – trend models of exports and imports of agro-industrial products between Ukraine and Romania [10]; O. Zadoia and P. M. Duc (2023) – models of economic openness of Ukraine and a number of European countries [12]. However, these publications did not use probabilistic-automatic modeling, which allows simulating the dynamics of the development of the economic system over time.

At the same time, probabilistic-automatic modeling in the field of economics was used by the following scientists: K. M. Afanasiev and I. H. Hanechko (2025) – developed a model of an enterprise for the production of large-sized containers [1]; E. P. Karpets (2024) – built a model for simulating the movement of financial resources in the regional labor market [4]; M. L. Lapishko *et al.* (2018) – proposed a model for predicting the cash flows of an insurer [5]; L. M. Perekhrest (2010) – formed a model of the technological development of a commercial bank [7]; O. L. Totska (2009) – built a model of the activities of a bakery enterprise [8, 85–93]; O. L. Totska (2020) – conducted modeling of the state of treasury accounts of a higher education institution [9, 261–279].

Given the gap in the use of probabilistic- automatic modeling in the field of research on Ukraine's foreign trade with the 27 EU countries, both in general and by country, this article is intended to fill it.

Purpose, objectives and research methods. The purpose of the article is to build a probabilistic-automatic model of the dynamics of the balance of export-import operations between Ukraine and the EU countries in terms of goods.

Research objectives:

1) determination of the initial parameters of the model;
2) formation of a graph of connections between automatons;
3) determination of the structure of the alphabet matrix of the system;
4) construction of a system of output functions of automatons;
5) formation of a table of conditional functionals-transitions;
6) determination of the vector of initial states of automatons;
7) construction of a system of distribution of independent random variables;
8) carrying out simulation runs of the model using Microsoft Excel.

To build the model, data from the State Statistics Service of Ukraine on the geographical structure of foreign trade in goods with the EU countries for 2022–2024 will be used [11].

The study will use the method of probabilistic- automatic modeling. It allows replacing the real system with a model consisting of a number of automatons – objects, each of which has an internal state, can perceive an input signal and produce an output. In our case, based on data for 2022–2024, we will obtain forecast data for 2025–2027.

Research results. *The initial parameters of the probabilistic-automatic model* are as follows. Ukraine annually carries out export-import operations in the field of trade in goods with all 27 EU countries. The internal states of its automatons:

$eg_i(t)$ – random variable (α_i) of exports of goods from Ukraine to the *i*-th EU country for the time period (t; $t+1$), million USD;

$ig_i(t)$ – random variable (β_i) of imports of goods from the *i*-th EU country to Ukraine for the time period (t; $t+1$), million USD;

$bs(t)$ – balance sheet of foreign trade of Ukraine with EU countries in terms of goods for the time period (t; $t+1$), million USD.

The graph of connections between the automatons of the model is presented in Figure 1.

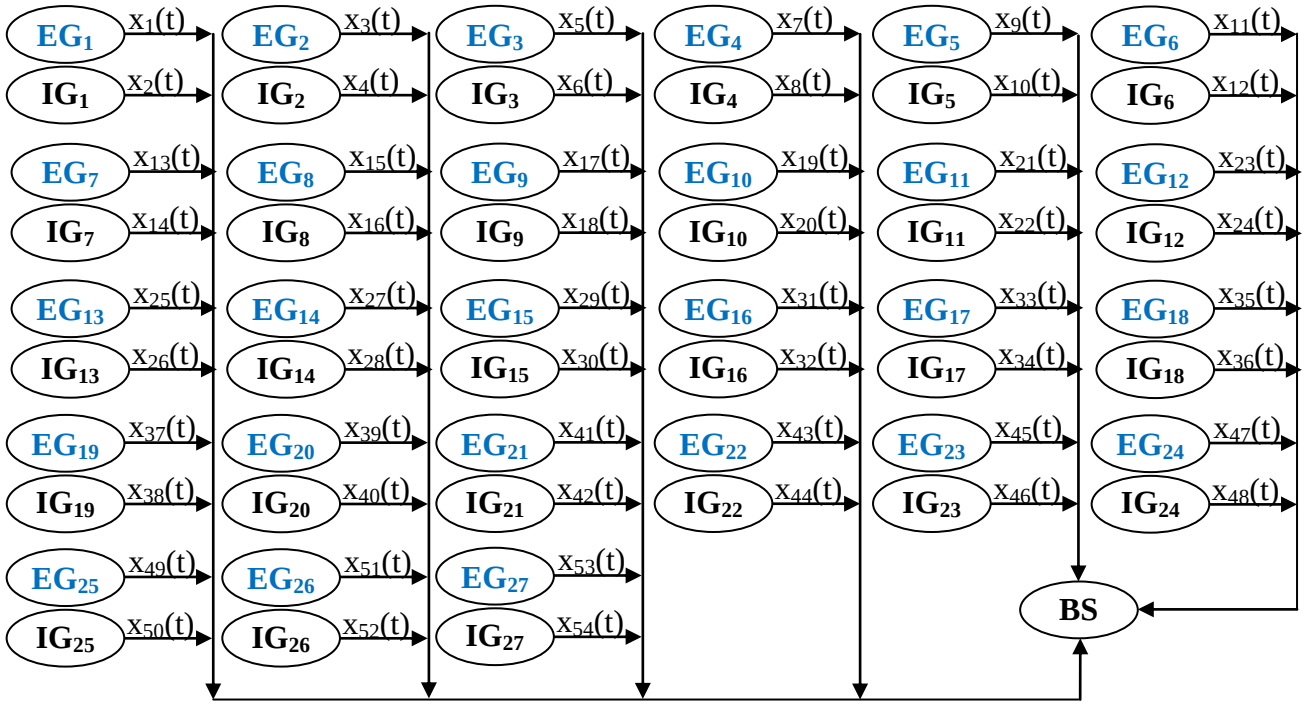

Fig. 1. Graph of connections between automatons of the model:
***EG_1–EG_{27}** – export of goods from Ukraine to 27 EU countries (**EG_1** – Austria, **EG_2** – Belgium, **EG_3** – Bulgaria, **EG_4** – Greece, **EG_5** – Denmark, **EG_6** – Estonia, **EG_7** – Ireland, **EG_8** – Spain, **EG_9** – Italy, **EG_{10}** – Cyprus, **EG_{11}** – Latvia, **EG_{12}** – Lithuania, **EG_{13}** – Luxembourg, **EG_{14}** – Malta, **EG_{15}** – Netherlands, **EG_{16}** – Germany, **EG_{17}** – Poland, **EG_{18}** – Portugal, **EG_{19}** – Romania, **EG_{20}** – Slovakia, **EG_{21}** – Slovenia, **EG_{22}** – Hungary, **EG_{23}** – Finland, **EG_{24}** – France, **EG_{25}** – Croatia, **EG_{26}** – Czechia, **EG_{27}** – Sweden, respectively);*
***IG_1–IG_{27}** – imports of goods from 27 EU countries to Ukraine (**IG_1** – Austria, **IG_2** – Belgium, **IG_3** – Bulgaria, **IG_4** – Greece, **IG_5** – Denmark, **IG_6** – Estonia, **IG_7** – Ireland, **IG_8** – Spain, **IG_9** – Italy, **IG_{10}** – Cyprus, **IG_{11}** – Latvia, **IG_{12}** – Lithuania, **IG_{13}** – Luxembourg, **IG_{14}** – Malta, **IG_{15}** – Netherlands, **IG_{16}** – Germany, **IG_{17}** – Poland, **IG_{18}** – Portugal, **IG_{19}** – Romania, **IG_{20}** – Slovakia, **IG_{21}** – Slovenia, **IG_{22}** – Hungary, **IG_{23}** – Finland, **IG_{24}** – France, **IG_{25}** – Croatia, **IG_{26}** – Czechia, **IG_{27}** – Sweden, respectively);*
***BS** – foreign trade balance sheet of Ukraine with EU countries in terms of goods;*
***$x_1(t)$–$x_{54}(t)$** – signals that show the output functions of the model automatons at time t.*
Source: Author's development.

The matrix of alphabets of the system is shown in Figure 2. It contains the internal alphabet of the automaton on the diagonal, the input alphabet in the column with the name of the automaton, and the output alphabet in the row.

	EG_1	EG_2	EG_3	EG_4	EG_5	…	EG_{27}	IG_1	IG_2	IG_3	IG_4	IG_5	…	IG_{27}	BS
EG_1	R	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	R
EG_2	Ø	R	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	R
EG_3	Ø	Ø	R	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	R
EG_4	Ø	Ø	Ø	R	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	R
EG_5	Ø	Ø	Ø	Ø	R	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	R
…	Ø	Ø	Ø	Ø	Ø	R	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	R
EG_{27}	Ø	Ø	Ø	Ø	Ø	Ø	R	Ø	Ø	Ø	Ø	Ø	Ø	Ø	R
IG_1	Ø	Ø	Ø	Ø	Ø	Ø	Ø	R	Ø	Ø	Ø	Ø	Ø	Ø	R
IG_2	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	R	Ø	Ø	Ø	Ø	Ø	R
IG_3	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	R	Ø	Ø	Ø	Ø	R
IG_4	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	R	Ø	Ø	Ø	R
IG_5	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	R	Ø	Ø	R
…	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	R	Ø	R
IG_{27}	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	R	R
BS	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	R

Fig. 2. Matrix of alphabets of the system:
R – the set of all rational positive numbers;
Ø – the empty set (no connection).
Source: Author's development.

The calculation of output signals is carried out using *a system of automatons' output functions*:

$x_1(t)=eg_1(t)$; $x_{12}(t)=eg_{12}(t)$; $x_{23}(t)=eg_{23}(t)$; $x_{34}(t)=ig_7(t)$; $x_{45}(t)=ig_{18}(t)$;
$x_2(t)=eg_2(t)$; $x_{13}(t)=eg_{13}(t)$; $x_{24}(t)=eg_{24}(t)$; $x_{35}(t)=ig_8(t)$; $x_{46}(t)=ig_{19}(t)$;
$x_3(t)=eg_3(t)$; $x_{14}(t)=eg_{14}(t)$; $x_{25}(t)=eg_{25}(t)$; $x_{36}(t)=ig_9(t)$; $x_{47}(t)=ig_{20}(t)$;
$x_4(t)=eg_4(t)$; $x_{15}(t)=eg_{15}(t)$; $x_{26}(t)=eg_{26}(t)$; $x_{37}(t)=ig_{10}(t)$; $x_{48}(t)=ig_{21}(t)$;
$x_5(t)=eg_5(t)$; $x_{16}(t)=eg_{16}(t)$; $x_{27}(t)=eg_{27}(t)$; $x_{38}(t)=ig_{11}(t)$; $x_{49}(t)=ig_{22}(t)$;
$x_6(t)=eg_6(t)$; $x_{17}(t)=eg_{17}(t)$; $x_{28}(t)=ig_1(t)$; $x_{39}(t)=ig_{12}(t)$; $x_{50}(t)=ig_{23}(t)$;
$x_7(t)=eg_7(t)$; $x_{18}(t)=eg_{18}(t)$; $x_{29}(t)=ig_2(t)$; $x_{40}(t)=ig_{13}(t)$; $x_{51}(t)=ig_{24}(t)$;
$x_8(t)=eg_8(t)$; $x_{19}(t)=eg_{19}(t)$; $x_{30}(t)=ig_3(t)$; $x_{41}(t)=ig_{14}(t)$; $x_{52}(t)=ig_{25}(t)$;
$x_9(t)=eg_9(t)$; $x_{20}(t)=eg_{20}(t)$; $x_{31}(t)=ig_4(t)$; $x_{42}(t)=ig_{15}(t)$; $x_{53}(t)=ig_{26}(t)$;
$x_{10}(t)=eg_{10}(t)$; $x_{21}(t)=eg_{21}(t)$; $x_{32}(t)=ig_5(t)$; $x_{43}(t)=ig_{16}(t)$; $x_{54}(t)=ig_{27}(t)$.
$x_{11}(t)=eg_{11}(t)$; $x_{22}(t)=eg_{22}(t)$; $x_{33}(t)=ig_6(t)$; $x_{44}(t)=ig_{17}(t)$;

Table 1 shows *the conditional functionals of the model transitions*, namely: the names of the automatons and the rules for changing their internal state.

Table 1. Conditional functionals of model transitions

No.	Automaton	Condition	No.	Automaton	Condition	No.	Automaton	Condition	No.	Automaton	Condition
1	EG_1	α_1	15	EG_{15}	α_{15}	29	IG_2	β_2	43	IG_{16}	β_{16}
2	EG_2	α_2	16	EG_{16}	α_{16}	30	IG_3	β_3	44	IG_{17}	β_{17}
3	EG_3	α_3	17	EG_{17}	α_{17}	31	IG_4	β_4	45	IG_{18}	β_{18}
4	EG_4	α_4	18	EG_{18}	α_{18}	32	IG_5	β_5	46	IG_{19}	β_{19}
5	EG_5	α_5	19	EG_{19}	α_{19}	33	IG_6	β_6	47	IG_{20}	β_{20}
6	EG_6	α_6	20	EG_{20}	α_{20}	34	IG_7	β_7	48	IG_{21}	β_{21}
7	EG_7	α_7	21	EG_{21}	α_{21}	35	IG_8	β_8	49	IG_{22}	β_{22}
8	EG_8	α_8	22	EG_{22}	α_{22}	36	IG_9	β_9	50	IG_{23}	β_{23}
9	EG_9	α_9	23	EG_{23}	α_{23}	37	IG_{10}	β_{10}	51	IG_{24}	β_{24}
10	EG_{10}	α_{10}	24	EG_{24}	α_{24}	38	IG_{11}	β_{11}	52	IG_{25}	β_{25}
11	EG_{11}	α_{11}	25	EG_{25}	α_{25}	39	IG_{12}	β_{12}	53	IG_{26}	β_{26}
12	EG_{12}	α_{12}	26	EG_{26}	α_{26}	40	IG_{13}	β_{13}	54	IG_{27}	β_{27}
13	EG_{13}	α_{13}	27	EG_{27}	α_{27}	41	IG_{14}	β_{14}	55	BS	$\sum_{i=1}^{27} eg_i(t) - \sum_{i=1}^{27} ig_i(t)$
14	EG_{14}	α_{14}	28	IG_1	β_1	42	IG_{15}	β_{15}			

Source: Author's development.

To form a vector of initial states and a distribution system of independent random variables, we will construct Table 2, which will display actual data on foreign trade in goods between Ukraine and the EU countries for 2022–2024.

Table 2. Geographical structure of foreign trade in goods of Ukraine with EU countries, million USD

EU country	Export			Import		
	2022	2023	2024	2022	2023	2024
Austria	822.1	635.0	626.9	515.3	537.8	625.0
Belgium	466.7	377.9	854.4	539.9	663.4	674.2
Bulgaria	1,426.1	908.0	1,133.6	2,082.7	2,219.2	2,360.1
Greece	184.1	258.3	409.2	756.1	1,374.1	2,067.1
Denmark	231.3	240.8	211.6	240.3	250.8	273.0
Estonia	125.4	97.3	75.5	95.7	128.3	122.1
Ireland	44.9	14.9	61.2	147.2	196.0	245.8
Spain	1,572.3	2,010.4	2,863.5	702.4	887.6	853.6
Italy	1,647.3	1,562.5	1,935.7	1,801.4	2,280.2	2,576.2
Cyprus	54.8	107.9	139.8	14.6	47.8	80.6
Latvia	297.0	336.0	303.9	235.9	280.0	197.0
Lithuania	662.1	652.8	594.7	1,323.1	1,306.0	1,194.4
Luxembourg	9.2	3.4	5.1	11.0	13.5	14.7
Malta	9.7	70.1	55.2	8.1	7.9	11.4
Netherlands	1,540.8	1,527.3	1,990.4	1,091.3	1,037.1	916.7
Germany	2,264.7	2,411.4	2,840.8	4,563.0	5,076.8	5,386.2
Poland	6,653.0	5,072.1	4,708.9	5,491.4	6,589.8	6,990.1
Portugal	135.7	225.6	235.9	60.8	70.2	81.3
Romania	3,855.8	3,863.0	1,760.8	1,503.2	1,655.1	1,710.8
Slovakia	1,506.8	1,102.9	942.6	988.7	1,677.5	2,001.1
Slovenia	59.0	65.0	64.0	248.1	242.0	265.0
Hungary	2,270.9	1,382.5	1,152.1	1,022.3	1,387.2	1,620.6
Finland	61.7	45.1	46.1	239.2	283.9	241.0
France	586.0	541.3	737.8	1,232.7	1,760.9	1,621.0
Croatia	73.5	87.4	65.1	67.9	82.5	112.6
Czechia	1,252.0	1,034.9	919.8	1,464.8	1,790.9	2,476.5
Sweden	78.0	81.9	95.5	514.8	794.6	994.7
EU-27	27,890.7	24,715.9	24,829.8	26,962.4	32,641.4	35,713.3

Note: The sum of import components does not equal the total due to rounding of data.
Source: Compiled by the author based on data from the State Statistics Service of Ukraine (2026) [11].

As we can see, in the analyzed period, Ukraine exported the largest amount of goods (over 1 billion USD) to 10 EU countries, such as Bulgaria, Spain, Italy, the Netherlands, Germany, Poland, Romania, Slovakia, Hungary, and Czechia. At the same time, the largest importers of goods to Ukraine were 12 EU countries, such as Bulgaria, Greece, Italy, Lithuania, the Netherlands, Germany, Poland, Romania, Slovakia, Hungary, France, and Czechia. The dynamics of the total export of Ukrainian goods to the EU was as follows: a decrease in 2023 and an increase in 2024. At the same time, imports of European goods to Ukraine increased significantly annually.

Based on Table 2, we will form *a vector of initial states* of the model automatons (at time $t=0$). In our case, it will take the values of the data for 2024, namely:

$eg_1(0)$=626.9; $eg_2(0)$=854.4; $eg_3(0)$=1,133.6; $eg_4(0)$=409.2; $eg_5(0)$=211.6; $eg_6(0)$=75.5; $eg_7(0)$=61.2; $eg_8(0)$=2,863.5; $eg_9(0)$=1,935.7; $eg_{10}(0)$=139.8; $eg_{11}(0)$=303.9; $eg_{12}(0)$=594.7; $eg_{13}(0)$=5.1; $eg_{14}(0)$=55.2; $eg_{15}(0)$=1,990.4; $eg_{16}(0)$=2,840.8; $eg_{17}(0)$=4,708.9; $eg_{18}(0)$=235.9; $eg_{19}(0)$=1,760.8; $eg_{20}(0)$=942.6; $eg_{21}(0)$=64.0; $eg_{22}(0)$=1,152.1; $eg_{23}(0)$=46.1; $eg_{24}(0)$=737.8; $eg_{25}(0)$=65.1; $eg_{26}(0)$=919.8; $eg_{27}(0)$=95.5;

$ig_1(0)$=625.0; $ig_2(0)$=674.2; $ig_3(0)$=2,360.1; $ig_4(0)$=2,067.1; $ig_5(0)$=273.0; $ig_6(0)$=122.1; $ig_7(0)$=245.8; $ig_8(0)$=853.6; $ig_9(0)$=2,576.2; $ig_{10}(0)$=80.6; $ig_{11}(0)$=197.0; $ig_{12}(0)$=1,194.4; $ig_{13}(0)$=14.7; $ig_{14}(0)$=11.4; $ig_{15}(0)$=916.7; $ig_{16}(0)$=5,386.2; $ig_{17}(0)$=6,990.1; $ig_{18}(0)$=81.3; $ig_{19}(0)$=1,710.8; $ig_{20}(0)$=2,001.1; $ig_{21}(0)$=265.0; $ig_{22}(0)$=1,620.6; $ig_{23}(0)$=241.0; $ig_{24}(0)$=1,621.0; $ig_{25}(0)$=112.6; $ig_{26}(0)$=2,476.5; $ig_{27}(0)$=994.7.

Table 3 shows the *distribution system of independent random variables*. Note that they are distributed according to the normal law.

Table 3. Distribution system of independent random variables, million USD

Random variable	Mathem. expectat.	Standard deviation	Random variable	Mathem. expectat.	Standard deviation	Random variable	Mathem. expectat.	Standard deviation
α_1	694.7	90.2	α_{19}	3,159.9	989.3	β_{10}	47.7	27.0
α_2	566.3	206.9	α_{20}	1,184.1	237.4	β_{11}	237.7	33.9
α_3	1,155.9	212.1	α_{21}	62.6	2.6	β_{12}	1,274.5	57.1
α_4	283.9	93.6	α_{22}	1,601.8	482.4	β_{13}	13.1	1.5
α_5	227.9	12.2	α_{23}	50.9	7.6	β_{14}	9.1	1.6
α_6	99.4	20.4	α_{24}	621.7	84.1	β_{15}	1,015.0	73.0
α_7	40.3	19.2	α_{25}	75.3	9.2	β_{16}	5,008.7	339.5
α_8	2,148.7	536.1	α_{26}	1,068.9	137.7	β_{17}	6,357.1	633.6
α_9	1,715.2	159.7	α_{27}	85.2	7.5	β_{18}	70.8	8.4
α_{10}	100.8	35.0	β_1	559.4	47.3	β_{19}	1,623.1	87.7
α_{11}	312.3	17.0	β_2	625.8	60.9	β_{20}	1,555.8	422.2
α_{12}	636.5	29.8	β_3	2,220.7	113.3	β_{21}	251.7	9.7
α_{13}	5.9	2.4	β_4	1,399.1	535.5	β_{22}	1,343.4	246.2
α_{14}	45.0	25.7	β_5	254.7	13.7	β_{23}	254.7	20.7
α_{15}	1,686.1	215.2	β_6	115.4	14.1	β_{24}	1,538.2	223.4
α_{16}	2,505.6	244.4	β_7	196.3	40.3	β_{25}	87.6	18.6
α_{17}	5,478.0	844.0	β_8	814.5	80.5	β_{26}	1,910.7	421.6
α_{18}	199.1	45.0	β_9	2,219.3	319.2	β_{27}	768.0	196.8

Source: Compiled by the author based on Table 1.

In our case, the mathematical expectation was calculated using the AVERAGE function of Microsoft Excel as the arithmetic mean of the indicators for 2022–2024, the standard deviation was calculated using the STDEVPA function of Microsoft Excel as the standard deviation of the same indicators.

Having formed all the required elements of the model, we can conduct its simulation runs using Microsoft Excel. In it, we will obtain the values of α_i and β_i using the "Random Number Generation" tool. Note that the unit of automatic time (T) is a year, namely: 0 – 2024, 1 – 2025, 2 – 2026, 3 – 2027.

Table 4. Probabilistic-automatic model for forecasting the balance sheet of foreign trade of Ukraine with EU countries in terms of goods, million USD

T	EG1	EG2	EG3	EG4	EG5	EG6	EG7	EG8	EG9	EG10	EG11
0	626.9	854.4	1,133.6	409.2	211.6	75.5	61.2	2,863.5	1,935.7	139.8	303.9
1	765.3	742.8	1,430.7	263.9	230.0	104.5	20.1	1,969.9	1,651.4	110.3	320.3
2	857.6	386.5	1,303.7	274.6	223.4	89.5	14.8	1,794.9	1,925.7	139.6	332.4
3	647.9	455.1	1,211.8	482.4	228.0	105.2	28.8	2,933.1	1,671.2	55.5	283.0

Table 4. (continued)

T	EG12	EG13	EG14	EG15	EG16	EG17	EG18	EG19	EG20	EG21
0	594.7	5.1	55.2	1,990.4	2,840.8	4,708.9	235.9	1,760.8	942.6	64.0
1	616.5	5.8	16.1	2,280.6	2,695.1	5,428.5	200.3	1,675.2	996.9	64.1
2	644.5	9.7	50.4	1,710.0	2,561.5	5,758.3	209.4	4,266.4	1,702.7	64.6
3	668.1	1.3	5.1	1,868.9	2,554.8	4,932.8	212.2	4,430.4	1,559.9	64.9

Table 4. (continued)

T	EG22	EG23	EG24	EG25	EG26	EG27	IG1	IG2	IG3	IG4	IG5
0	1,152.1	46.1	737.8	65.1	919.8	95.5	625.0	674.2	2,360.1	2,067.1	273.0
1	2,055.8	61.0	645.0	71.0	1,227.8	86.8	559.1	575.4	2,293.4	2,057.9	254.4
2	821.8	48.3	596.7	74.0	818.8	97.7	590.5	591.1	2,222.1	1,613.3	257.9
3	2,013.8	57.5	690.3	87.9	1,014.0	100.9	635.5	694.6	2,051.9	804.3	254.0

Table 4. (continued)

T	IG6	IG7	IG8	IG9	IG10	IG11	IG12	IG13	IG14	IG15	IG16
0	122.1	245.8	853.6	2,576.2	80.6	197.0	1,194.4	14.7	11.4	916.7	5,386.2
1	104.9	255.3	720.3	2,392.7	86.4	282.3	1,270.3	13.3	10.6	907.9	5,365.6
2	110.9	129.8	738.0	1,337.5	53.6	250.5	1,301.1	13.6	8.7	1,181.5	4,975.5
3	119.5	230.1	885.9	1,761.8	72.7	251.1	1,236.7	12.6	7.8	1,004.6	5,505.8

Table 4. (continued)

T	IG17	IG18	IG19	IG20	IG21	IG22	IG23	IG24	IG25	IG26	IG27
0	6,990.1	81.3	1,710.8	2,001.1	265.0	1,620.6	241.0	1,621.0	112.6	2,476.5	994.7
1	6,182.2	87.1	1,691.7	2,261.0	250.5	1,356.7	248.7	1,777.0	33.7	1,954.6	843.5
2	5,677.2	71.7	1,556.0	1,414.0	264.6	1,409.6	278.7	1,758.6	103.8	2,155.6	645.7
3	5,587.0	66.9	1,709.4	1,741.4	248.4	1,569.5	246.2	1,618.6	72.5	1,627.8	526.8

Table 4. (continued)

T	BS
0	-10,882.7
1	-8,100.9
2	-3,933.6
3	-2,178.8

Source: Compiled by the author.

According to Table 4, the foreign trade balance sheet of Ukraine with EU countries in terms of goods in 2025–2027 will be negative, that is, imports will exceed exports, but this difference will decrease annually.

Discussion. According to the model, positive dynamics of trade in goods between Ukraine and the EU countries will be observed annually in 2025–2027 in the following cases: exports to Lithuania (EG12), Slovenia (EG21), Croatia (EG25). In other cases, fluctuations in indicators or a decrease in the level relative to 2024 are expected. Note that since the resulting indicator (balance sheet) is affected by 54 partial indicators (27 indicators of exports and imports, respectively), its deviation from the forecast data may be smaller than similar deviations of its component parts.

The suitability of the model for forecasting will be verified after the State Statistics Service of Ukraine publishes data on the geographical structure of Ukraine's foreign trade in goods with EU countries for 2025.

Conclusions. Simulation modeling allows predicting the dynamics of various economic indicators, including Ukraine's foreign trade in goods. In particular, the constructed probabilistic-automatic model forecasts the export of goods from Ukraine to 27 EU countries and the import of goods from these countries to Ukraine for 2025–2027 based on data for 2022–2024. The results of three simulation runs conducted using Microsoft Excel suggest that the value of the foreign trade balance sheet will be as follows: -8,100.9 million USD in 2025; -3,933.6 million USD in 2026; -2,178.8 million USD in 2027. This will occur due to the annual increase in exports of domestic goods to the EU (25,735.7 million USD; 26,777.5 million USD; 28,364.6 million USD, respectively) and a decrease in imports of goods from the EU to Ukraine (33,836.6 million USD; 30,711.1 million USD; 30,543.4 million USD).

We see further research directions in building similar models for research on trade in services between Ukraine and the EU.

Acknowledgements. Scientific research under the project "Foreign trade in goods of Ukraine with EU countries: analysis, forecasting, modeling" (registration number – No. 2025.02/0006) was carried out with the funds of the grant of the President of Ukraine provided by the National Research Foundation of Ukraine.

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Received: 05.02.2026 *Accepted: 14.05.2026*
Received after review: 30.04.2026 *Published: 30.06.2026*

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Імовірнісно-автоматне моделювання сальдо зовнішньоторговельного балансу України з країнами ЄС у частині товарів

Анотація. Україна здійснює інтенсивну торгівлю товарами з країнами ЄС. Цьому сприяє зручне географічне розташування, розгалужена мережа доріг й інші чинники.

Постановка проблеми. Для планування діяльності підприємств, пошуку зовнішніх партнерів, а також для формування зовнішньоторговельної політики держави доцільно проводити аналіз і прогнозування показників торгівлі, у т. ч. за допомогою побудови імітаційних моделей.

Нерозв'язані аспекти. Зважаючи на прогалину використання імовірнісно-автоматного моделювання у сфері дослідження зовнішньої торгівлі України з 27 країнами ЄС як загалом, так і в розрізі країн, ця стаття покликана її заповнити.

Мета статті. Метою статті є побудова імовірнісно-автоматної моделі динаміки сальдо експортно-імпортних операцій між Україною та країнами ЄС у частині товарів.

Основний матеріал. У статті визначення початкові параметри моделі; сформовано граф зв'язків між автоматами; визначено структуру матриці алфавітів системи; побудовано систему функцій виходів автоматів; сформовано таблицю умовних функціоналів-переходів; визначено вектор початкових станів автоматів як фактичні дані зовнішньої торгівлі товарами між Україною та 27 країнами ЄС у 2024 р.; побудовано систему розподілу незалежних випадкових величин; проведено імітаційні прогони моделі за допомогою програми Microsoft Excel.

Висновки. Спрогнозовано, що сальдо зовнішньоторговельного балансу України з країнами ЄС у частині товарів в 2025–2027 рр. буде від'ємним, тобто імпорт перевищуватиме експорт, але ця різниця щорічно зменшуватиметься.

Ключові слова: *експорт товарів, імпорт товарів, імітаційна модель, прогнозування динаміки, випадкові величини.*

Формул: 0; рис.: 2, табл.: 4, бібл.: 12.

Для цитування: Totska Olesia. Probabilistic-automatic modeling of the balance sheet of foreign trade of Ukraine with EU countries in terms of goods. Фінансово-кредитні системи: перспективи розвитку. №2(21) 2026. С. 144-153. https://doi.org/10.26565/2786-4995-2026-2-11

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Стаття надійшла до редакції 05.02.2026 *Статтю рекомендовано до друку 14.05.2026*
Стаття надійшла після рецензування 30.04.2026 *Статтю опубліковано 30.06.2026*