Modelling and Forecasting Economic Indicators of Ukraine Based on Trend Models

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Abstract. *The present study is devoted to the modelling and forecasting of the primary economic indicators of Ukraine, utilising econometric methodologies, with a particular focus on trend models. In the context of globalisation and economic instability, the study of the relationships between macro-economic variables is of particular relevance. This paper undertakes an analysis of the impact of such factors as the hryvnia/US dollar exchange rate, inflation, exports and imports on gross domestic product. The application of regression analysis enabled the identification of significant economic interdependencies and the determination of key variables with predictive value for the assessment of economic growth. The employment of the Python programming language enabled the processing of statistical data, the construction of multivariate regression models, and the forecasting of future macro-economic trends. The present study combines both theoretical and practical aspects of economic process analysis, which is realised by using multivariate regression to assess the relationships between gross domestic product, minimum wage, inflation and the national currency exchange rate. A significant finding is the existence of a close relationship between the exchange rate and gross domestic product, as evidenced by the high coefficient of determination of the model (R-squared = 0.98), indicating a strong explanatory power. The findings indicate that an augmentation in the US dollar exchange rate by one hryvnia results in a surge in gross domestic product exceeding 213 million UAH, under the assumption of constant factors. Furthermore, the study employed correlation analysis to identify the most significant variables. The strong correlation between the gross domestic product and key economic indicators, including the minimum wage (correlation coefficient of 0.99) and the consumer price index (correlation coefficient of 0.87), underscores their significant influence in shaping economic trends. The utilisation of trend analysis and data approximation through the employment of polynomial functions has facilitated the projection of gross domestic product and exchange rate growth in the 2025–2030 period. This suggests the possibility of stable economic development, even in the context of challenging macro-economic conditions.*

Keywords: *econometric models, GDP, exchange rate, forecasting, regression analysis, macro-economic indicators.*

JEL Classification: *C51, C53, F31*

1 Introduction

It is evident that the contemporary economy is distinguished by a pronounced degree of globalisation and instability. In this context, the analysis of relationships among key macro-economic indicators is of particular importance. The exchange rate, particularly the US dollar against the hryvnia, represents a pivotal factor influencing the country's economic development. Its fluctuations are indicative not only of changes in international markets but also of the domestic economic environment, including inflation, the dynamics of exports and imports, as well as social aspects such as the minimum wage. The modelling of such economic processes enables the forecasting of economic trends and the evaluation of the effectiveness of economic regulation measures (Leontyuk-Melnyk Olga et al., 2016; Radzikhovska Larisa et al., 2021).

Econometric models are most often used to analyse and forecast economic processes. These equations are of a functional nature, and their purpose is to describe the relationship between the variable under investigation and the factors upon which it depends (Oliskevych M. et al., 2017a; Oliskevych M. et al., 2017b).

It is evident that the majority of economic processes, at both the micro- and macro-levels, are influenced by a considerable number of factors. It is

therefore recommended that multivariate regression models be employed to describe such processes. It is evident that the construction of econometric models necessitates the analysis of a substantial volume of input data. Consequently, their processing is now effectively conducted using modern information technologies. Econometric models can be readily implemented with the assistance of computers, as they are predicated on time series derived from statistical sources. In contradistinction to structural models, the calculation of additional indicators does not require such extensive time.

In this study, the results outlined above were obtained through the analysis of original data using the Python programming language. The employment of contemporary Python instruments facilitated the expeditious processing of voluminous datasets, the formulation of regression models, and the generation of forecasts for pivotal macro-economic indicators, including the US dollar exchange rate, gross domestic product, and minimum wage.

2 Literature review

The study of econometric models has been the subject of many scientific works, including the research of L. Klein and T. Haavelmo, who laid the foundations of modern econometrics. Significant contributions to the improvement of econometric research methods have been made by scholars such as D. Heckman and D. McFadden, whose work has opened up new horizons for the analysis of complex economic systems. The issue of forecasting with the help of economic models is highlighted in the works of R. Frisch and R. Klein, who proposed effective methods for assessing and forecasting key macro-economic indicators. The principles of construction and practical application of regression analysis have been the focus of active development in the studies of such scholars as Cleophas T.J., and Zwinderman A.H. (2024), Goloskokov O.E. (2008), and Maronna R. (2012). The purpose of the article is to reveal the peculiarities of practical application of modern information technologies for forecasting economic processes based on econometric models.

3 Results and Discussion

The primary objective of correlation analysis is to ascertain the nature and extent of the relationship between variables within the econometric model under investigation. The practical application of regression analysis in economic research enables the assessment of whether the identified relationship between the factor attributes expressed by the regression equation is statistically significant or random (Oliskevych M. et al., 2017a; Oliskevych M. et al., 2017b).

Modern economic theories make extensive use of mathematical models and probabilistic and statistical methods for their analysis. The main means of studying economic objects are methods of mathematical statistics, particularly regression and correlation analysis, as well as econometrics tools (Cleophas & Zwinderman, 2024; Goloskokov, 2008; Maronna, 2012).

Gross domestic product (GDP) is a widely employed and universally recognised indicator of economic performance. In this regard, a statistical analysis of Ukraine's real GDP over the past decade was conducted, with a focus on the impact of selected factors on its growth and decline. To this end, a multivariate regression model was employed.

Before constructing such an econometric model, it is necessary to identify the key factors that influence economic growth. These include the following (Table 1):

– Exports (as a percentage of GDP);
– imports (as a percentage of GDP);
– inflation rate;
– US dollar exchange rate (against the hryvnia);
– GDP in current prices (million UAH);
– GDP per capita (UAH);
– consumer price index for the year (%);
– minimum wage (UAH) (Ministry of Finance of Ukraine. (n.d.)).

In order to analyse the dependence of gross domestic product on key macro-economic indicators, such as exports, imports, inflation and the hryvnia/US dollar exchange rate, it was proposed to utilise a multivariate linear regression model implemented in the Python programming language.

Prior to the construction of the model, preliminary data processing was imperative, encompassing the identification of variable types and their conversion to a numerical format.

After that, the regression model will take the following form:

$$Y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4 + \beta_5 x_5 + \beta_6 x_6 + E$$

Where:

– Y is the dependent variable: GDP (GDP at current prices, million UAH);
– x_1: imports as a percentage of GDP;
– x_2: exports as a percentage of GDP;
– x_3: inflation index (%);
– x_4: minimum wage (UAH);
– x_5: USD exchange rate (UAH);
– x_6: consumer price indices (%);
– β_0 – intercept;
– $\beta_1, \beta_2, ..., \beta_6$ – coefficients of variables;
– E – random error.

The results of calculating the model parameters are presented in Table 2 and Table 3.

Table 1 Macro-economic indicators

Year	GDP at current prices, million UAH	USD exchange rate, UAH	Consumer price indices for the year, %	Minimum wage, UAH	Imports as a percentage of GDP	Exports as a percentage of GDP	Inflation, %
2014	1 586 915	11,89	124,9	1 218	53,2	49,2	124,9
2015	1 988 544	21,84	143,3	1 378	54,8	52,8	143,3
2016	2 385 367	25,55	112,4	1 600	55,5	49,3	112,4
2017	2 981 227	26,6	113,7	3 200	54,3	47,9	113,7
2018	3 560 302	27,2	109,8	3 723	53,8	45,2	109,8
2019	3 977 198	25,85	104,1	4 173	49	41,2	104,1
2020	4 222 026	26,96	105	5 000	40,1	39	105
2021	5 450 849	27,7	110	6 100	41,9	40,7	110
2022	5 239 114	32,37	126,6	6 700	52,3	35,5	126,6
2023	6 627 961	36,57	105,1	7 100	49,5	28,6	105,1
2024	7 052 150.5	41,85	110,4	8 000	54,9	32,9	112,0

Source: Ministry of Finance of Ukraine (n.d.)

Table 2 Estimated coefficients and statistical significance of model variables

Variable	Coefficient	Std error	t-statistic	P-value
Const	4 097 423,045	115 474,103	35,483	3,76 * 10-6
USD exchange rate, UAH	327 765,166	316 513,162	1,035	0,359
Consumer price indices for the year, %	-2 530 457,946	4 107 653,965	-0,616	0,571
Minimum wage, UAH	1 040 803,029	533 067,100	1,952	0,123
Imports as a percentage of GDP	-70 187,220	195 137,849	-0,359	0,737
Exports as a percentage of GDP	-323 776,883	384 398,463	-0,842	0,447
Inflation, %	2 491 870,086	4 106 580,377	0,607	0,577

Source: compiled by the author

Table 3 Results of calculating model parameters

Metric	Value	Metric	Value
R-squared	0,9825	Mean dependent var	4 097 423,0455
Adjusted R-squared	0,9562	SD dependent var	1 745 508,1752
Sum of squared residuals	586 707 815 654,6279	Akaike info criterion	316,9155
Log-likelihood	-151,4578	Schwarz criterion	319,7008
F-statistic	37,4156	Durbin-Watson stat	3,3231
Prob (F-statistic)	0,001796		

Source: compiled by the author

In order to assess the reliability and adequacy of the built regression model, it is necessary to check its statistical significance. This will allow the determination of the significance of the obtained model coefficients for forecasting and analysing the relationships between the macro-economic variables under study. The value of Prob (F-statistic) for the built model is 0.00179. The extremely low value (less than 0.05) indicates that the null hypothesis (that all coefficients on the independent variables are equal to zero) can be rejected. It is evident that there is a substantial body of evidence indicating that at least one of the independent variables exerts a considerable influence on GDP.

It is evident from the R-squared value of 0.9825 that 98.25% of the variation in the dependent variable is attributable to changes in the

independent variables. This finding suggests that the model demonstrates a high level of adequacy. The estimated sample regression model is as follows:

$$GDP = 213\ 333.69 * USD\ exchange\ rate - 1\ 805\ 713.99$$

This means that an appreciation of the dollar by 1 hryvnia increases GDP by about 213,333.69 million UAH, all other things being equal.

The next step is to build a correlation matrix (Figure 1).

Data for which the correlation coefficient is less than 0.7 are excluded from further analysis and forecasting, as their relationship with the dependent variable is not sufficiently pronounced. Following the implementation of the requisite adjustments (see Figure 2), a novel regression model was formulated.

As demonstrated by the correlation matrix, a number of robust correlations are evident between pivotal economic indicators and GDP, signifying their substantial influence on the economy.

There is an almost perfect correlation between the minimum wage and GDP (0.99), indicating a direct link between rising incomes and increased economic activity. The Consumer Price Index (CPI) also shows a strong relationship with GDP, confirming the importance of price stability for economic growth. The correlation between the US dollar exchange rate and GDP (0.94) highlights the economy's sensitivity to changes in the foreign exchange market.

Furthermore, the strong correlation between the consumer price index and inflation (0.99) indicates a high degree of interdependence between the two indices. This is logical, as inflation is the primary factor that affects the dynamics of the price index. The high correlation between the minimum wage and the dollar exchange rate (0.93) indicates that the exchange rate has a significant impact on household income, especially in times of economic instability.

The filtered matrix is notable for its absence of weak relationships, a state of affairs which permits the focus to be maintained exclusively on significant relationships. Consequently, the minimum wage,

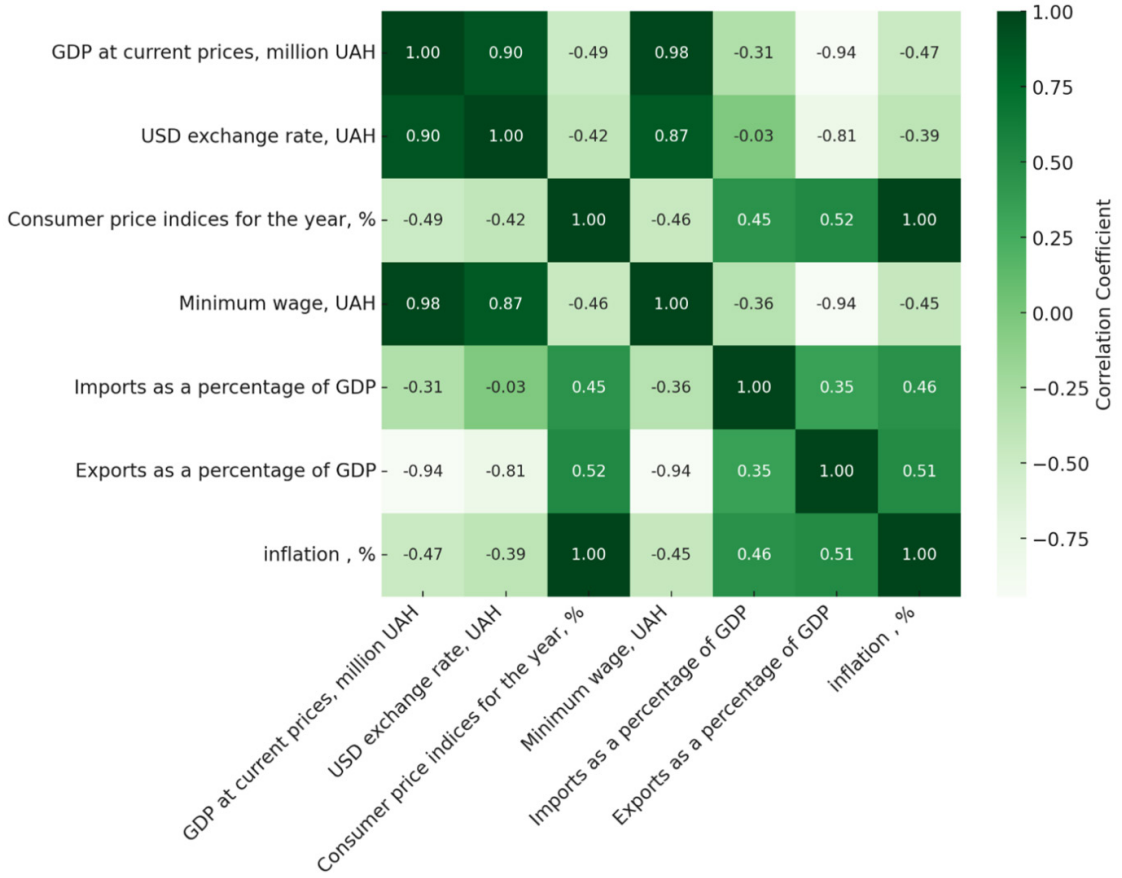

Figure 1 Correlation matrix

Source: compiled by the author

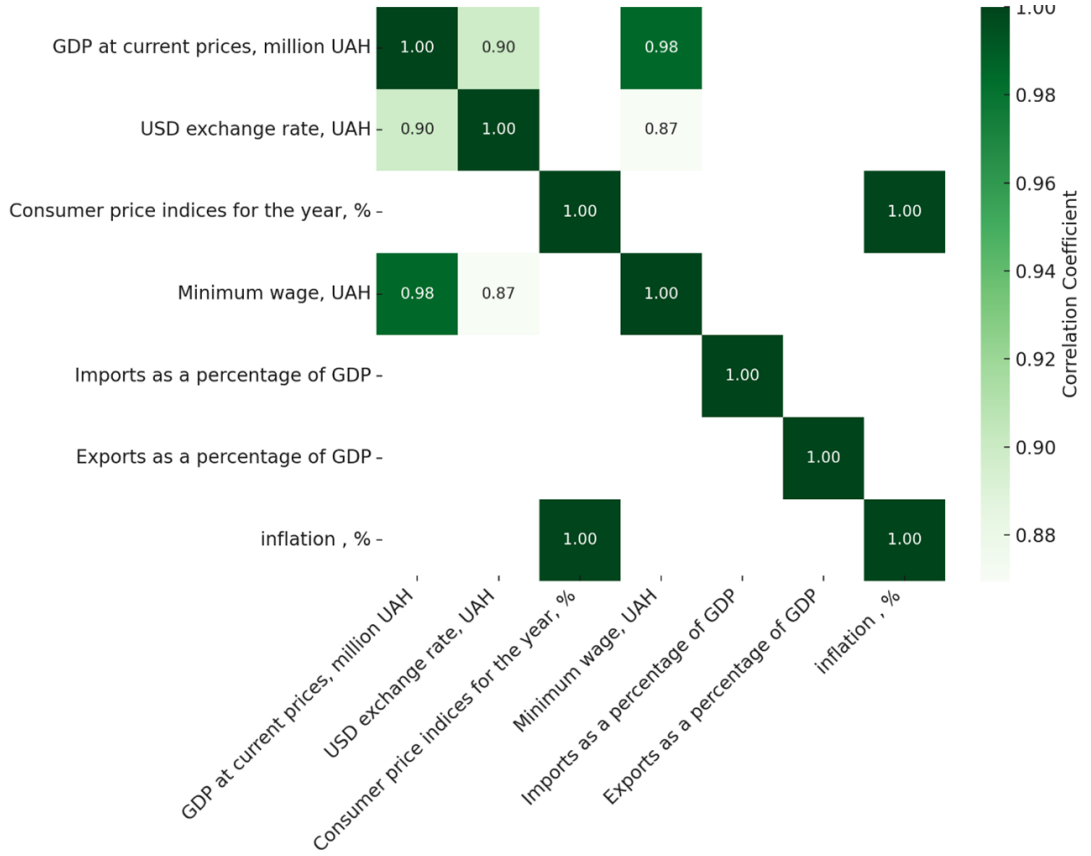

Figure 2 Correlation matrix after correction

Source: compiled by the author

the exchange rate, and the consumer price index are pivotal indicators that influence GDP and should be utilised to forecast economic dynamics.

The estimated model parameters after filtering are shown in Tables 4 and 5.

The subsequent stage of the study will be a trend analysis. In the initial stage of the research, the graphical dependencies of the main macro-economic indicators over time were plotted in order to identify general trends in their development (see Figure 3).

Table 4 Estimated coefficients and statistical significance of model variables after filtering

Variable	Coefficient	Std error	t-statistic	P-value
Const	1 016 968,293	1 286 447,321	0,791	0,455
USD exchange rate, UAH	40 930,717	26 463,467	1,547	0,166
Consumer price indices for the year, %	-6 684,732	9 508,612	-0,703	0,505
Minimum wage, UAH	620,117	87,103	7,119	0,00019

Source: compiled by the author

Table 5 The results of calculating the model parameters after filtering

Metric	Value	Metric	Value
R-squared	0,9788	Mean dependent var	4 097 423,0455
Adjusted R-squared	0,9697	SD dependent var	1 745 508,1752
Sum of squared residuals	711 179 941 445,9376	Akaike info criterion	313,0319
Log-likelihood	-152,5159	Schwarz criterion	314,6235
F-statistic	107,6264	Durbin-Watson stat	2,6419
Prob (F-statistic)	3,214*10-6		

Source: compiled by the author

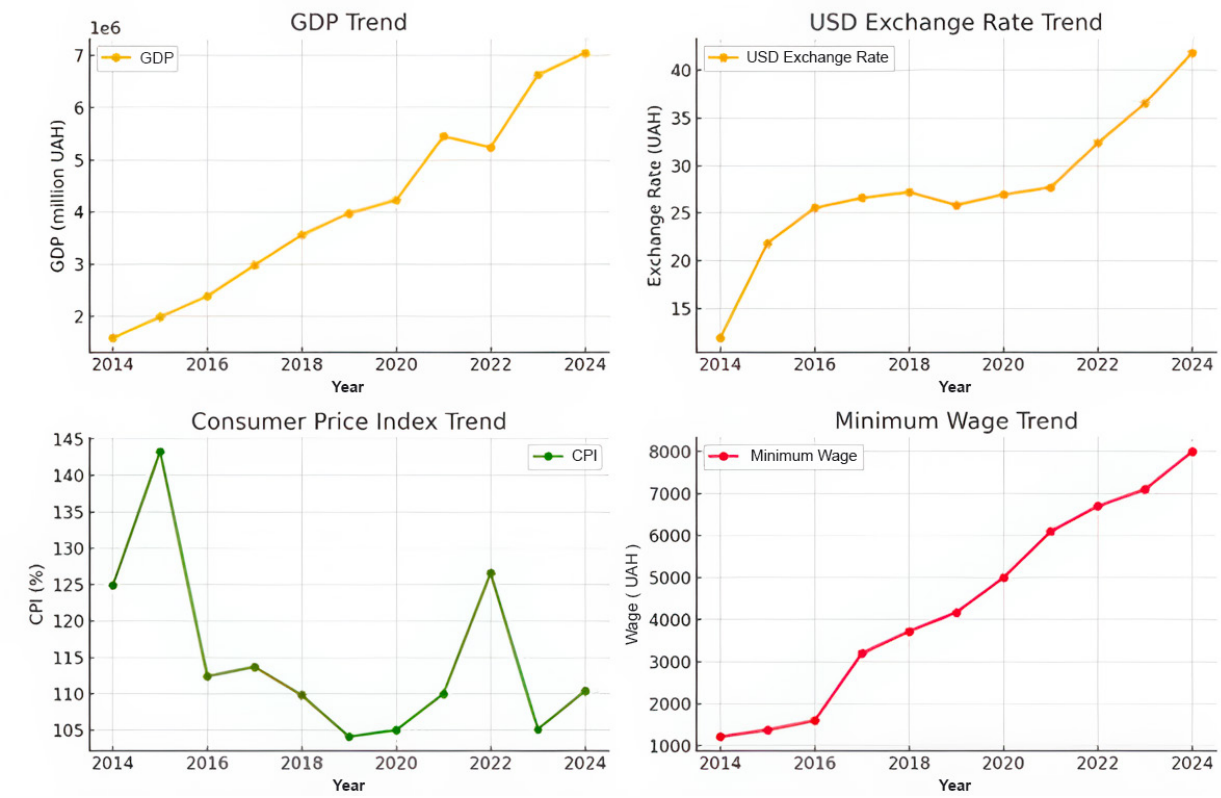

Figure 3 Graphs of the functions of GDP, the dollar exchange rate, the consumer price index, and the minimum wage, where the independent variable is the respective years

Source: compiled by the author

It is evident that there is a high degree of correlation between the growth of the US dollar against the hryvnia and gross domestic product. This finding suggests the potential for a substantial impact of the foreign exchange market on economic development. Consequently, a detailed analysis of this relationship is recommended. The Python programming language was utilised to construct a graph of the dynamics of the US dollar/hryvnia exchange rate, which was then approximated to identify general trends (see Figure 4).

The graph displays the fluctuation of the USD/UAH exchange rate from 2014 to 2024, with the incorporation of an approximation line. The blue dots represent the actual exchange rate for each year, which has been steadily increasing since 2014. In order to model the overall trend, a second-degree polynomial approximation was employed, which is capable of taking into account the nonlinear nature of exchange rate changes. The green line signifies the primary approximation, with the red lines denoting the upper and lower bounds (+2/-2) surrounding the main trend, thereby indicating the potential range of future changes.

The fitting equation $y = ax^2 + bx + c$, describes the relationship between years and the US dollar, where $R^2 \approx 0.99$ indicates a high level of model fit to real data. This indicates that the trend accurately reflects changes in the dollar over time. The chart illustrates a marked increase in the value of the dollar since 2014, a development that is presumably attributable to economic and political factors. The approximation presented herein can be employed to forecast the dollar exchange rate in the future, taking into account possible fluctuations within the outlined limits.

Based on the trend analysis, a forecast of the above factors was made for the future period of 2025–2030. The data is shown in Table 6 and Figure 5.

Table 6 Forecast of the US dollar exchange rate against the hryvnia for the period 2025–2030

Year	Predicted USD excange rate value
2025	41,09
2026	43,60
2027	46,17
2028	48,81
2029	51,51
2030	54,27

Source: compiled by the author

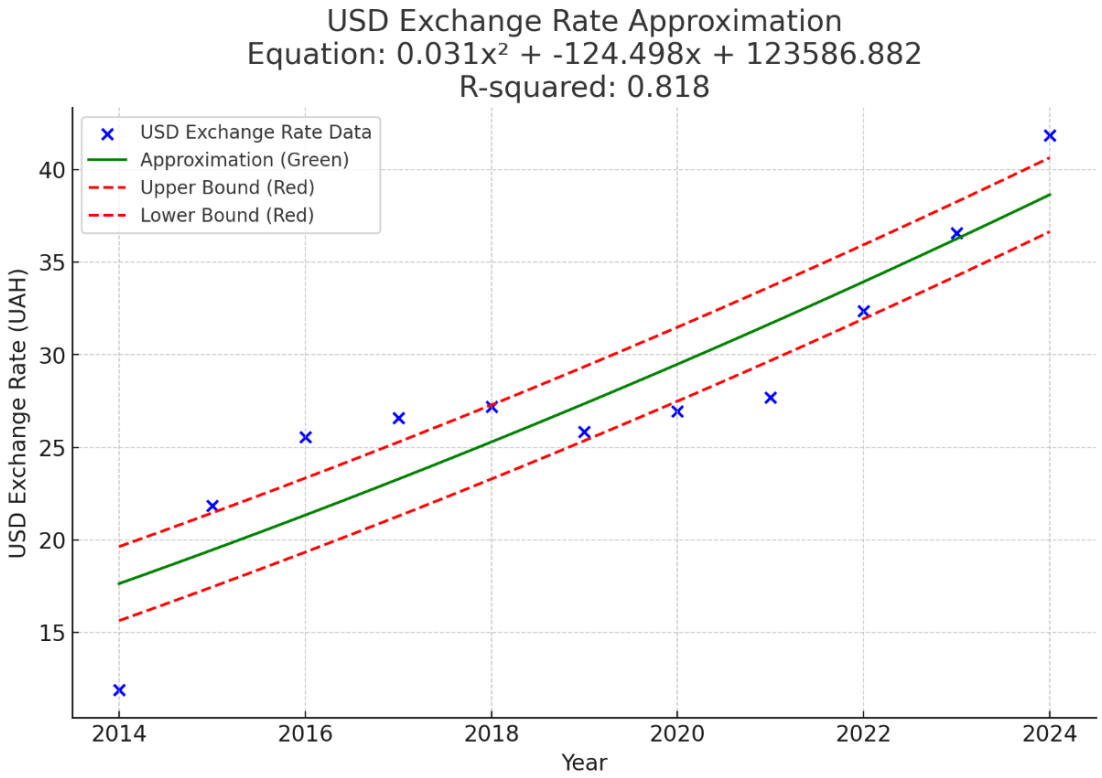

Figure 4 Graph of dollar exchange rate dependence on the year with a second-degree approximation model

Source: compiled by the author

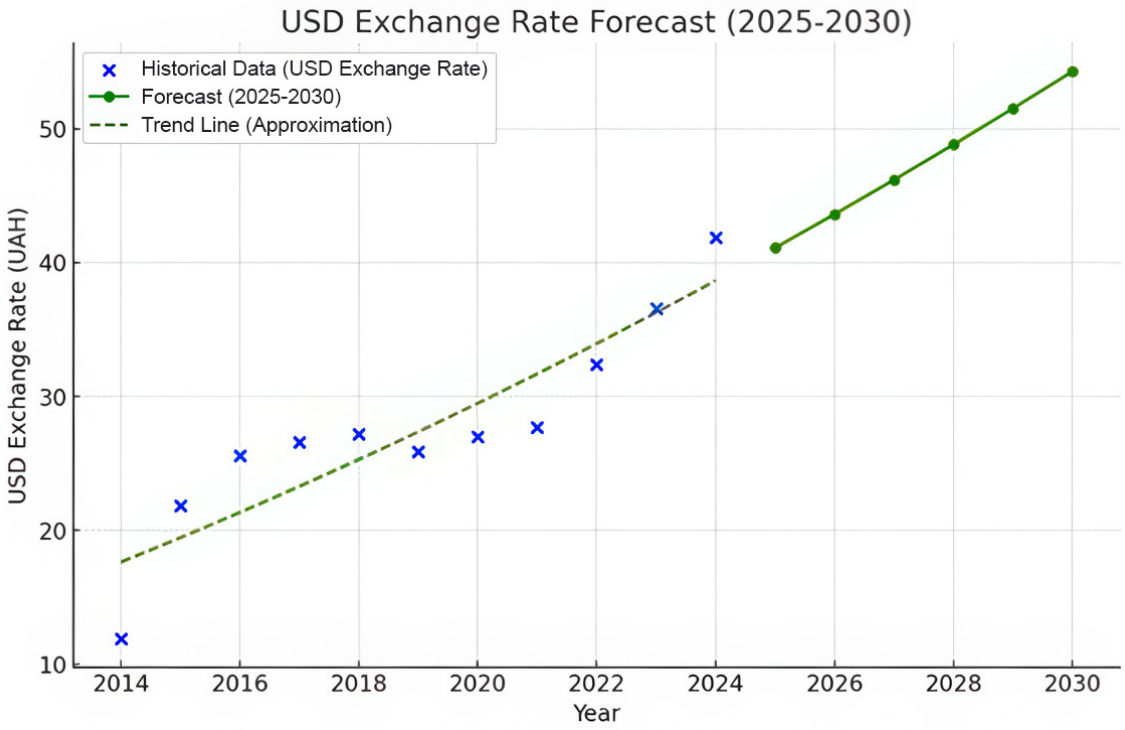

Figure 5 Forecast of the US dollar exchange rate against the hryvnia for the future period of 2025–2030

Source: compiled by the author

In a similar manner, GDP was estimated and forecast for the 2025–2030 time period. The results are presented in Figure 6 and Table 7.

Table 7 GDP forecast for the future period of 2025–2030

Year	Predicted GDP (million UAH)
2025	7 774 333,397
2026	8 521 042,127
2027	9 298 648,628
2028	10 107 152,899
2029	10 946 554,941
2030	11 816 854,753

Source: compiled by the author

The results of the analysis suggest that the real GDP of the state is likely to exhibit annual growth. However, it is important to acknowledge the limitations of trend extrapolation as a forecasting method. This is due to the inherent instability of factors within the Ukrainian economy, which significantly limits the accuracy of predictions (Salyha S. Ya., & Zavadska N. O., 2012).

4 Conclusions

A thorough examination of the US dollar/hryvnia exchange rate dynamics for the period 2014–2024 has revealed a consistent upward trend, which can be attributed to the impact of both economic and political factors. The utilisation of a second-degree model to approximate the data resulted in a high degree of correspondence to empirical observations ($R^2 \approx 0.82$), thereby facilitating the prediction of an additional increase in the exchange rate during the 2025–2030 period. The findings of the study indicate the necessity for a carefully balanced exchange rate policy in order to minimise the potential negative impact of exchange rate fluctuations on macro-economic indicators, including gross domestic product.

The analysis of gross domestic product demonstrates an overall upward trend, notwithstanding the presence of short-term economic downturns, most notably in 2022. Forecasts for the period 2025–2030 also demonstrate positive dynamics, which may be attributable to an increase in the minimum wage, stabilisation of domestic consumer demand, and increased investment. Further research could be directed towards the evaluation of the impact of specific economic reforms, the process of economic integration with international markets, and the enhancement of forecasting models through the incorporation of additional variables that encompass more intricate macro-economic interactions.

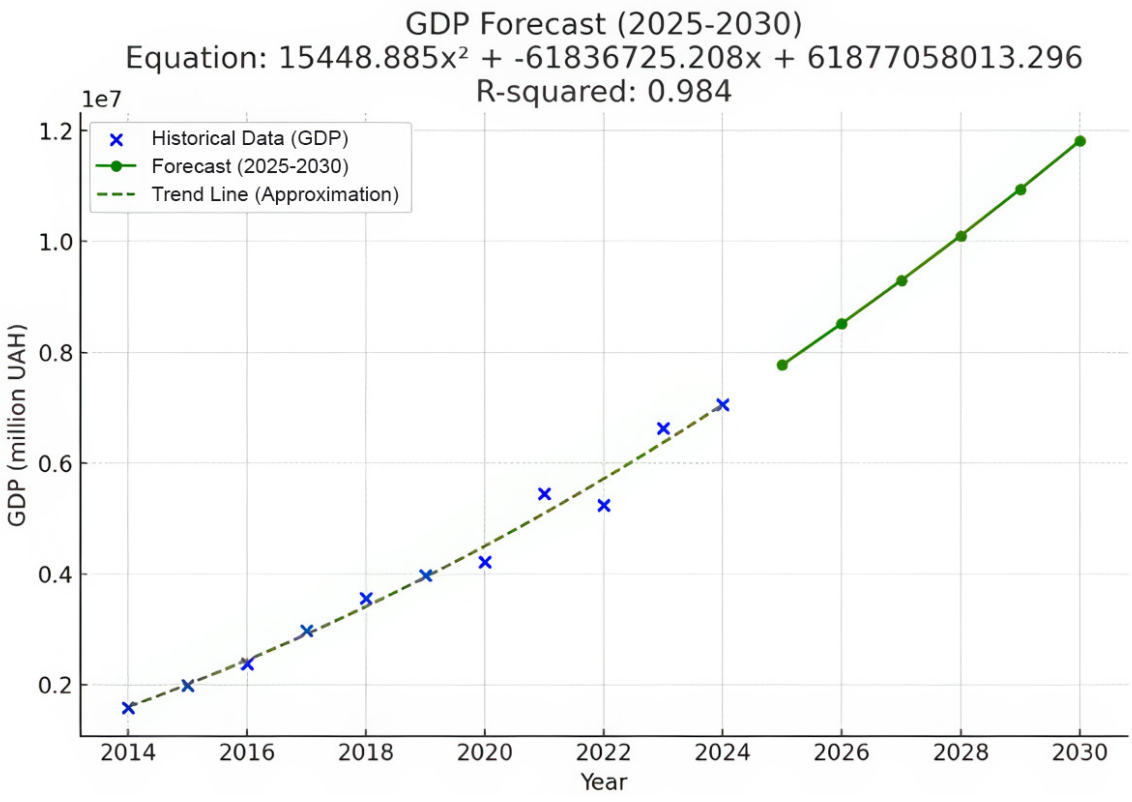

Figure 6 GDP forecast for the future period of 2025–2030

Source: compiled by the author

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