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Neurolinguistic Exchange Rate Forecasting at War as a Bankruptcy Economic Protection Mechanism

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ABSTRACT

The problem of forecasting financial indicators and exchange rates refers to one of the most difficult and topical economic and financial tasks. The interest and complexity of forecasting the currency exchange rate in Ukraine has increased manifold since the beginning February 24, 2022 of a full-scale war between Russia and Ukraine. Forecasting the exchange rate in Ukraine has become extremely important primarily for the existence of the national economy in military conditions and prevention of bankruptcy of enterprises. The object of research is the average exchange rate of the US dollar to the Ukrainian hryvnia. The subject of the research are the instrumental and economic-mathematical methods of artificial intelligence, the theory of fuzzy sets, genetic algorithms, which enable a verified forecast of the exchange rate in Ukraine for a period of one year. The hypothesis of the study is the assumption that the exchange rate of the Ukrainian currency under the war conditions will fall 2-7 times within 1 year. The purpose of the research is to forecast the currency exchange rate in Ukraine in the conditions of war using methods of neurolinguistic modeling, based on a linguistic description of the factors influencing the exchange rate, as well as to obtain linguistic and quantitative forecast values to reduce the risks of bankruptcy. 16 factors of influencing the currency exchange rate in Ukraine grouped into economic, political, military factors have been identified and also described in a linguistic form. A neurolinguistic economic-mathematical model of forecasting the currency exchange rate in Ukraine was developed and a forecast of this indicator for 1 year was made. The results of the study suggest that the currency exchange rate in Ukraine can decrease more than twice within 1 year which can create a risk for the bankruptcy of enterprises. The dependence of the currency exchange rate of Ukraine on the state of the economy and the war was also plotted.

INTRODUCTION

The issue of forecasting exchange rates is one of the most topical and difficult tasks of modern science. Existing methods, indices and algorithms for the most precise forecasting of financial indicators do not provide accurate verified forecasts. Such a situation necessitates constant search for methods to solve this problem. Classical mathematical methods of forecasting, technical and fundamental analyses, analysis are constantly improved, but now they fail to provide the specified boundary conditions set by financiers (Yan et al., 2021). The purpose of the forecast is definitely to obtain the maximum benefit for all the financial market participants. To achieve this goal, it is necessary to provide the most accurate possible forecast of the dynamics and values of the financial indicator (the currency exchange rate in Ukraine). This task is complicated by the war unleashed February 24, 2022 in Ukraine. The war factor brought about completely new conditions and added new problems to the solution of this task. It has almost changed the existing system of forecasting currency rates in Ukraine. Only some scientific works (Kozlovskiy, 2001) offer an attempt to forecast the exchange rate in Ukraine taking into account the indicator of "force majeure circumstances (catastrophe, disaster, military actions)".

On the basis of the research (Kozlovskiy, 2001), a scientific school for forecasting complex economic processes was established to propose and incorporate the methods of fuzzy logic and genetic algorithms in solving various economic problems. The scientific results obtained in these studies enable us to draw a conclusion about the effectiveness of the methods of neurolinguistic modeling and the method of the theory of fuzzy sets in solving various economic problems. This allows us to conclude that incorporating the methods of neurolinguistic modeling, namely the apparatus of the theory of fuzzy sets is quite reasonable to solve the problem of forecasting the exchange rate in Ukraine in the conditions of war.

Methods of forecasting financial indicators became widely used with the hyperactive development of the world cryptocurrency market in the world economy. This process of cryptocurrency market development also triggered the search for methods of qualitative forecasting of financial indicators and their values in the short and long term. Modern tendencies in the world economy and financial sphere testify that the task of forecasting financial indicators is extremely indispensable (Okuneviciute Neverauskiene et al., 2021).

Suffice it to mention the economic, financial and political aspect of forecasting the exchange rate. The exchange rate is a special financial indicator that depends on the state of the country's economy, on the legislative aspects of the exchange rate regulation of the central bank and financial institutions, as well as on government policy, which may largely depend on world financial institutions, such as the International Monetary Fund (IMF, 2022), the World Bank (The World Bank, 2022), the World Trade Organization (WTO, 2022) and others. Such institutional dependence of the exchange rate complexifies the process of its forecasting. The exchange rate has a definite tendency to be described by qualitative rather than quantitative characteristics. In this respect, the best methodological approach to modeling and forecasting economic and financial indicators are the methods of neurolinguistics modeling.

Incorporating neurolinguistic modeling methods will enable to describe the war factor in Ukraine as well as other factors of direct and indirect influence (such as the policy of the National Bank of Ukraine, international support of Ukraine, political stability in the state, etc.), and qualitatively forecast the exchange rate in Ukraine. On the basis of the most accurate forecast values obtained, financial and economic agents will be able to plan their activities indicatively, in order to avoid bankruptcy in war conditions.

1. LITERATURE REVIEW

Virtually any economic entity experiences the influence of exchange rate fluctuations on its financial results. Direct macroeconomic implications are also documented in the literature (Kudej et al., 2021). Knowing the range of changes in the exchange rate can prevent the bankruptcy of enterprises that ensure the economic development of the state (Dankiewicz, 2020; An et al., 2020; Karas and Reznakova, 2018). In these conditions, the urgent task is not only to minimize currency risks, but also to forecast its level. The influence of currency risks on the state of the state's financial sector is highlighted in the works of numerous modern economists. Thus, in the study (Radhwan et al., 2015) it is proposed to use the differential evolution method for forecasting exchange rates and the genetic algorithm method for model optimization.

The authors (Radhwan et al., 2015; Khodaparasti, 2014) also compared the accuracy of their proposed model with modeling based on regression of support vectors. The results of this experiment showed clear advantages of differential evolution methods based on chaos theory and genetic algorithm with previously existing approaches.

Classical and modernized linear programming and regression analysis methods were shown in the work of Meade (2002), in which the author concluded that linear modeling of the exchange rate shows a more accurate forecast compared to non-linear modeling for a local, short period. Meade N. (2002) used a linear AR-GARCH model in contrast to the work of Sharma et al. (2021), which proved the effectiveness of using both symmetric and asymmetric models of autoregressive conditional heteroscedasticity (GARCH) in forecasting the volatility of five developing countries, such as China, India, Indonesia, Brazil and Mexico.

Lin et al. (2012) tried to address the nonlinear and non-stationary characteristics of financial time series such as foreign exchange rates through proposing a hybrid forecasting model using empirical mode decomposition (EMD) and least squares support vector regression (LSSVR) for foreign exchange rate forecasting. EMD was used to decompose the dynamics of foreign exchange rate into several intrinsic mode function (IMF) components and one residual component.

Strozzi & Zaldivar (2005), and Strozzi & Comenges (2006) introduced the application of state space reconstruction techniques to estimate state space volume and its variation. They defined a trading methodology by considering a sort of acceleration in a high dimensional state space system as a kind of momentum indicator similar to those used in financial technical analysis. This trading methodology has been applied to high-frequency exchange rates between the US Dollar and 18 other foreign currencies from the Euro zone. They concluded that, in terms of prediction power, high-frequency foreign exchange time series have a different behavior from a random walk, i.e. are more predictable. In this sense a certain amount of determinism is embedded in the analyzed financial time series that made their prediction more accurate than a random walk.

Qia and Wu (2002) Employed neural network (NN) to study the nonlinear predictability of exchange rates for four currencies at the 1-, 6- and 12-month forecast horizons. They found that neural network model with market fundamentals cannot beat the random walk (RW) in out-of-sample forecast accuracy. In general, the model performed more poorly when it becomes more complex or when the forecast horizon extends. Their overall results were more on the negative side and suggested that neither nonlinearity nor market fundamentals appear to be very important in improving exchange rate forecast for the chosen horizons.

The problem of forecasting exchange rates in the world economy and finance acquired a new meaning after the onset of Covid-19 pandemic. Thus, in the research of Zu (2022) and Chukurna et al. (2019), it was proposed to use machine learning models (interpretable machine learning, IML) for forecasting 12 exchange rates of currencies. The results of this study indicate that machine learning methods are best suited for forecasting the exchange rate in the short term on small sets of input data.

Asadullah et al. (2021) proposed to use a combination of time series models i.e., ARIMA (Al-Gounmein & Ismail, 2020), an exponential smoothing model i.e., Naïve (Dunis et al., 2008), and one multivariate model – Non-Linear to forecast the exchange rate Auto Regressive Distributive Lag ie, NARDL. The results proved that NARDL outperforms all individual models, i.e., ARIMA, Naïve, and exponential smoothing. By applying a combination of different models via different techniques, the combination of NARDL and Naïve models outperforms all individual and combined models by scoring the least MAPE value, i.e., 0.612. Further evidence shows that the combination of models plays a vital role in forecasting, as stated by Poon and Granger (2003).

Thus, the existing methods of forecasting the currency exchange rate are basically quantitative and have both their strong and weak points: forecast terms, verification, amount of data, etc. The analysis shows that qualitative characteristics are practically not used for forecasting the currency exchange rate.

The purpose of the research is to forecast the currency exchange rate in Ukraine in the conditions of war using methods of neurolinguistic modeling, that incorporates a linguistic description of the factors influencing the exchange rate, as well as to obtain linguistically and quantitatively expressed forecast values to reduce the risks of bankruptcy.

2. METHODOLOGY

To build a neurolinguistic mathematical model for forecasting the currency exchange rate in Ukraine in war conditions, we will apply the following methodological algorithm, which has been successfully tested for solving similar economic and financial problems (Kozlovskiy, 2001; Kozlovskiy et al., 2020) and shown in Figure 1.

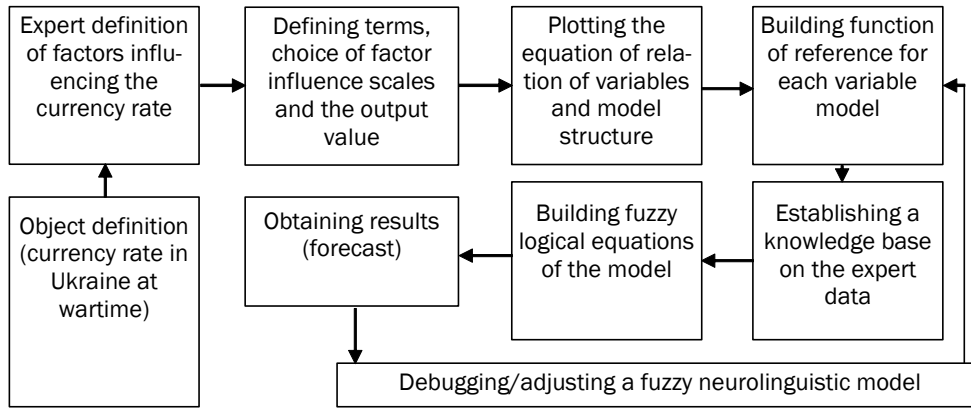


Figure 1. Stages of research

Source: Developed by the authors based on (Kozlovskiy, 2001)

We will apply this methodological approach to forecasting the currency exchange rate in Ukraine in wartime conditions. The apparatus of fuzzy set theory (Zadeh, 1976) was chosen as the mathematical apparatus for building this model. The stages of the research are as follows:

Stage 1. Formulation of the problem and construction of a logical conclusion tree. Basification (identification of the object, determination of influencing factors on the forecast indicator, formulation of the equation and construction of the model structure). We will consider an economic object of the following type:

$$y = f(x_1, x_2, \dots, x_n) \quad (1)$$

with n inputs as economic and financial indicators ($x_i, i = 1, n$) and one output (y), for which we build a conclusion tree.

A logical conclusion tree is a graph whose structure reflects the classification of factors $\{x_1, x_2, \dots, x_n\}$ that affect the predicted indicator (y). At this stage, fuzzification, i.e. selection of vague terms for the linguistic evaluation of factors of influence and formalization of these terms in the following stages are done.

Stage 2. Construction of membership functions. In most systems of fuzzy logical inference, the membership functions of linguistic terms are given in the following parametric form (Rotshtein & Shtovba, 2009):

$$\mu^T(x) = \frac{1}{1 + \left[\frac{x-b}{c} \right]^2}, \quad (2)$$

where: b and c are setting parameters: b is the coordinate of the maximum of the function; c is the concentration-stretch coefficient.

Stage 3. Construction of fuzzy knowledge bases. The results of the so-called virtual (i.e. fictitious) experiment are entered into the fuzzy knowledge base. In the process of such a virtual experiment, the expert

answers the question: what the linguistic assessment of the initial indicator for a given combination of influencing factors will be.

Stage 4. Fuzzy logical inference. Fuzzy logical inference is the approximation of the dependence $y = f(x_1, x_2, \dots, x_n)$ using a fuzzy knowledge base and operations with fuzzy sets.

Stage 5. Defuzzification. Obtaining simulation results. Defuzzification is the procedure of converting a fuzzy set into a clear number. There are several methods of defuzzification, but the most convenient for solving economic problems is the "center of gravity" method (Rotshtein & Shtovba, 2009). Defuzzification of a fuzzy set using the "center of gravity" method is called the calculation of the value Y according to the formula (Rotshtein & Shtovba, 2002):

$$Y = \frac{\sum_{i=1}^n \left[y_{\min} + (i-1) \cdot \frac{y_{\max} - y_{\min}}{n-1} \right] \cdot \mu_i}{\sum_{i=1}^n \mu_i} \quad (3)$$

where: n is the number of terms of the variable y ; y_{\min} , y_{\max} – the size of the measurement scale; μ_i is the value of membership functions.

The defuzzification procedure is a procedure for obtaining the equation results of the forecasting model of currency exchange rate in Ukraine in wartime conditions.

Stage 6. Debugging a fuzzy model. According to the factors affecting the accuracy of the model, various methods of its debugging/adjustment can be applied. These methods include: a) expansion of the scope of the knowledge base; b) adjustment of membership functions. It should also be noted that currently methods of debugging fuzzy models are using genetic algorithm methods (Rotshtein & Shtovba, 2007).

Debugging a fuzzy model is reduced to solving the problem of finding such a vector D that provides:

$$D(Q, B, C) = \sum_{i=1}^n [f(x^i, Q, B, C) - Y^i]^2 \rightarrow \min \quad (4)$$

where: $f(x^i, Q, B, C)$ – forecast value of the selected indicator; x^i – a set of input influencing factors; $Q = (q_1, q_2, \dots, q_m)$ is a vector of weight coefficients of fuzzy rules; $B = (b_1, b_2, \dots, b_m)$ and $C = (c_1, c_2, \dots, c_m)$ are vectors of the membership function parameters; Y^i is a set of values of the initial parameter (predictive indicator).

The problem represented by formula (4) consists in finding the optimal values of parameters that provide a minimum of discrepancies between the predicted and real output factors of the model. Problem (4) can be solved by the gradient algorithm or Newton's method, which are described in detail in works on the theory of optimization (Polyak, 1983) and allow to carry out optimization with a significant expenditure of computer time, since these methods are focused on finding only a local optimum. That is why genetic algorithms, which solve complex optimization problems much more effectively than traditional methods of mathematical programming, are more popular recently.

The method of the genetic optimization algorithm is a process of stochastic search, based on the nature's evolution mechanisms. The fundamental difference between genetic optimization algorithms and classical optimization methods is that they do not use partial derivatives when choosing the optimal search direction, but are based on crossing, mutation, and selection operations.

3. RESULTS

Step by step will we apply the developed methodological approach to forecasting the currency exchange rate in Ukraine in war conditions. The first and main stage of modeling is the determination of factors affecting the currency exchange rate in Ukraine. So, as the task of our research is neurolinguistic modeling, the choice of influencing factors is proposed to be made in the form of both quantitative and linguistic expert assessment. Taking into account expert studies of such institutions as the International Monetary Fund (IMF, 2022), the World Bank (The World Bank, 2022), the World Trade Organization (WTO,

2022), as well as analytical studies of the National Bank of Ukraine (NBU, 2022) identified the main factors influencing the exchange rate in Ukraine (pair US dollar / Ukrainian hryvnia (USD/UAH)) - table. 1. We will calculate the USD/UAH exchange rate as the average commercial exchange rate on the market. Expert factors influencing the currency exchange rate USD/UAH, their range of changes, linguistic assessment, as well as the values of the parameters for the membership functions (formula 2) are given in the table. 1.

Table 1. Factors affecting the USD/UAH exchange rate and their assessment (since the beginning of the full-scale war in Ukraine, 24.02.2022)

Factor	Designation	Range	Linguistic assessment parameters (terms) and the range of their change	Values of b and c parameters of the membership function for (2)	
				b	c
<i>Input factors</i>					
<i>Economic factors (EF)</i>					
The amount of money in circulation (change from date 24.02.2022)	AMC	0...1000%	Increases very much (IVM), 50...1000	500	300
			Increases a lot (IL), 20...50	150	300
			Expedient increase (EI), 0...20	20	200
Accounting rate	AR	0...100 (point)	High (H), 20...100	60	35
			Average (A), 10...20	25	30
			Low (L), 0...10	5	25
Currency reserves of the country	CRC	0...100 billion USD	High (H), 30...100	70	25
			Average (A), 20...30	30	30
			Low (L), 0...20	5	25
Inflation index (month)	II	-5...100% (point)	High (H), 10...100	30	30
			Average (A), 5...10	8	20
			Low (L), -5...5	2	15
Trade balance (month)	TB	-10...10 billion USD	Positive (P), 1...10	5	4
			Sustainable (S), 0...1	1	7
			Negative (N), -10...0	0	5
Gross domestic product (change from date 24.02.2022)	GDP	-100...30%	Growth (G), 5...30	15	10
			Stable (S), 0...5	0.5	15
			Reduction (R), -100...0	0	5
Financial support of Ukraine	FSU	0...100 billion USD	High (H), 40...100	70	35
			Average (A), 10...40	30	25
			Low (L), 0...10	5	15
<i>Political factors (PF)</i>					
Policy of the National Bank of Ukraine	PNBU	0...100	Hard with full state regulation (H), 60...100	80	15
			Mixed with partial regulation (M), 30...60	45	25
			Free market (F), 0...30	15	20
Relations of Ukraine with international organizations (IMF, WTO, WB)	RUIO	0...100	High (H), 60...100	80	20
			Average (A), 30...60	43	25
			Low (L), 0...30	12	15
Rating of Ukraine according to Fitch	RUF	0...100	High - A, AA, AAA (H), 70...100	80	25
			Average - B, BB, BBB (A), 50...70	60	22
			Low - C, CC, CCC (L), 30...50	40	30
			Bad - RD, D (B), 0...30	10	20
Rating of Ukraine according to S&P	RUSP	0...100	High - A, AA, AAA (H), 70...100	80	25
			Average - B, BB, BBB (A), 50...70	60	22
			Low - CC, CCC (L), 30...50	40	30
			Bad - SD (B), 0...30	10	25
Political stability in Ukraine	PSU	0...100	Positive (P), 70...100	80	20
			Sustainable (S), 40...70	60	30
			Negative (N), 0...40	20	25
<i>War factors (WF)</i>					
War (strengthens/weakens)	W	0...100	Decrease in military actions (DMA), 0...25	12	15
			Stability on the military front (SMF), 25...65	35	20
			Increase in military actions (IMA), 65...100	80	25
International military support of Ukraine	IMS	0...100	High (H), 60...100	80	25
			Average (A), 30...60	45	35
			Low (L), 0...30	15	45

Material losses of Ukraine (infrastructure, economy, social sphere)	MLU	0,5...5 trillion USD	High (H), 2...5	2	2
			Average (A), 1...2	1.5	2
			Low (L), 0,5...1	0.5	3
Military and political situation in Russia	MPSR	0...100	Negative (N), 60...100	80	12
			Sustainable (S), 30...60	45	28
			Positive (P), 0...30	12	18
<i>Output factors</i>					
Economic factors (EF)	EF	0...100	Positive (P), 70...100	80	20
			Sustainable (S), 40...70	60	30
			Negative (N), 0...40	20	25
Political factors (PF)	PF	0...100	Positive (P), 70...100	80	20
			Sustainable (S), 40...70	60	30
			Negative (N), 0...40	20	25
War factors (WF)	WF	0...100	Positive (P), 70...100	80	20
			Sustainable (S), 40...70	60	30
			Negative (N), 0...40	20	25
Currency exchange rate USD/UAH (mid-market rate)	CER	5...200 ₴/USD	Positive (P), 5...29	15	20
			Sustainable (S), 29...40	34	25
			Negative (N), 40...80	60	45
			Very Negative (VN), 80...200	130	50

Source: Developed by the authors

Also, Table 1 shows the neurolinguistic assessment, the range of changes and the parameters of the membership functions of the terms of the predicted indicator - the currency exchange rate in Ukraine during the war (CER), for which both quantitative and linguistic characteristics are specified.

Let us denote the linguistic variables of factors EF, PF, WP by the following relationships:

$$EF = f_{EF}(AMC, AR, CRC, II, TB, GDP, FSU) \quad (5)$$

$$PF = f_{PF}(PNBU, RUIO, RUF, RUSP, PSU) \quad (6)$$

$$WF = f_{WF}(W, IMS, MLU, MPSR) \quad (7)$$

The value of the predicted indicator (the currency exchange rate in Ukraine in wartime (CER)) can then be expressed by formula (8):

$$CER = f_{CER}(EF, PF, WF, t_i) \quad (8)$$

where t_i is the forecasting time (3M - 3 months; 6M - 6 months; 1Y - 1 year).

The structure of the model for forecasting the currency exchange rate in Ukraine in the war conditions (CER) is depicted in the form of a "tree of logical conclusion" - figure 2.

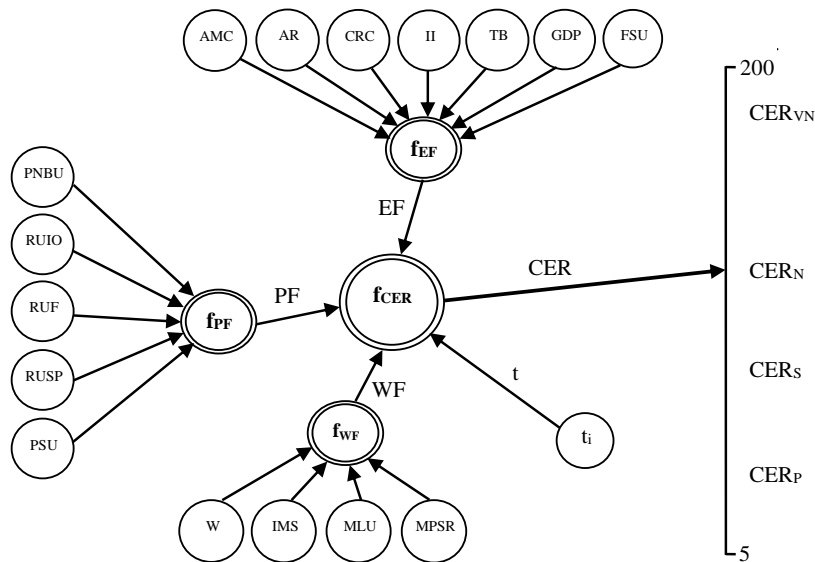


Figure 2. The structure of the currency exchange rate forecasting model in Ukraine in war conditions
 Source: Developed by the authors

The next stage of building a model for forecasting the currency exchange rate in Ukraine is the construction of membership functions for all factors and the initial indicator. Fig. 3 shows the membership function for the initial indicator - the currency exchange rate (CER) with a range of changes from UAH 5 to UAH 200 (according to the values in Table 1).

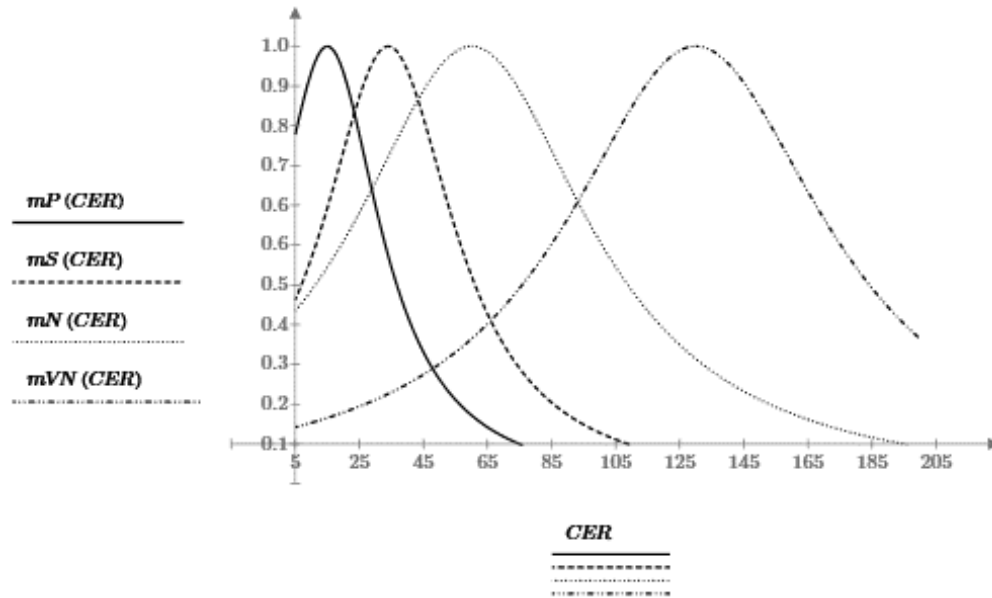


Figure 3. Membership function of the output indicator CER
 Source: Developed by the authors

In order to form the equation of the model of forecasting the currency exchange rate in Ukraine in the war conditions by neurolinguistic modeling, apart from describing the influencing factors, it is also necessary to determine the dependence and influence of these indicators on the forecasted indicator. For this purpose, basing on expert data, hierarchical knowledge bases were developed in accordance with the

dependencies defined by formulas (5)..(7). These dependencies are If-Then rules (Matviychuk et al., 2019). According to this rule, the rules with the same initial value to form the final equations will be combined using the logical operator "OR" (" \cup "). Also, each entry of the knowledge base is assigned a value of "rule weight - q", that is, an assessment of entry quality of the database (in the range from 0 to 1). This indicator "q" will be necessary for adjusting/debugging the model (by methods of genetic algorithms). The hierarchical knowledge base of the initial indicator (CER) according to formula (8) is given in table. 2.

Table 2. Knowledge base of the output indicator CER

<i>EF</i>	<i>PF</i>	<i>WF</i>	<i>t</i>	<i>CER</i>	<i>q</i>
P	P	P	3M	P	q ₁
S	P	S	6M	P	q ₂
S	P	S	1Y	P	q ₃
S	S	S	3M	S	q ₄
P	S	S	6M	S	q ₅
S	P	P	1Y	S	q ₆
N	P	S	3M	N	q ₇
S	N	N	6M	N	q ₈
P	N	N	1Y	N	q ₉
N	N	N	3M	VN	q ₁₀
S	N	N	3M	VN	q ₁₁
N	P	N	6M	VN	q ₁₂

Source: Developed by the authors

Having formed the knowledge bases of the input factors influence on the initial indicator 'the currency exchange rate in Ukraine in the conditions of war', it is possible to write fuzzy logic equations. The equation of the dependence of the EF, PF, WF factors on the respective influences (according to Table 1) is given in Appendix C (equations C.1...C3). The final equation of the model for forecasting the currency exchange rate of Ukraine in war conditions (according to the dependencies in Table 2) is given in the form of formula (9).

$$\begin{aligned}
 \mu^P(CER) &= q_1 \cdot [\mu^P(EF) \cdot \mu^P(PF) \cdot \mu^P(WF) \cdot \mu^{3M}(t)] \cup \\
 & q_2 \cdot [\mu^S(EF) \cdot \mu^P(PF) \cdot \mu^S(WF) \cdot \mu^{6M}(t)] \cup \\
 & q_3 \cdot [\mu^S(EF) \cdot \mu^P(PF) \cdot \mu^S(WF) \cdot \mu^{1Y}(t)] \cup \\
 \mu^S(CER) &= q_4 \cdot [\mu^S(EF) \cdot \mu^S(PF) \cdot \mu^S(WF) \cdot \mu^{3M}(t)] \cup \\
 & q_5 \cdot [\mu^P(EF) \cdot \mu^S(PF) \cdot \mu^S(WF) \cdot \mu^{6M}(t)] \cup \\
 & q_6 \cdot [\mu^S(EF) \cdot \mu^P(PF) \cdot \mu^P(WF) \cdot \mu^{1Y}(t)]; \\
 \mu^N(CER) &= q_7 \cdot [\mu^N(EF) \cdot \mu^P(PF) \cdot \mu^S(WF) \cdot \mu^{3M}(t)] \cup \\
 & q_8 \cdot [\mu^S(EF) \cdot \mu^N(PF) \cdot \mu^N(WF) \cdot \mu^{6M}(t)] \cup \\
 & q_9 \cdot [\mu^P(EF) \cdot \mu^N(PF) \cdot \mu^N(WF) \cdot \mu^{1Y}(t)]; \\
 \mu^{VN}(CER) &= q_{10} \cdot [\mu^N(EF) \cdot \mu^N(PF) \cdot \mu^N(WF) \cdot \mu^{3M}(t)] \cup \\
 & q_{11} \cdot [\mu^S(EF) \cdot \mu^N(PF) \cdot \mu^N(WF) \cdot \mu^{3M}(t)] \cup \\
 & q_{12} \cdot [\mu^M(EF) \cdot \mu^P(PF) \cdot \mu^N(WF) \cdot \mu^{6M}(t)]. \tag{9}
 \end{aligned}$$

This equation (9) is a proposed mathematical description of the neurolinguistic model of forecasting the currency exchange rate of Ukraine in the war conditions for the near and short-term perspective. This forecast will be a mechanism for protecting Ukrainian enterprises from bankruptcy.

Basing on the obtained equation of the economic model for forecasting the currency exchange rate in Ukraine in war conditions and the determined expert input values of the model input variables as of August 17, 2022, we will make a forecast of the currency exchange rate for 2022-2023. Forecasting will

incorporate the formula (3), where the conditional indicator "y" will be substituted by the value of the CER indicator. The forecast of the currency exchange rate in Ukraine is shown in figure 4.

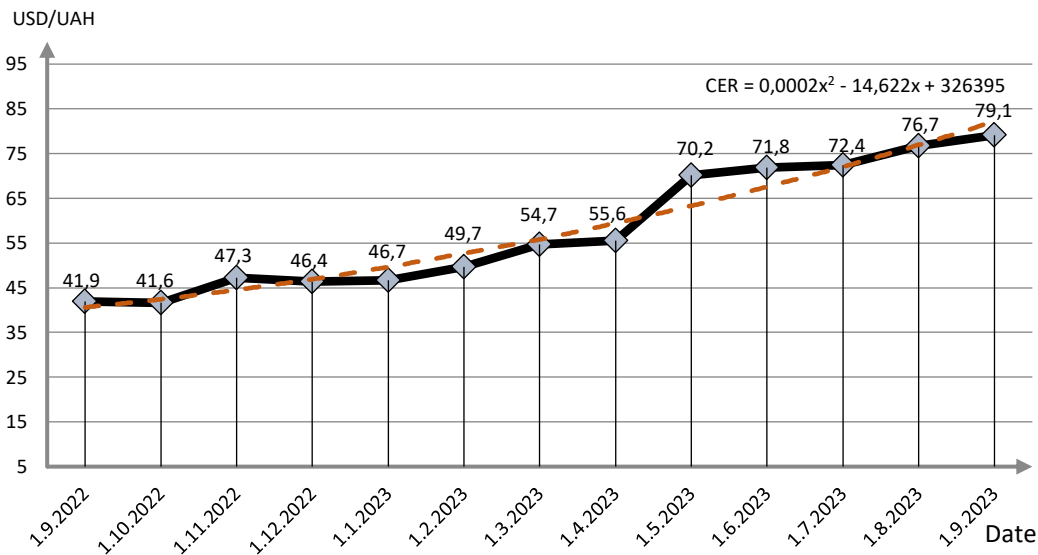


Figure 4. Forecast of the currency exchange rate in Ukraine during the war

Source: Developed by the authors

Suffice it to note, that the forecast was made through model optimization using the genetic algorithm method (the description of this method is not given in this study, but will be presented in another publication of the authors), where more than 50 iterations (formula 4) were incorporated for adjusting the indicator q (the initial value of which was "1") and the parameters of the membership functions b, c of the terms of the model input factors (the initial values of which were given in Table).

Figure 4 also shows the equation of the polynomial approximation of the 2nd degree of this forecast, which is expedient to use for the analysis of a large set of data of an unstable value. The analysis of this forecast indicates a negative trend in the USD/UAH exchange rate. In part, this is a natural change, since the war conditions cause collapse of the economy, mass migration, undermining the main branches of the national economy, destruction of infrastructure and loss of economic and financial ties, which badly affects the national currency of Ukraine.

We have also detected the graphical dependence of the CER output indicator on paired values (EF, WF) performed in the Matlab mathematical package using Image Toolbox – see Figure 5.

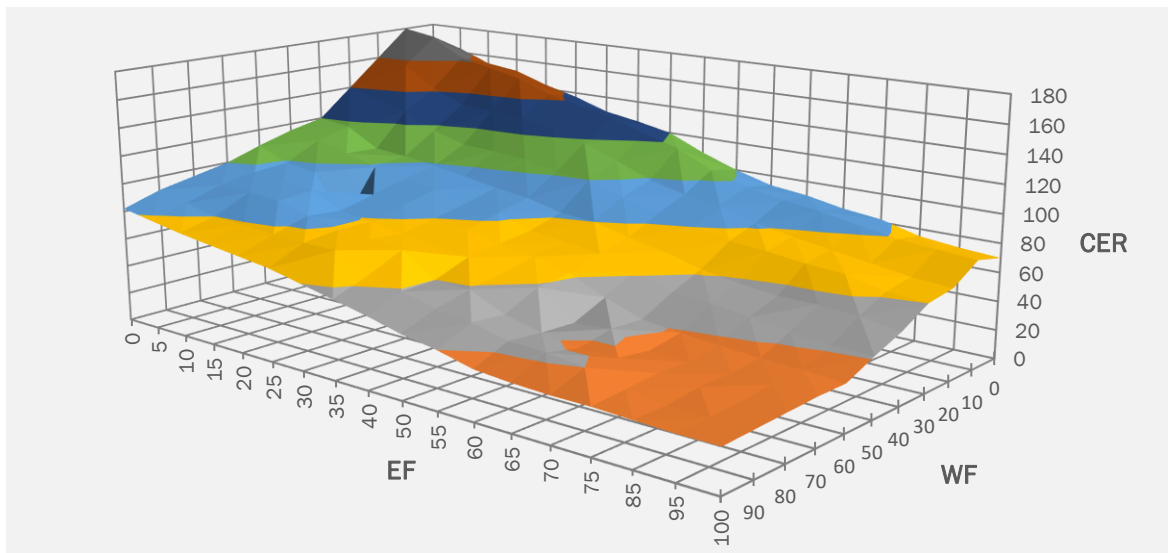


Figure 5. Forecast of the dependence of the currency exchange rate of Ukraine on the state economics and wars CER (EF, WF)

Source: Developed by the authors

Analysis of Fig. 5 indicates that without ceasing the war in Ukraine, the USD/UAH exchange rate will further deteriorate. We expect devaluation of the national currency of Ukraine - the hryvnia, while the instruments of the National Bank of Ukraine for curbing this negative trend will be leveled by catastrophic military, economic and financial losses of Ukraine. To peg the currency exchange in the conditions of military aggravation and economic deterioration, it is necessary to use the instruments of state-legal regulation.

4. DISCUSSION

The problem of forecasting financial indicators is one of the most difficult tasks of modern science. Existing methods of forecasting exchange rates by means of technical and fundamental analysis do not provide a reliable forecast when using qualitative input factors. Technical analysis methods (Moosa, 2000) of forecasting exchange rates are based on the fact that exchange rates are determined by supply and demand. Technical analysis is mainly used for minor changes in the main economic factors affecting the exchange rate. The popularity of technical analysis is explained by dissatisfaction with the fundamental models for determining the exchange rate, which have low prediction and explanatory potential. The behavior of exchange rates since the introduction of the floating rate in the early 1970s has been characterized by significant deviations from the equilibrium rate implied by fundamental models, such as PPP (purchasing power parity) or the monetary model (Schröder & Dornau, 2000). Fundamental analysis is the study of economic factors of influencing foreign exchange rates to forecast future rates. The FTS (Fundamental – Technical – Speculative) method was an attempt to combine the methods of technical and fundamental analysis. However, even this method does not give a high-quality forecast in the conditions of a very unstable economy (Lech, 2003).

Forecasting exchange rates can also be carried out by analytical models (Witkowska, 2005), based on a system of hypotheses formulated in mathematical form. However, this method does not have high verification, since it does not use qualitative factors (Miciuła, 2014). Econometric models of exchange rate forecasting, based on monitoring rates and their interpolation, also have a low verification rate under unstable economic, politic and military conditions. Econometric models have are most reliable only for stable and less volatile economies, to which Ukraine, however, does not refer.

Relying on the available information about the nature and quality of the input factors of influence on the foreign exchange rate in Ukraine, and taking into account the absence of all analytic dependencies, that describe the relation of input and output factors, we can state about the inapplicability of classical currency forecasting methods, since they describe the process by differential or other equations. The conventional exchange rate forecasting models using statistical data gathered from thousands of experiments are very much time-consuming and complex. Therefore, the chosen mathematic apparatus of fuzzy sets to solve the problem of exchange rate forecasting in Ukraine is expedient and effective. It enables to formalize natural cause-and-effect relations between the input and output values. Applying fuzzy set theories makes it possible to describe these relations in a natural language, avoiding time-consuming procedures of gathering and processing a great number of experimental data (Kozlovskiy et al., 2019; Kozlovskiy et al., 2020; Kozlovskiy et al., 2021b; Bilenko and Kozlovskiy, et al., 2022).

Debatable in the conducted modelling remains the issue of quantity and quality of the chosen factors of influence on the exchange rate in Ukraine in wartime conditions. But suffice it to note, that the number of these factors in this model can be increased according to the new factors of influence emerging as a result of military actions in Ukraine. This is one of the main advantages of this economic mathematic model. The forecast of the currency exchange rate in Ukraine by 01.09.2023, obtained in this research may be adjusted through the extended procedure of model optimization by genetic algorithm methods, as well as by adding rules to the established knowledge base. Knowledge base upgrading for this model and performing a higher iteration of model optimization will enable to improve verification rate of the exchange rate prognosis in Ukraine in wartime conditions.

CONCLUSION

Prognosing currency exchange rate in wartime conditions is a completely new scientific problem. Scientific research in this sphere is scarce, since wartime conditions trigger changes not only in the economic, financial and political domains, but can also lead to a geopolitical and international shift on a global scale. This causes the emergence of a huge number of unexpected factors of influence on the currency exchange rate. These factors are sometimes difficult to consider. Therefore, to solve the problem of considering multiple factors and estimating their influence on the currency exchange rate, it is expedient to use methods of neurolinguistic modeling, to which we refer the methods of fuzzy sets. The fuzzy sets theory enables both qualitative description of factors influencing the currency exchange rate and linguistic description of the output value rate (currency exchange rate). The advantages of this mathematic apparatus for solving the research problem are undeniable.

The main idea of this research was to prognose the currency exchange rate in Ukraine in wartime conditions. For this purpose, the factors of influence on exchange rate were determined. The advantage of the choice of factors of influencing the exchange rate was their aptness to linguistic expression, which largely simplified the procedure of subjective evaluation of these factors of influence on the exchange rate for further modeling and prognosing. The developed economic and mathematic model of forecasting the currency exchange rate in Ukraine enables on the basis of qualitative and quantitative estimations to obtain a reliable forecast of the currency exchange rate in the short-term perspective (up to 1 year).

This research proposes a totally new approach to forecasting the currency exchange rate in Ukraine in wartime conditions. This approach involves the use of the following groups of influencing factors: economic, political and military. Each group consists of 4-7 detailed factors of influence which can be described by the methods of neurolinguistic evaluation. The condition of these factors is described with the help of terms set by fuzzy descriptions of their state. The use of fuzzy description enables to reduce the impact of faulty evaluations while prognosing a certain value.

Forecasting a currency exchange rate is necessary for any economic unit, that is developing measures to minimize its economic losses (bankruptcy) while realizing a foreign currency risk. Such losses can occur when the forecast of the currency rate was faulty, i.e., when the estimated currency rates obtained by the above mentioned models did not coincide with the actual rate. Such discrepancy of the prognosed and actual rate was caused by the model error. It is the errors of forecast models of currency exchange rate, that we refer to the currency risk, that may cause losses to the economic unit. To avoid it, the economic

unit has the possibility to take managerial decisions to eliminate own losses at currency rate fluctuation. The proposed in this research model of forecasting currency exchange rate in Ukraine can be serve as a system of support of managerial decisions (bankruptcy economic protection mechanism) for the units of the financial and economic market of Ukraine in wartime conditions.

REFERENCES

- An, Y., Stępień, M., Abusalma, A., Lozitskaya, O. (2020), "Management of cash flows between a debtor and a creditor in the enterprise bankruptcy process", *Polish Journal of Management Studies*, Vo. 22, No. 1, pp. 43-56.
- Asadullah, M., Bashir, A., Aleemi, A.R. (2021), "Forecasting Exchange Rates: An Empirical Application to Pakistani Rupee", *The Journal of Asian Finance, Economics and Business*, Vol. 8, No. 4, pp. 339-347.
- Al-Gounmein, R.S., Ismail, M.T. (2020), "Forecasting the exchange rate of the Jordanian Dinar versus the US dollar using a Box-Jenkins seasonal ARIMA Model", *International Journal of Mathematics and Computer Science*, Vol. 15, No. 1, pp. 27-40.
- Bilenko, D., Kozlovskiy, S., Ivanyuta, N., Baidala, V., Lavrov, R., Kozlovskiy, V. (2022), "Efficiency Assessment of Tax Measures in the European Countries Against the Effects of COVID-19", *Problems of Sustainable Development*, Vol. 17, No. 1, pp. 16-22 (in Ukrainian).
- Chukurna, O., Nitsenko, V., Kralia, V., Sahachko, Y., Morkunas, M., Volkov, A. (2019), „Modelling and managing the effect of transferring the dynamics of exchange rates on prices of machine-building enterprises in Ukraine”, *Polish Journal of Management Studies*, Vol. 19, No. 1, pp. 117-129.
- Dankiewicz, R. (2020), "Analysis of companies' bankruptcy in Poland as compared with the cost of protection under trade credit insurance", *Journal of International Studies*, Vol. 13, No. 4, pp. 197-212. doi:10.14254/2071-8330.2020/13-4/14.
- Dunis, C. L., Laws, J., Sermpinis, G. (2008), "Modeling and trading the EUR/USD exchange rate at the ECB fixing", *European Journal Finance*, Vol. 16, No. 6, pp. 541-560.
- International Monetary Fund (2022), <https://www.imf.org>
- Karas, M., Reznakova, M. (2018), "Building a bankruptcy prediction model: could information about past development increase model accuracy?", *Polish Journal of Management Studies*, Vol. 17, No. 1, pp. 116-130.
- Khodaparasti, R.B. (2014), "The role of macroeconomic variables in the stock market in Iran", *Polish Journal of Management Studies*, Vol.10, No. 2, pp. 54-64.
- Kozlovskiy, S.V. (2001), "Application of the latest methods of modeling the state of the currency market of Ukraine", *Bulletin of the Ternopil Academy of National Economy*, Vol. 12, pp. 80-91 (in Ukrainian).
- Kozlovskiy, S., Butyrskiy, A., Poliakov, B., Bobkova, A., Lavrov R., Ivanyuta, N. (2019), "Management and comprehensive assessment of the probability of bankruptcy of Ukrainian enterprises based on the methods of fuzzy sets theory", *Problems and Perspectives in Management*, Vol. 1, No. 3, pp. 370-381.
- Kozlovskiy, S., Nikolenko, L., Peresada, O., Pokhlyiuk, O., Yatchuk, O., Bolgarova, N., Kulhanik, O. (2020), "Estimation level of public welfare on the basis of methods of intellectual analysis", *Global Journal of Environmental Science and Management*, Vol. 6, No. 3, pp. 355-372.
- Kozlovskiy, S., Petrunenko, I., Baidala, V., Myronchuk, V., Kulnich, T. (2021b), "Assessment of public welfare in Ukraine in the context of the COVID-19 pandemic and economy digitalization", *Problems and Perspectives in Management*, Vol. 19, No. 1, pp. 416-431.
- Kudej, M., Gavurova, B., Rowland, Z. (2021), "Evaluation of the selected economic parameters of Czech companies and their potential for overcoming global crises during the Covid-19 pandemic", *Journal of International Studies*, 14(1), 258-275. doi:10.14254/2071-8330.2021/14-1/18.
- Lin, C.S., Chiu, S.H., Lin, T.Y. (2012), "Empirical mode decomposition-based least squares support vector regression for foreign exchange rate forecasting", *Economic Modelling*, Vol 29, No. 6, pp. 2583-2590.
- Lech, A. (2003), *Risk Management – Key to Stability*, WIB Publishing House, Warsaw (in Poland).
- Matviychuk, A., Lukianenko, O., Miroshnychenko, I. (2019), "Neuro-fuzzy model of country's investment potential assessment", *Fuzzy Economic Review*, Vol. 24, No. 2. <http://www.sigef.net/2014-09-26-07-16-23/summaries-and-abstracts/item/653-neuro-fuzzy-model-of-country-s-investment-potential-assessment>

- Miciuła, I. (2014), "The Concept of FTS Analysis in Forecasting Trends of Exchange Rate Changes", *Economics & Sociology*, Vol. 7, No. 2, pp. 172-182.
- Meade, N. (2002), "A comparison of the accuracy of short term foreign exchange", *International Journal of Forecasting*, Vol. 18, No. 1, pp. 67-83.
- Moosa, I.A. (2000), *Technical Analysis. In: Exchange Rate Forecasting: Techniques and Applications. Finance and Capital Markets Series*, Palgrave Macmillan, London.
- National Bank of Ukraine (2022), <https://bank.gov.ua>
- Poon, S., Granger, C.W.J. (2003), "Forecasting volatility in financial markets: A review", *Journal of Economic Literature*, Vol. 41, pp. 478-538.
- Polyak, B.T. (1983), *Introduction to optimization*, Science, Moscow (in Russian).
- Qia, M., Wu, Y. (2002), "Nonlinear prediction of exchange rates with monetary fundamentals", *Journal of Empirical Finance*, Vol. 10, No. 5, pp. 623-640.
- Okuneviciute Neverauskiene, L., Danileviciene, I., Rutkauskas, V.A. (2021), "Portfolio of Macroeconomic Processes as a Tool of the Country's Economic Efficiency Management", *Transformations in Business & Economics*, Vol. 20, No 2 (53), pp. 62-84.
- Radhwan, A., Kamel, M., Dahad, M., Hassanien, A. (2015), "Forecasting Exchange Rates: A Chaos-Based Regression Approach", *International Journal of Rough Sets and Data Analysis*, Vol. 2, No. 1, pp. 38-57.
- Rotshtein, A., Shtovba, S. (2009), "Modeling of the Human Operator Reliability with the Aid of the Sugeno Fuzzy Knowledge Base", *Automation and Remote Control*, Vol. 70, pp. 163-169.
- Rotshtein, A., Shtovba, S. (2007), "Genetic Optimization of Multidimensional Technological Process Reliability", *Computational Intelligence in Reliability Engineering (SCI)*, Vol. 39, pp. 287-300.
- Rotshtein, A.P., Shtovba, S.D. (2002), "Influence of Defuzzification Methods on the Rate of Tuning a Fuzzy Model", *Cybernetics and Systems Analysis*, Vol. 38, pp. 783-789.
- Sharma, S., Aggarwal, V., Yadav, M.P. (2021), "Comparison of linear and non-linear GARCH models for forecasting volatility of select emerging countries", *Journal of Advances in Management Research*, Vol. 18, No. 4, pp. 526-547.
- Schröder, M., Dornau, R. (2000), "Do Forecasters use Monetary Models? An Empirical Analysis of Exchange Rate Expectations", *Applied Financial Economics*, Vol. 12, No. 8, pp. 535-543.
- Strozzi, F., Comenges, J. M. Z. (2006), "Towards a non-linear trading strategy for financial time series. Chaos, Solitons, and Fractals", Vol. 28, No. 3, pp. 601-615.
- Strozzi, F., Zaldivar, J. M. (2005), "Non-linear forecasting in high-frequency financial time series", *Physica A: Statistical Mechanics and its Applications*, Vol. 353, pp. 463-479.
- The World Bank (2022), <https://www.worldbank.org>
- Witkowska, D. (2005), *Basic Econometrics and Forecasting Theory*. Economic Publishing House Cracow (in Poland).
- WTO "World Trade Organization" (2022), <https://www.worldbank.org>
- Zadeh, L. (1976), *The concept of a linguistic variable and its application to making approximate decisions*, World, Moscow (in Russian).
- Zhi, S., Xuanye C., You, W. (2022), "Exchange rates forecasting and trend analysis after the COVID-19 outbreak: new evidence from interpretable machine learning", *Applied Economics Letters*, 15.06. 2022. <https://www.tandfonline.com/doi/full/10.1080/13504851.2022.2089621?needAccess=true>
- Yan, Q., Wang, Y., Qin, G. Zhu, J., Zidonis, Z. (2021), "Short-Term Load Forecasting Based on Improved Particle Swarm Optimisation and Long Short-Term Memory Network", *Transformations in Business & Economics*, Vol. 20, No 1 (52), pp. 154-177.