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ANALYSIS AND FORECASTING THE LEVEL OF POVERTY IN UKRAINE

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АНАЛІЗ ТА ПРОГНОЗУВАННЯ РІВНЯ БІДНОСТІ В УКРАЇНІ

The article examines the current state and future trends of poverty in Ukraine. The main factors contributing to poverty in Ukraine and their impact on the life of the population have been studied. To identify the dependence between indicators, a correlation analysis was performed with the visualization of the correlation matrix. The use of the correlation matrix in the article made it possible to effectively identify and analyze the relationships between the main economic indicators, such as GDP, private consumption and government spending, and the level of poverty in Ukraine. This made it possible to assess the strength and direction of the influence of each of the indicators on the poverty level, which contributed to the formation of more accurate predictive models. Determining the key factors that have a significant impact on poverty will allow for the development of targeted recommendations for social and economic policy and identify potential problem areas in the social protection system.

A forecast of the level of poverty in Ukraine was made based on various models (Drift, Mean, Naive and Trend), as well as mathematical modeling was carried out to assess the impact of various economic indicators on the level of poverty and forecasts of future changes were made. The models were evaluated using statistics such as mean square error (MSE), root mean square error (RMSE), mean absolute error (MAE), mean relative error (MPE), mean absolute percentage error (MAPE), mean absolute scaled error (MASE) and root mean square standardized error (RMSSE). This made it possible to accurately predict trends and develop measures to prevent the growth of poverty. Time series analysis has helped identify long-term trends and seasonal fluctuations, which are important for predicting future changes. Forecasting the poverty level based on different models showed high uncertainty. The Naive and Mean models showed relatively better prediction accuracy. However, the Naive model was the best because of its smaller relative error (MAPE). In general, data from the World Bank indicate significant challenges for Ukraine related to the war and economic instability.

The results of the study emphasize the importance of developing comprehensive socio-economic reforms and targeted policies aimed at reducing the level of poverty in Ukraine.

У статті розглядається сучасний стан та майбутні тенденції бідності в Україні. Досліджено основні фактори, що сприяють бідності в Україні, та їх вплив на життя населення. Для виявлення залежності між показниками, проведений кореляційний аналіз з візуалізацією кореляційної матриці. Використання кореляційної матриці в статті дозволило ефективно виявити та проаналізувати взаємозв'язки між основними економічними показниками, такими як ВВП, приватне споживання та урядові витрати, і рівнем бідності в Україні. Це дало змогу оцінити силу та напрямок впливу кожного з показників на рівень бідності, що сприяло формуванню точніших прогностичних моделей. Визначення ключових факторів, що мають значний вплив на бідність, дозволить розробити цільові рекомендації для соціально-економічної політики та виявити потенційні проблемні зони в системі соціального захисту.

Виконаний прогноз рівня бідності в Україні на основі різних моделей (Drift, Mean, Naive та Trend), а також здійснено математичне моделювання для оцінки впливу різних економічних показників на рівень бідності та створено прогнози щодо майбутніх змін. Моделі оцінено за допомогою статистичних показників, таких як середня квадратична похибка (MSE), корінь середньоквадратичної помилки (RMSE), середня абсолютна похибка (MAE), середня відносна помилка (MPE), середня абсолютна похибка у відсотках (MAPE), середнє абсолютне відхилення (MASE) і корінь середньоквадратичної стандартизованої помилки (RMSSE). Це дозволило точно передбачити тенденції та розробити заходи для запобігання зростанню бідності. Аналіз часових рядів допоміг виявити довгострокові тенденції та сезонні коливання, що є важливими для прогнозування

майбутніх змін. Прогнозування рівня бідності на основі різних моделей показало високу невизначеність. Моделі Naïve та Mean показали відносно кращу точність прогнозів. Проте, модель Naïve виявилася найкращою через її меншу відносну помилку (MAPE). В цілому, дані Світового банку свідчать про значні виклики для України, пов'язані з війною та економічною нестабільністю.

Результати дослідження підкреслюють важливість розробки комплексних соціально-економічних реформ і цілеспрямованих політик, спрямованих на зниження рівня бідності в Україні.

Keywords: poverty, economic indicators, correlation matrix, forecasting, time series, trend.

Ключові слова: бідність, економічні показники, кореляційна матриця, прогнозування, часовий ряд, тренд.

Statement of the problem in general terms and its connection with important scientific or practical tasks. In the light of current global challenges and unfavorable events, it is important to focus on the problem of poverty, which lately has become more relevant. Growing instability and economic difficulties demonstrate the need for research and modeling of poverty, particularly in the context of Ukraine. The war has a significant impact on the economy and social situation, increasing the need for balanced and effective poverty reduction strategies.

From a scientific point of view, poverty research helps to understand the mechanisms of social inequality, identify the main factors, which affect the economic well-being of citizens, and develop theoretical models for forecasting and managing socio-economic processes.

The research's relevance lies in several key factors. First, poverty remains one of the most serious global problems affecting billions of people, which creates

barriers to development, education, health, and general well-being. Secondly, it is central to the UN Sustainable Development Goals, which seek to eradicate poverty in all its forms by 2030. Thirdly, poverty is closely related to other socio-economic indicators, such as unemployment, inflation, and income inequality, which makes it necessary to study this subject in depth. Modern methods of mathematical modeling make it possible to obtain accurate forecasts and develop effective strategies to combat poverty. Forecasting results are crucial for taking informed decisions by governments, international organizations, and charity foundations, which makes this research especially important in the light of current economic events.

Analysis of recent research and publications. Among the domestic scientists who have studied the level of poverty in Ukraine are: Petrushyna T.O., Pavliuk T.I., Novak I.G.; among foreign scientists - Hall O., Dompe F., Wahab I., Mavunho Janku F. A. Significant contribution to solving the problem of analyzing the level of poverty by means of mathematical modeling was made by such authors as: Oduwole G. K., Shehu S. L., Agbata B. S., Msuur S., Jeremiah A., Jane O. O.

However, given the ongoing economic, political, and institutional transformations that significantly affect the level of unemployment, the study of this problem remains relevant and requires further research.

Formulation of the goals of the article. The purpose of the article is to analyze and forecast the level of poverty in Ukraine using mathematical modeling methods in order to identify its dynamics, main causes and factors of influence.

Presentation of the main research material. In order to analyze poverty, the database of macro indicators for Ukraine from the World Bank data for 2015 to 2023 was selected, namely year (Year), poverty rate (change) (Poverty), real GDP growth (GDP), private consumption (Private), government spending (Government), gross fixed investment (Gross), exports of goods and services (Exports), imports of goods and services (Imports), inflation (Inflation), value added in the following sectors: Agriculture, Industry, Services, current account balance (% of GDP), net direct

investment from abroad (% of GDP), fiscal balance (% of GDP), revenues (% of GDP), debt (% of GDP), primary balance (% of GDP).

The graph of the variables' dynamics by year (Figure 1) shows how selected economic indicators changed from 2016 to 2022. It can be seen that the majority of indicators significant fluctuated, especially in the period from 2022, when a full-scale war in Ukraine began. It has affected such indicators as GDP, exports, imports, and poverty rates. The sharp changes in 2022, in particular, reflect the impact of the war on the economic situation in the country.

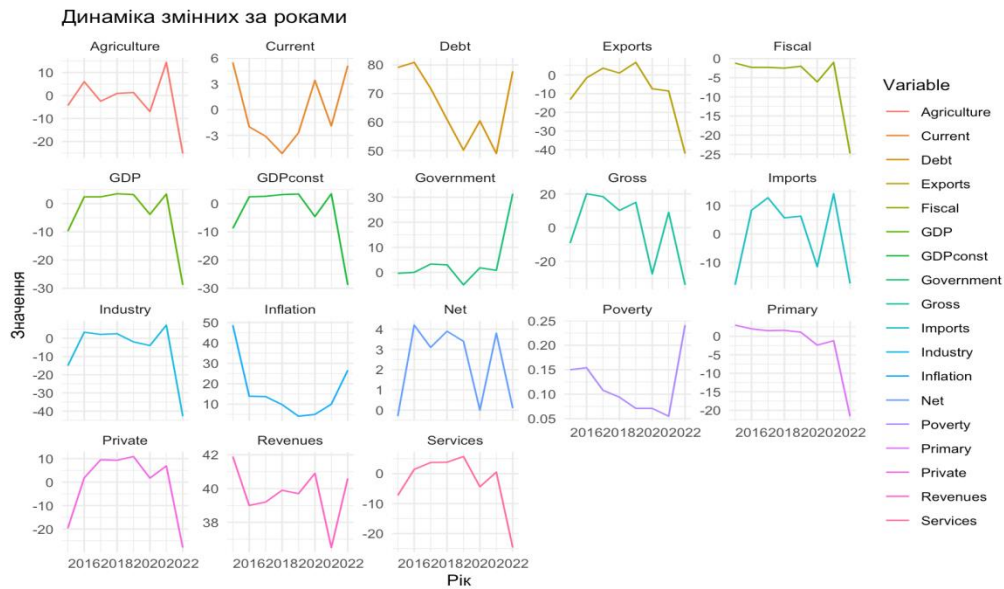


Fig. 1. Dynamics of variables by years.

Source: developed by the authors based on [1].

To identify the dependence between the indicators, a correlation analysis was conducted with the visualization of the correlation matrix, using the calculated Pearson correlation coefficient according to the formula:

$$r = \frac{n * \sum X_i * Y_i - \sum X_i * \sum Y_i}{\sqrt{[n * \sum X_i^2 - (\sum X_i)^2] * [n * \sum Y_i^2 - (\sum Y_i)^2]}} \quad (1)$$

where X_i and Y_i - the quantitative indicators to be compared;

n - the number of data (observations).

The correlation analysis shows a correlation between poverty and GDP of -0.836, which indicates a strong inverse relationship. That is, as GDP increases, the poverty rate decreases. Similarly, the correlation between poverty and private consumption is -0.845, which also indicates a strong inverse relationship: an increase in private consumption is associated with a decrease in poverty. In the case of government expenditure, the correlation with poverty is 0.795, indicating a direct relationship: as government expenditure increases, poverty increases.

The correlation matrix provides a clearer representation of the relationships. (Figure 2).

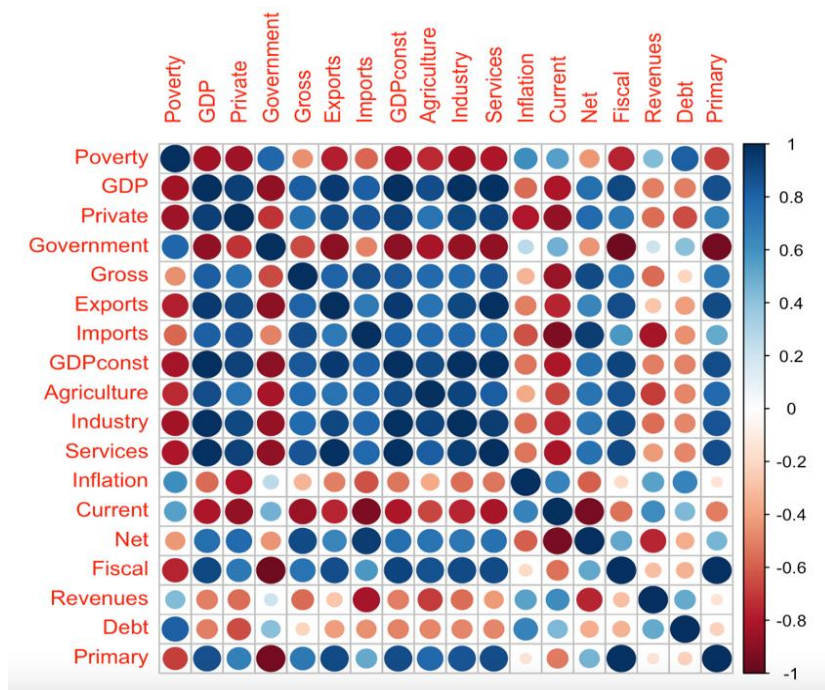


Fig. 2. Correlation matrix

Source: compiled by the authors

After analyzing the correlation between GDP and other variables, it is noticeable that GDP has a strong positive relationship with private consumption (0.934), exports (0.952), and industry (0.986). It can be said that GDP growth is accompanied by an increase in private consumption, exports, and industrial activity.

As regards the correlation between private consumption and other indicators, private consumption is highly correlated with exports (0.896), imports (0.851), and services (0.926). This indicates that an increase in private consumption is associated with an increase in exports, imports, and services.

Government spending has a strong inverse correlation with many economic indicators, including GDP (-0.882), private consumption (-0.712), exports (-0.897), and industry (-0.861). Inflation has a strong inverse relationship with private consumption (-0.797) and GDP (-0.567).

Overall, we have identified the macro indicators that have the greatest impact on poverty in Ukraine, namely GDP, private consumption, and government spending.

Having selected the indicators with the greatest impact, a graph of their dynamics from 2015 to 2023 and the World Bank's projected data through 2026 was built (Figure 3).

After the beginning of a full-scale war in Ukraine in 2022, economic indicators have undergone significant changes. In 2022, GDP, private consumption, and exports plummeted, reflecting the severe economic disruption caused by the war. This decline can be attributed to the destruction of infrastructure, reduced production, and disruption of trade routes.

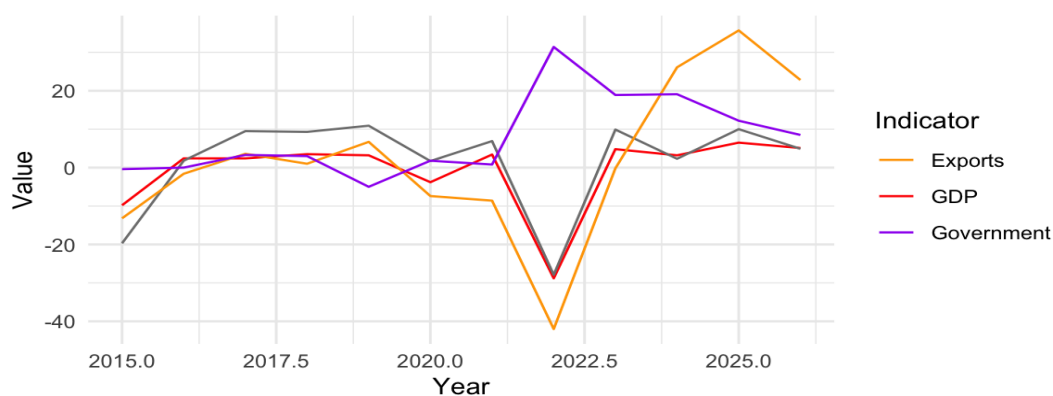


Fig. 3. Graph of macroeconomic indicators dynamics through 2026.

Source: compiled by the authors

According to the World Bank's forecasts, a gradual recovery of economic indicators will begin in 2023. After the fall exports show the sharpest fluctuations and significant growth, which may indicate the resumption of trade relations and stabilization of the economic situation. GDP and private consumption show a more stable rehabilitation, indicating a gradual recovery of economic activity in the country.

Since the war broke out in Ukraine, government spending has fluctuated significantly. In particular, there is a sharp decline in 2022, likely due to the military operations and economic instability. After that, spendings are projected to gradually recover, which may indicate the government's efforts to stabilize the economy and support recovery.

Thus, an attempt was made to build a poverty forecast for Ukraine based on different models: Drift, Mean, Naive and Trend. Initial data is presented up to 2022, after which the forecasting for 2023-2026 starts.

The forecasts for 2023-2026 show different scenarios depending on the model used. That is, the largest spread of forecasts is observed in the Drift and Naive models, reflecting the greater uncertainty in these methods. The Mean model predicts a more stable poverty rate, while the Trend model shows a gradual decline in poverty. This is likely due to expectations of a gradual economic recovery (Figure 4).

The prediction ranges, represented by the gray areas, show the levels of uncertainty: dark gray areas represent 80% probability, and light gray areas - 95% means probability. In the context of the unstable economic situation and the current state of war, this emphasizes the high uncertainty of the forecasts.

Thus, analysis of the graph shows that, despite the overall recovery trend, poverty remains high with a great degree of uncertainty about the future.

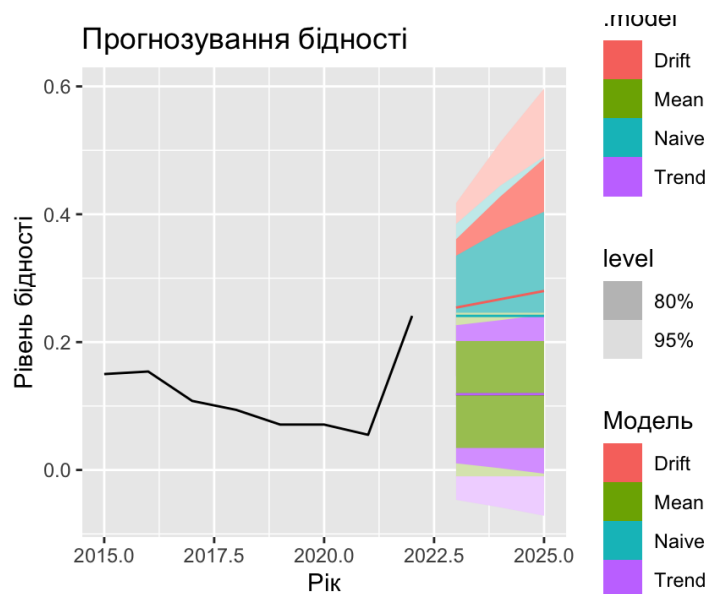


Figure 4. Poverty level forecasting graph

Source: compiled by the authors

The graph (Figure 5) represents the STL decomposition for the poverty rate in Ukraine for the period of 2015-2022. The decomposition shows not only the total poverty rate, but also its trend, and the residuals, which demonstrates unexplained variations.

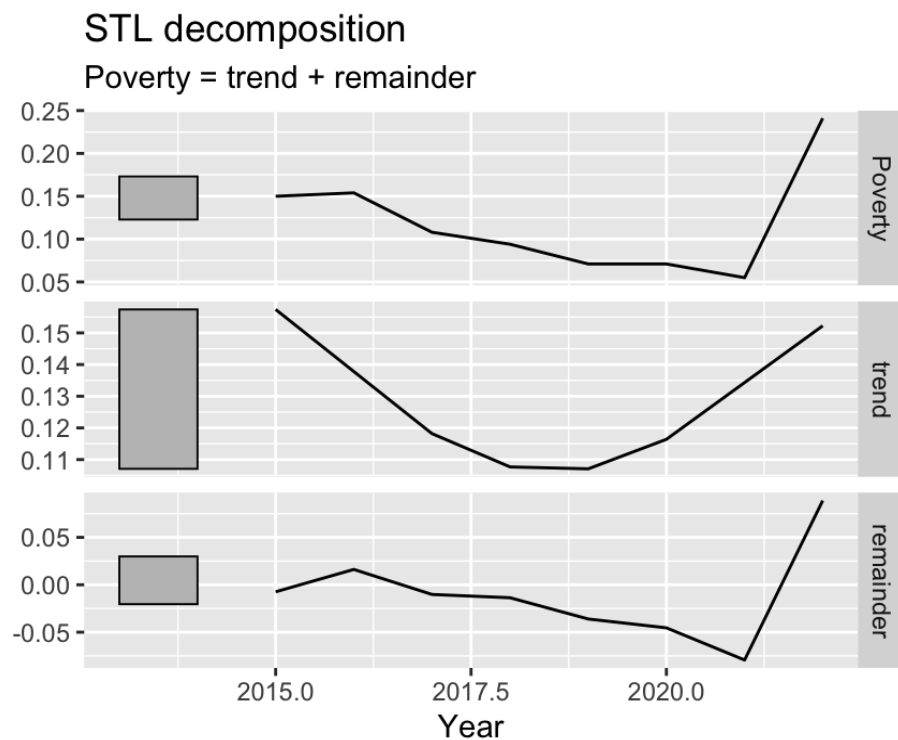


Fig. 5. Graph of time series decomposition by STL method

Source: compiled by the authors

According to the top part of the graph, the overall poverty rate shows a steady decline from 2015 to 2021, followed by a sharp increase in 2022.

The LOESS method is used to calculate the trend. LOESS (Locally Estimated Scatterplot Smoothing) is a local regression smoothing method that applies polynomial functions to local subsets of data:

$$T_t = LOESS(y_t, span) \quad (2)$$

where T_t - the trend component at time t ;

$span$ - a parameter that determines the width of the smoothing window.

The trend, in our case, repeats the behavior of the overall poverty rate, but more smoothly. It shows a gradual decline up to 2020, followed by a slight increase in 2021 and a sharp rise in 2022.

The residuals show short-term variations that are not explained by the trend and fluctuate around zero line, indicating the presence of random factors that affect the poverty rate. The sharp increase in the residuals in 2022 indicates an unpredictable factor such as war.

To evaluate the model, we decided to split the data into training and test data, and then run the model on the training data set and the forecast on the test data set.

The results of the forecast accuracy evaluation show a comparison of the four models: Drift, Mean, Naive, and Trend (Table 1). The main metrics include mean error (ME), root mean square error (RMSE), mean absolute error (MAE), mean relative error (MPE), mean absolute relative error (MAPE), mean absolute deviation (MASE), and root mean square standard error (RMSSE).

Mean Error (ME) measures the average deviation of forecasted values from actual values. It is an indicator that shows whether the forecasts are systematically over or underestimated.

Table 1: Assessment of forecast accuracy

№	model	type	MSE	RMSE	MAE	MPE	MAPE
1	Drift	Test	0.0908	0.134	0.0908	55.2	55.2
2	Mean	Test	0.00693	0.0844	0.0768	-40.1	74.8
3	Naive	Test	0.0513	0.0986	0.062	13.8	33.2
4	Trend	Test	0.0941	0.137	0.0941	58.5	58.5

Source: compiled by the authors

Root Mean Squared Error (RMSE) measures the average error between predicted and actual values, taking into account the squares of the deviations, which allows to take into account larger errors more precisely ~~strictly~~, since the squares of the values increase faster.

The Mean Absolute Error (MAE) measures the average absolute deviation of the predicted values from the actual values and shows the average error without taking into account its direction.

Mean Percentage Error (MPE) measures the average relative deviation of predicted values from actual values as a percentage. It shows how large the errors are in relative terms.

Mean Absolute Percentage Error (MAPE) measures the average absolute deviation of predicted values from actual values in percentage terms, which allows you to assess the accuracy of the forecast regardless of the units of measurement.

The Drift model showed an average error of 0.0908, RMSE of 0.134, and MAPE of 55.2%. Thus, the model tends to underestimate or overestimate poverty with an average error of 0.0908 and a root mean square error of 0.134. The relative error averages 55.2%.

The Mean model showed a significantly lower mean error of 0.00693 and RMSE of 0.0844, but its MAPE is 74.8%, the model has better accuracy in absolute values, but is not as effective in relative changes.

The Naive model has an average error of 0.0513, RMSE of 0.0986, and MAPE of 33.2%. It showed better results in relative errors compared to other models, in particular, Drift and Trend.

The Trend model has an average error of 0.0941, RMSE of 0.137, and MAPE of 58.5%. It demonstrates similar results to the Drift model, but with slightly worse performance.

Naive can be considered the best model because of its lower relative error (MAPE), although Mean also shows good results in other metrics. Also, Mean is more similar to the predicted values of macro indicators and their trends, but given the war, this model is a rather optimistic option.

Conclusions and prospects for further research. The analysis of World Bank data for the period from 2015 to 2026 showed that the poverty rate in Ukraine has a strong inverse relationship with GDP and private consumption, as well as a positive relationship with government spending and inflation. After the outbreak of full-scale war in 2022, economic indicators experienced fluctuations, leading to a significant increase of poverty in 2022. Forecasting based on different models showed high uncertainty, which emphasizes the difficulty of predicting future economic conditions. However, the Naive and Mean models demonstrated relatively better forecast accuracy.

Prospects for further developments in this area include expanding the use of modern technologies, such as satellite imagery, machine learning methods, and Big Data, to improve the accuracy of forecasts and poverty analysis. Another important area is monitoring and evaluating the effectiveness of socioeconomic policies, which will help identify the most effective measures and adjust strategies to meet the real needs of the population. To develop regionally targeted support programs it is necessary to run deeper regional research and detailed analysis of poverty levels in different regions of Ukraine. Studying the impact of international assistance will allow for better integration of international resources into anti-poverty strategies.

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