“Effect of Ukraine’s public debt management on its macroeconomic development: VAR modeling”

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EFFECT OF UKRAINE'S PUBLIC DEBT MANAGEMENT ON ITS MACROECONOMIC DEVELOPMENT: VAR MODELING

Abstract

One of the tools of economic policy of any country is efficient public debt management, which influences and determines the dynamics of key macroeconomic indicators. The study aims to assess how public debt management affects Ukraine's macroeconomic development. The analyzed period includes data of 2015–2021. Econometric modeling is used to establish the existence of causal relationships between the dynamics of public debt and changes in key macroeconomic indicators using the Granger causality test and VAR (Vector Autoregression) model. The obtained results demonstrate that during the study period, the strongest links existed between the public debt and GDP, debt servicing and Ukraine's total state budget expenditures, public debt and consumer price index, real effective exchange rate index of the hryvnia to the US dollar, and political stability index. At the same time, the calculations proved that public debt does not have a significant impact on foreign direct investment and the level of imports of goods and services. The proposed model allows for forecasts for future periods and can be used in developing public debt management policy.

Keywords public debt management, macroeconomic development, GDP, consumer price index, economic growth, VAR model, Ukraine

JEL Classification H60, H63, H69

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INTRODUCTION

Public debt is crucial for governments to finance their activities, stimulate economic growth, and respond to unforeseen circumstances. In 2022, for instance, the total global public debt, encompassing both domestic and external debt of general governments, reached an unprecedented USD 92 trillion. Russian-Ukrainian full-scale war, which started in February 2022, had a shocking effect on Ukraine's macroeconomic stability. Increased military expenditures, higher government spending, and lower revenues have led to the sharp growth of public debt as the government seeks additional ways to finance these costs. Consequently, an efficient system of public debt management is vital for ensuring Ukraine's macroeconomic stability during wartime (Razinkova et al., 2023a, 2023b).

Public debt management involves creating and implementing strategic mechanisms for influencing state debt, which ensures the ability to attract the necessary financing and achieve targeted expenditure indicators at an acceptable level of risk and any other goals. From a macroeconomic policy perspective, it is imperative to maintain stability in the level and growth rate of public debt and ensure it can be serviced under various scenarios, all while achieving cost and risk targets. The creation of the public debt management strategy should rely on meeting particular benchmarks for the overall debt amount, the cost of its

servicing, and the effects of various risk types on the government's ability to attain the state's macroeconomic policy objectives. Clear coordination between state institutions responsible for implementing fiscal and monetary policies and debt management authorities enhances efficiency, achieves favorable outcomes, lowers debt service expenses, and establishes an optimal debt portfolio structure in amount, interest rates, terms, and currencies (Aiyedogbon et al., 2022).

The impact of public debt on Ukraine's macroeconomic development can be studied using econometric modeling. One of the options is the VAR (Vector Autoregression) model, which analyzes the correlation of public debt dynamics with macroeconomic indicators.

1. LITERATURE REVIEW AND HYPOTHESES

Public debt management holds paramount importance in the realm of macroeconomic policy. In general, the issue of public debt formation and management is one of the most studied in the academic economic literature. The significant increase in the public debt of many countries has raised the issue of optimizing the assessment, analysis, and development of an effective management system.

Numerous studies have examined how external debt impacts a country's macroeconomic development. For instance, Reinhart and Rogoff (2009) explored this topic extensively, finding that long-term increases in external debt can lead to an economic crisis. Kumhof and Yakadina (2017) and Son (2023) demonstrated that larger public debts lead to increased public borrowing while also establishing a correlation between debt, interest rates, and business cycle dynamics.

Ruiz-Arranz et al. (2005) revealed variations in the ratio of external debt to economic growth in developing countries based on their level of debt and other characteristics. They concluded a negative marginal relationship between debt and growth at medium debt levels. Countries with stable policies and institutions encounter issues when debt surpasses 15-30% of GDP. However, the impact of debt becomes insignificant if its levels exceed 70-80% of GDP.

Mohd Daud and Podivinsky (2012) focused on the impact of external debt on the expansion of economic growth in 31 developing countries. The findings demonstrate that growing amounts of external debt correlate with sluggish economic growth in developing countries. Furthermore, this article presents evidence that a country's debt service ratio does not diminish the level of investment it attracts.

Extensive empirical analyses assessed the sustainability of external debt levels. This includes examining debt-to-GDP ratios, debt service capacity, and other financial indicators (Shkolnyk & Koilo, 2018; Makedon & Korneyev, 2014; Grynko & Gviniashvili, 2015; Petrushenko et al., 2022).

Manasseh et al. (2022) proved that external debt and its instability negatively and significantly affect economic growth in Sub-Saharan Africa. Furthermore, they found that the interaction between governance indicators, external debt, and its volatility positively impacts economic growth. This study suggests that governments should steer clear of excessive external debt. To improve the quality of debt management, it is crucial to ensure political stability, minimize corruption, and implement sound policies and regulations that can foster economic growth through the development of the private sector.

Gövdeli (2019) analyzes the impact of external debt, economic openness, and the consumer price index on economic growth in Turkey. The findings show that external debt positively influences economic growth, whereas economic openness and the consumer price index have a negative effect. Therefore, this study suggests that controlling the consumer price index and promoting openness can boost economic growth through external debt.

Gómez-Puig and Sosvilla-Rivero (2015) affirmed the potential existence of bidirectional causal relationships between economic growth and public debt in central and peripheral countries with-

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in the European Economic and Monetary Union. The findings demonstrate a correlation between high public debt and low economic growth in Spain. The debt of Belgium, Greece, Italy, and the Netherlands negatively affects growth once it surpasses an endogenously determined breakpoint and debt threshold ranging from 56% to 103%, depending on the country.

Shittu et al. (2020) confirm a non-linear relationship between external debt and economic growth. Improved quality of governance counteracts the negative impact of external debt and public administration on economic performance. Turan and Yanıkkaya (2021) analyzed the impact of total, public, and private external debt on growth rates and on total, public, and private investment using data from developing countries. The findings indicate that the growth of total external debt has a significant and negative effect on growth rates, particularly in countries with fragmented and inefficient governments.

Studies of public debt management also explore the relationships between public debt, economic growth, and fiscal policy (Korneyev et al., 2022; Naumenkova et al., 2023). Time series analysis, economic and mathematical analysis as the assessment tools of public debt dynamics, sustainability, and forecasting are used by Zhuravka et al. (2019a, 2019b) and Gontareva et al. (2022).

Following the literature review, the study aims to assess how public debt management affects Ukraine's macroeconomic development indicators. The following hypotheses are proposed:

H1: A causal relationship exists between the public debt indicator and macroeconomic indicators.

H2: Econometric modeling makes it possible to formalize the relationship between the public debt indicator and macroeconomic indicators.

H3: An econometric equation that formalizes the relationship between public debt and macroeconomic indicators can be utilized to develop and improve public debt management policy.

2. METHODS

External public debt is affected by a variety of economic indicators, including GDP, exports, imports, exchange rates, balance of payments, inflation, interest rates, government spending, and political stability.

Analysis of these and other indicators can be conducted through the use of econometric models and statistical analyses. Regression analysis can identify the macroeconomic indicators with the most substantial impact on external public debt and determine the most significant ones. This enables forecasting of future external debt based on changes in these indicators, affecting management decisions regarding the impact on public debt at the macroeconomic level.

One of the options is the VAR (Vector Autoregression) model, which analyzes the dynamics of macroeconomic indicators and their correlation with external public debt. The model enables calculating the effects of modifying one indicator on other indicators. This feature proves valuable for predicting future external debt and drawing conclusions about macroeconomic developments.

The fundamental notion behind a VAR is that every variable in the model is dependent on its own preceding value, along with the preceding values of other variables. Therefore, VAR permits the consideration of the interrelationships between variables and their reciprocal impact on the predicted values.

When creating a VAR model, the initial step is selecting the variables to be incorporated. Generally, these variables are macroeconomic indicators, like GDP, inflation, exchange rates, or budget deficit. A time interval is first selected, and data for every variable are collected within this period. Following this, the data are analyzed, and the coefficients for the VAR model are determined, reflecting the relationships between the variables. Finally, a forecast for future values can be made utilizing the related coefficients in conjunction with the previous values of the variables.

The advantage of VAR models is the ability to analyze the relationship between variables and

their mutual influence on predicted values. Furthermore, VAR can evaluate the impact of external factors on a nation's economy and predict future trends.

In a VAR model, a system of n variables $y_1, y_2, \ldots y_n$ that can interact with each other over time is considered. Typically, a VAR model contains p periods, where p represents the number of variables within the model. The vector $y_{(t)}$ reflects the values of each variable, $y_{1,(t)}, y_{2,(t)}, \ldots y_{n,(t)}$, at any given time, t.

The VAR model utilizes an autoregressive form for every variable in the system, incorporating its previous values and the previous values of other variables. Therefore, for a VAR model of order p, each variable y_j can be expressed by an equation:

$$y_{j,(t)} = a_{0,j} + a_{1,j,1} \cdot y_{1,(t-1)} + \ldots + a_{1,j,p} \cdot y_{p,(t-1)} + \varepsilon_{j,(t)}, \quad (1)$$

where $a_{0,j}$ – a constant, $a_{1,j,1} \ldots a_{1,j,p}$ – autoregressive coefficients, $\varepsilon_{j,(t)}$ – a discrete noise process.

Thus, a system of n equations exists for every time t, which can be expressed as a vector.

$$y_{(t)} = A_1 \cdot y_{(t-1)} + A_2 \cdot y_{(t-2)} + \ldots + A_p \cdot y_{(t-p)} + \varepsilon_{(t)}, \quad (2)$$

where $A_1, A_2, \ldots, A_p$ – matrices of autoregressive coefficients of order p, $\varepsilon_{(t)}$ – a noise vector.

This model can be used to predict the future values of variables $y_1, y_2, \ldots y_n$, as well as to study the relationships between them.

The process of constructing a VAR model consists of the following steps:

1) Analyzing the characteristics of the time series;
2) Testing for causality (existence of relationships between variables);
3) Examining for the time series' stationarity;
4) Transforming the time series into stationary ones (if necessary);
5) Identifying the optimal model order;
6) Preparing the data accordingly;
7) Developing and evaluating the model;
8) Forecasting future periods based on the model and transforming results (if necessary).

3. RESULTS AND DISCUSSION

For this study, a number of indicators that are representative of the effectiveness of public debt management will be selected. The following indicators are employed for the impact variables, with their respective index numbers for the tables containing the results of the Granger causality test shown in parentheses:

- general government debt to GDP ratio (1);
- debt servicing to total state budget expenditures (2);
- consumer price index (3);
- index of real effective exchange rate of UAH to USD (4);
- volume of foreign direct investment (5);
- imports (6);
- political stability index (7).

The statistical data for the study period from 2015 to 2021, including quarterly details, are provided in Appendix A. The graphical analysis to identify causal relationships is presented in Appendix B.

The data indicate certain trend phenomena in indicator dynamics, although their presence may not always be readily apparent. For example, the ratio of public debt to GDP peaked at the end of 2016 and subsequently decreased. Debt servicing displays a seasonal component and a decreasing trend over time.

The consumer price index experienced abnormally high values in 2015, followed by a de-

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creasing movement trend. The real effective exchange rate index has exhibited a steady increase. Imports follow a similar pattern, although regional variations occur. Direct investment in Ukraine exhibits greater instability, including seasonality and notable fluctuations. The Political Stability Index has steadily improved, with occasional dips in some quarters.

The paper uses the Granger causality test to establish causality between two-time series. The purpose of this test is to examine whether information from one series can predict another. If rejected, the hypothesis indicates significant relationships between the series. The Granger causality test is essential in economic analysis since it identifies causal connections between economic indicators.

In the analysis, a thorough evaluation of the correlations between the chosen indicators with lags of 1, 2, 3, and 4 is conducted. Table 1 displays the outcomes of the test indicator calculations.

Table 1. Significance of Granger causality test statistics for identifying causal relationships between specific macroeconomic indicators and the general government debt to GDP ratio in Ukraine during the period 2015–2021

	Direction of influence of the selected indicators					
Lags	**1 to 2**	**2 to 1**	**1 to 3**	**3 to 1**	**1 to 4**	**4 to 1**
1	12.314	3.545	1.774	18.058	14.063	8.789
2	3.017	1.330	4.075	1.446	3.763	0.671
3	5.175	0.274	2.945	1.568	2.584	2.152
4	0.512	0.717	4.594	1.608	1.938	2.161
Lags	**1 to 5**	**5 to 1**	**1 to 6**	**6 to 1**	**1 to 7**	**7 to 1**
1	3.282	6.565	0.061	3.946	25.670	9.086
2	4.548	3.894	8.255	4.152	0.834	3.567
3	1.362	4.830	6.201	3.009	1.586	0.401
4	0.460	3.461	3.833	2.007	1.084	0.994

To interpret the obtained results, the study compares the test statistics values with the critical values to determine their significance level. If the critical values exceed the significance level selected (in this case, 0.05), the hypothesis of no causal relationship is rejected, and one accepts the alternative hypothesis that a causal relationship exists between the selected pairs of macroeconomic indicators. The results are presented in Table 2.

Table 2. The p-value for the statistics of the Granger causality test examining causal relationships between specific macroeconomic indicators and the ratio of total government debt to GDP of Ukraine during the period 2015–2021

	Direction of influence of the selected indicators					
Lags	**1 to 2**	**2 to 1**	**1 to 3**	**3 to 1**	**1 to 4**	**4 to 1**
1	0.002	0.072	0.195	0.000	0.001	**0.007**
2	0.071	0.286	0.032	0.258	0.040	0.522
3	0.009	0.843	0.061	0.232	0.085	0.129
4	0.728	0.593	0.013	0.224	0.156	0.123
Lags	**1 to 5**	**5 to 1**	**1 to 6**	**6 to 1**	**1 to 7**	**7 to 1**
1	0.083	0.017	0.807	0.059	0.000	**0.006**
2	0.023	0.036	0.002	**0.030**	0.448	0.046
3	0.286	0.012	**0.004**	0.057	0.227	0.754
4	0.764	0.034	**0.024**	0.145	0.400	0.441

Based on the data garnered, a causal connection exists between Ukraine's general government debt to GDP ratio and nearly all the chosen macroeconomic metrics, predominantly with a time lag of 1 or 2.

Thus, based on the first hypothesis (*H1*), a causal relationship between the public debt indicator and macroeconomic indicators was proved. Consequently, the selected indicators can be used to construct an econometric model that will allow the inclusion of all or part of these indicators.

The following step establishes if these time series have stationarity, for which numerous typical tests exist. The study employs the Augmented Dickey-Fuller test (ADF-test), which is a widely used statistical test for examining the stationarity of a time series. A unit root is a time series attribute that renders it non-stationary. Specifically, a unit root is present in a time series when $\alpha = 1$ in the below equation.

$$Y_t = \alpha Y_{t-1} + \beta X_e + \varepsilon, \qquad (3)$$

where Y_t – the value of the time series at time '*t*', X_e – an exogenous variable (a separate explanatory variable that is also a time series).

The existence of a unit root in a time series implies that it is non-stationary. The quantity of unit roots present corresponds to the number of separate operations needed to render the series stationary.

It is significant to note that the null hypothesis assumes a unit root's presence, represented by α = 1,

and, therefore, the resulting p-value should be below the significance level, usually set at 0.05, to reject the null hypothesis. Thus, the paper deduces that the series is stationary.

Input parameters for the test for all indicators:

1) Null hypothesis: The indicator possesses a unit root.

2) External variable: Constant.

3) Number of lags: 0 (maximum number of lags = 6).

4) Critical values for test statistics at different levels of confidence are as follows:

   - 1% = –3.711
   - 5% = –2.981
   - 10% = –2.630

Table 3 presents the results of the augmented Dickey-Fuller test.

The statistical test results demonstrate that the time series is stationary, as the test statistics values surpass the critical values, with a 95% confidence level. Consequently, the null hypothesis of unit root presence is refuted, and the alternative hypothesis of unit root absence is validated.

The subsequent stage involves identifying the ideal order of the model. To determine the appropriate order of the VAR model, the study systematically chooses ascending orders of the model and selects the one that produces the lowest AIC. Other comparative estimators, including SC, FPE, and HQ, may also be considered. Table 4 displays the test outcomes.

Therefore, optimal values for all information criteria are reached with a 2-time period delay. Consequently, a model order of 2: VAR is selected.

Prior to the next step, data transformation is necessary to reduce dimensionality. The initial data for imports and FDI are in absolute terms and measured in millions of USD. To decrease the complexity of import data, the study uses natural logarithms. Similarly, the absolute value before applying the natural logarithm is taken for foreign direct investment volume.

Subsequently, a system of equations based on the selected variables is generated utilizing the econometric software package, eViews. The findings are presented in Appendix C. Based on the summary statistics, including R-squared, adjusted R-squared, F-statistics, and other information

Table 3. Results of the augmented Dickey-Fuller test for chosen macroeconomic indicators from 2015 to 2021

Indicator	Test statistic value	Probability
General government debt to GDP ratio	–4.085	0.004
Debt service to total state budget expenditures	–8.135	0.000
Consumer price index	–3.382	0.021
Index of the real effective exchange rate of UAH to USD	–5.545	0.000
Volume of foreign direct investment	–8.130	0.000
Volume of imports	–3.284	0.027
Political stability index	–18.341	0.000

Table 4. Search results for the optimal order of the VAR model for selected macroeconomic indicators over 2015–2021

Lag	LogL	LR	FPE	AIC	SC	HQ
0	179.3233	NA	4.13E–15	–13.2556	–12.9169	–13.1581
1	312.1074	183.8549	7.58E–18	–19.7006	–16.9908	–18.9203
2	444.3941	111.9348*	3.36e–20*	–26.10723*	–21.02646*	–24.64416*

Note: * indicates the order of the model for the selected lag. LR: sequential modified LR test statistics (each test for 5% level). FPE: final prediction error. AIC: Akaike's information criterion. SC: Schwarz information criterion. HQ: Hannan-Quinn information criterion.

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criteria, it can be concluded that most of the equations obtained are suitable for further forecasting of the chosen macroeconomic indicators. However, the exception is the equation for the amount of foreign direct investment, which cannot produce valid results according to all criteria.

The resulting system of equations is as follows:

$$\begin{aligned} d\_gdp = {} & 0.1613 \cdot d\_gdp(-1) - 0.0649 \cdot d\_gdp(-2) - 0.0376 \cdot cpi(-1) - \\ & -0.0159 \cdot cpi(-2) + 0.1187 \cdot d\_service(-1) + 0.1414 \cdot d\_service(-2) - \\ & -0.0006 \cdot fdi(-1) + 0.0002 fdi(-2) + 0.0227 fx(-1) + 0.0296 \cdot fx(-2) - 0.3247 \cdot imprt(-1) + \\ & +0.1933 \cdot imprt(-2) - 0.0711 \cdot p\_stab(-1) - 0.0734 \cdot p\_stab(-2) + 1.6059, \end{aligned} \tag{4}$$

$$\begin{aligned} cpi = {} & 0.2139 \cdot d\_gdp(-1) - 1.49259 \cdot d\_gdp(-2) + 0.9554 \cdot cpi(-1) - \\ & -0.4119 \cdot cpi(-2) + 0.5386 \cdot d\_service(-1) + 0.7249 \cdot d\_service(-2) + \\ & +0.0008 \cdot fdi(-1) + 0.0026 \cdot fdi(-2) - 0.0277 \cdot fx(-1) - 0.2265 \cdot fx(-2) - \\ & -0.1045 \cdot imprt(-1) - 0.1708 \cdot imprt(-2) - 0.0312 \cdot p\_stab(-1) + 0.0468 \cdot p\_stab(-2) + 3.5738, \end{aligned} \tag{5}$$

$$\begin{aligned} d\_service = {} & 0.6740 \cdot d\_gdp(-1) + 0.2292 \cdot d\_gdp(-2) + 0.0523 \cdot cpi(-1) + \\ & +0.0141 \cdot cpi(-2) - 0.7800 \cdot d\_service(-1) - 0.0789 \cdot d\_service(-2) - 0.0021 \cdot fdi(-1) - \\ & -0.0019 \cdot fdi(-2) + 0.2700 \cdot fx(-1) - 0.16288 \cdot fx(-2) + 0.1721 \cdot imprt(-1) - \\ & -0.1110 \cdot imprt(-2) + 0.0535 \cdot p\_stab(-1) - 0.0601 \cdot p\_stab(-2) - 0.8409, \end{aligned} \tag{6}$$

$$\begin{aligned} fdi = {} & 15.4630 \cdot d\_gdp(-1) - 140.6529 \cdot d\_gdp(-2) + 0.9734 \cdot cpi(-1) - \\ & -25.3591 \cdot cpi(-2) + 17.8932 \cdot d\_service(-1) - 21.4664 \cdot d\_service(-2) - 0.3077 \cdot fdi(-1) - \\ & -0.2251 \cdot fdi(-2) - 4.2836 \cdot fx(-1) - 10.7940 \cdot fx(-2) + 52.1675 \cdot imprt(-1) - \\ & -73.0505 \cdot imprt(-2) - 9.9701 \cdot p\_stab(-1) - 7.2988 \cdot p\_stab(-2) + 286.8160, \end{aligned} \tag{7}$$

$$\begin{aligned} fx = {} & 1.7552 \cdot d\_gdp(-1) - 2.3199 \cdot d\_gdp(-2) - 0.1005 \cdot cpi(-1) + 0.0166 \cdot cpi(-2) - \\ & -0.1935 \cdot d\_service(-1) - \ 0.6081 \cdot d\_service(-2) - 0.0007 \cdot fdi(-1) + 0.0003 \cdot fdi(-2) + \\ & +0.7089 \cdot fx(-1) - 0.1491 \cdot fx(-2) + 0.6863 \cdot imprt(-1) - 0.6420 \cdot imprt(-2) + \\ & +0.0023 \cdot p\_stab(-1) - 0.0447 \cdot p\_stab(-2) + 0.1787, \end{aligned} \tag{8}$$

$$\begin{aligned} imprt = {} & -1.6258 \cdot d\_gdp(-1) - 0.1662 \cdot d\_gdp(-2) - 0.1471 \cdot cpi(-1) + \\ & +0.1463 \cdot cpi(-2) - 0.2797 \cdot d\_service(-1) - 0.4665 \cdot d\_service(-2) + \\ & +0.0033 \cdot fdi(-1) + 0.0010 \cdot fdi(-2) + 0.0474 \cdot fx(-1) - 0.0059 \cdot fx(-2) + \\ & +1.2873 \cdot imprt(-1) - 0.8283 \cdot imprt(-2) - 0.1079 \cdot p\_stab(-1) - 0.0536 \cdot p\_stab(-2) + 6.5403, \end{aligned} \tag{9}$$

$$\begin{aligned} p\_stab = {} & 2.5337 \cdot d\_gdp(-1) - 0.4798 \cdot d\_gdp(-2) - 0.5429 \cdot cpi(-1) + 0.3580 \cdot cpi(-2) - \\ & -0.8491 \cdot d\_service(-1) - 0.7732 \cdot d\_service(-2) + 0.0027 \cdot fdi(-1) + 0.0029 \cdot fdi(-2) + \\ & +0.1551 \cdot fx(-1) + 0.0663 \cdot fx(-2) + 0.4070 \cdot imprt(-1) + 0.2238 \cdot imprt(-2) + \\ & +0.4780 \cdot p\_stab(-1) + 0.2179 \cdot p\_stab(-2) - 7.7799, \end{aligned} \tag{10}$$

A comparison between the model-generated data and historical data is included in Appendix D. The information criteria used to evaluate the quality of equations obtained from the model-generated data produce results that are within acceptable limits for the general government debt to GDP ratio, debt service to total state budget expenditures, consumer price index, real effective exchange rate of the hryvnia to the US dollar, and political stability index. Regarding imports, there is a discrepancy between the predicted and actual figures, but the general trend remains comparable. However, foreign direct investment significantly differs from actual data, resulting from the low quality of the equation.

Due to their inadequacies, these indicators must be excluded from the model, despite their objectively established correlation with the public debt indicator. The equations resulting from the VAR model for the 5 indicators are given in Appendix E.

The obtained equations provide evidence for the second hypothesis (*H2*) and establish a formalized link between the public debt indicator and macroeconomic indicators using econometric modeling, namely the VAR model.

The value of the findings should be assessed based on their potential to predict future indicators using the model. Table 5 displays the results of the VAR model for chosen macroeconomic indicators, while a graphical depiction of the outcomes is featured in Appendicies F and G.

Table 5. Forecasting the values of chosen macroeconomic indicators by employing the VAR model from 2021 to 2023

Period	D_GDP	D_SERVICE	CPI	FX	P_STAB
2021–1	29.85%	13.73%	8.50%	0.9458	–0.32
2021–2	29.26%	10.44%	9.50%	0.9649	–0.33
2021–3	26.52%	11.23%	11.00%	0.9947	–0.35
2021–4	25.51%	7.75%	10.00%	1.0172	–0.38
2022–1	25.57%	12.20%	5.32%	1.0375	–0.29
2022–2	26.21%	9.88%	0.10%	1.0688	–0.24
2022–3	26.48%	10.99%	–1.01%	1.0612	–0.19
2022–4	26.42%	9.33%	–0.90%	1.0516	–0.17
2023–1	26.07%	9.90%	0.26%	1.0310	–0.16
2023–2	25.63%	8.96%	1.18%	1.0221	–0.16
2023–3	25.21%	9.45%	2.13%	1.0177	–0.17
2023–4	24.87%	9.01%	2.62%	1.0250	–0.18

Unfortunately, it is impossible to compare model data with actual data due to the context of conflict, territory losses, and the destruction of cities and

$$d\_gdp = 1.0232 \cdot d\_gdp(-1) - 0.2964 \cdot d\_gdp(-2) + 0.03699 \cdot d\_service(-1) + \\ +0.0685 \cdot d\_service(-2) - 0.01771 \cdot cpi(-1) + 0.03798 \cdot cpi(-2) - 0.0855 \cdot fx(-1) + \\ +0.0665 \cdot fx(-2) + 0.0188 \cdot p\_stab(-1) - 0.0489 \cdot p\_stab(-2) + 0.0712, \quad (11)$$

$$d\_service = 0.3692 \cdot d\_gdp(-1) + 0.0311 \cdot d\_gdp(-2) - 0.8014 \cdot d\_service(-1) - \\ -0.0575 \cdot d\_service(-2) - 0.0807 \cdot cpi(-1) + 0.1246 \cdot cpi(-2) + 0.0951 \cdot fx(-1) - \\ -0.0398 \cdot fx(-2) + 0.0412 \cdot p\_stab(-1) - 0.1071 \cdot p\_stab(-2) + 0.0035, \quad (12)$$

$$cpi = 0.4138 \cdot d\_gdp(-1) - 0.5281 \cdot d\_gdp(-2) + 0.5568 \cdot d\_service(-1) + \\ +0.6427 \cdot d\_service(-2) + 1.1592 \cdot cpi(-1) - 0.5541 \cdot cpi(-2) + 0.0189 \cdot fx(-1) - \\ -0.2748 \cdot fx(-2) - 0.0214 \cdot p\_stab(-1) + 0.1266 \cdot p\_stab(-2) + 0.2077, \quad (13)$$

$$fx = -0.0456 \cdot d\_gdp(-1) - 1.1117 \cdot d\_gdp(-2) - 0.0466 \cdot d\_service(-1) - \\ -0.5339 \cdot d\_service(-2) - 0.0704 \cdot cpi(-1) - 0.1049 \cdot cpi(-2) + 0.7392 \cdot fx(-1) - \\ -0.0953 \cdot fx(-2) - 0.1719 \cdot p\_stab(-1) - 0.0629 \cdot p\_stab(-2) + 0.6817. \quad (14)$$

$$p\_stab = 0.3620 \cdot d\_gdp(-1) - 0.4208 \cdot d\_gdp(-2) - 0.6141 \cdot d\_service(-1) - \\ -0.5717 \cdot d\_service(-2) - 0.3991 \cdot cpi(-1) + 0.11167 \cdot cpi(-2) + 0.5753 \cdot fx(-1) + \\ +0.0846 \cdot fx(-2) + 0.2476 \cdot p\_stab(-1) + 0.1693 \cdot p\_stab(-2) - 0.6462. \quad (15)$$

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villages. Only tentative conclusions can be drawn regarding the predicted course of events, and the dynamics of indicators can be considered solely for academic interests. The model, as presented, objectively illustrates the dynamics of all selected indicators in the study. Based on this, similar results are expected for forecast values.

Currently, Ukraine's general government debt to GDP is decreasing gradually and stabilizing at a rate of 25%. Likewise, the debt service to total state budget expenditures has a downward trend with suppressed fluctuations and should eventually reach 9%.

The Consumer Price Index experiences the most volatile fluctuations, varying within a fairly wide range. In 2022, it temporarily experienced deflation but is expected to recover to 2.6% in 2023. The Real Effective Exchange Rate Index trends upward from 2021 to 2022 but declines in 2023 after reaching its peak. The Political Stability Index has reached a plateau with values near -0.17-0.18, which is expected to gradually improve Ukraine's political situation.

Thus, the obtained model is a system of econometric equations that formalizes the relationship between public debt and macroeconomic indicators, allows making forecasts for future periods that confirm their reliability in retrospect and can be used in the development/improvement of public debt management policy, which is evidence of the third hypothesis (*H3*) of this study.

The Granger causality test is used in the study to prove the existence of a causal relationship between the ratio of general government debt to GDP of Ukraine and all selected macroeconomic indicators in most cases with a time lag of 1 or 2, and between some indicators – with other time lags, which is evidence of the first hypothesis (*H1*). These results are consistent with the evidence of Gómez-Puig and Sosvilla-Rivero (2015) on causal relationships between public debt and economic growth.

Using econometric modeling, the study formalizes the relationship between the ratio of public sector debt to GDP of Ukraine and a number of macroeconomic indicators, such as debt service to total state budget expenditures of Ukraine, consumer price index, real effective exchange rate index of the hryvnia to the US dollar, and political stability index, using VAR model. The inappropriateness of using such indicators as foreign direct investment and the level of imports in the VAR model is proved. These results address the second hypothesis (*H2*).

The studies of other researchers are based on alternative econometric models. For example, Mohd Daud and Podivinsky (2012) chose the Generalized Method of Moments (GMM) framework, and Ruiz-Arranz et al. (2005) proposed their own equation based on OLS regressions. These methods are used to determine the dependence of debt on various macroeconomic indicators, which is a key, though not fundamental, difference from the results of this paper. The first study selected GDP growth per capita, investment, central government balance sheet, trade growth conditions, inflation, net private capital flows, and an indicator of economic openness. The second study prefers the following: gross investment, population, financial balance, trade openness, external debt and debt service payments, secondary education, and changes in the terms of trade. In the case of this study, investments and indicators related to foreign trade turnover turned out to be unsuitable for modeling.

The obtained regression equations have an advantage over other methods, as they allow not only to explain the level of public debt by changes in macroeconomic indicators but also to determine the dependence of each of the studied indicators on others, including the level of public debt. Comparison of actual data with the modeled data suggests that the model has sufficient forecasting potential. The identified relationship shows that a reduction in the level of public debt leads to an improvement in macroeconomic indicators. Therefore, this approach can be used to develop practical public debt management policy measures aimed at achieving this long-term goal, as well as to forecast related macroeconomic indicators and use the results in the context of the overall management of Ukraine's economic development, which in turn serves as evidence of the third hypothesis (*H3*) of this paper.

CONCLUSION

The study aims to assess how public debt management affects the macroeconomic development of Ukraine. It utilizes a VAR model to analyze the relationships between macroeconomic indicators and Ukraine's external public debt. The methodology comprises numerous phases, including time series scrutiny, causality and stationarity assessments, and other protocols to construct a suitable econometric model. The study analyzes diverse macroeconomic indicators encompassing debt-to-GDP ratio, debt servicing, consumer price index, real effective exchange rate index, political stability index, and imports.

The VAR model yielded satisfactory results for several macroeconomic indicators, displaying high R-squared and other pertinent quality indicators. Nonetheless, specific indicators, e.g., foreign direct investment, were found to have a minor impact, and, therefore, were excluded from the model. The results indicate that general government debt and debt service tend to decrease. However, the consumer price index is subject to volatile dynamics, and the real effective exchange rate index tends to decrease in 2023.

The model enables forecasting macroeconomic indicators for future periods. However, limitations due to hostilities, territory loss, and destroyed settlements must be considered, preventing comparison of model data with real-world data. Future research should improve the model, considering conflict dynamics and identifying additional reserves to enhance forecast accuracy.

AUTHOR CONTRIBUTIONS

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APPENDIX A

Table A1. Dynamics of Ukraine's macroeconomic indicators selected to identify interdependent relationships with public debt (quarterly values for 2015–2021)

Year	Quarter	General government debt to GDP	Debt service, % of total state budget expenditures	Consumer price index, to the corresponding month of the previous year	Index of real effective exchange rate	Foreign direct investment, USD million	Imports, USD million	Index of political stability
		1	2	3	4	5	6	7
2015	1	30.77%	16.44%	45.80%	0.6445	(3,862)	64,108	–1.19
	2	35.45%	18.03%	57.50%	0.7776	2,255	57,922	–0.57
	3	39.73%	15.43%	51.90%	0.8274	230	53,522	–0.89
	4	39.63%	12.06%	43.30%	0.7959	(1,920)	50,224	–0.74
2016	1	40.61%	20.02%	20.90%	0.7159	(963)	49,368	–0.78
	2	40.45%	12.17%	6.90%	0.7556	1,568	49,320	–0.76
	3	41.18%	17.59%	7.90%	0.7235	571	50,570	–0.70
	4	39.11%	9.27%	12.40%	0.7930	156	52,461	–0.72
2017	1	37.56%	17.13%	15.10%	0.7726	921	54,921	–0.69
	2	36.97%	11.89%	15.60%	0.7999	1,037	57,829	–0.70
	3	36.39%	17.53%	16.40%	0.7886	270	60,068	–0.64
	4	34.65%	8.33%	13.70%	0.7756	465	62,688	–0.56
2018	1	33.69%	14.22%	13.20%	0.8094	1,720	64,380	–0.50
	2	31.23%	10.42%	9.90%	0.8585	378	66,354	–0.44
	3	30.33%	13.97%	8.90%	0.8327	(184)	68,914	–0.54
	4	30.70%	9.61%	9.80%	0.8774	1,844	70,555	–0.52
2019	1	30.50%	13.43%	8.60%	0.9141	629	71,775	–0.49
	2	30.65%	10.61%	9.00%	0.9342	1,422	73,560	–0.45
	3	29.32%	12.67%	7.50%	1.0126	1,972	75,149	–0.39
	4	28.72%	8.71%	4.10%	1.0454	1,387	76,067	–0.29
2020	1	28.03%	13.13%	2.30%	0.9646	(1,829)	75,510	–0.22
	2	29.29%	10.13%	2.40%	0.9596	1,079	69,475	–0.25
	3	28.93%	12.14%	2.30%	0.9052	(10)	64,956	–0.30
	4	30.65%	4.90%	5.00%	0.9013	441	63,085	–0.31
2021	1	29.85%	13.73%	8.50%	0.9458	1,390	63,820	–0.32
	2	29.26%	10.44%	9.50%	0.9649	1,059	70,046	–0.33
	3	26.52%	11.23%	11.00%	0.9947	2,217	76,719	–0.35
	4	25.51%	7.75%	10.00%	1.0172	1,977	84,175	–0.38

APPENDIX B

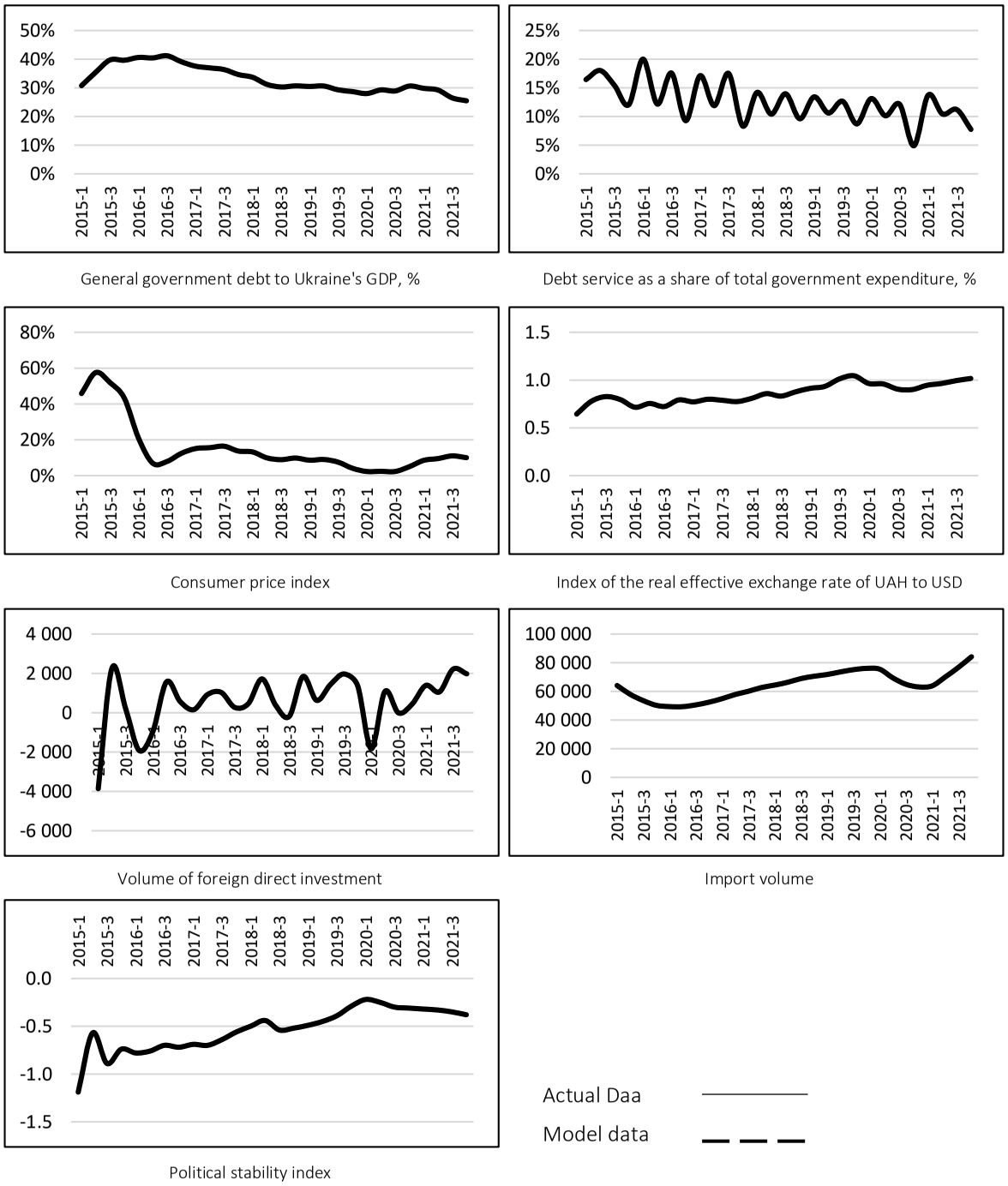

Figure B1. Dynamics of Ukraine's macroeconomic indicators that are interdependent with the public debt (2015–2021)

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APPENDIX C

Table C1. Results of VAR modeling for selected macroeconomic indicators for the period 2015–2021

	D_GDP	CPI	D_SERVICE	FDI	FX	IMPRT	P_STAB
D_GDP(–1)	0.161336	0.213897	0.67401	15.46298	1.755192	–1.62585	2.533673
	–0.25854	–0.7785	–0.77339	–178.11	–1.36327	–0.61506	–1.7671
	[0.62403]	[0.27476]	[0.87150]	[0.08682]	[1.28749]	[–2.64338]	[1.43380]
D_GDP(–2)	–0.06494	–1.49253	0.229197	–140.653	–2.31986	–0.16615	–0.47971
	–0.19217	–0.57863	–0.57484	–132.384	–1.01328	–0.45716	–1.31343
	[–0.33796]	[–2.57941]	[0.39872]	[–1.06246]	[–2.28946]	[–0.36344]	[–0.36523]
CPI(–1)	–0.03765	0.955354	0.052302	0.973443	–0.10045	–0.14706	–0.54286
	–0.04793	–0.14433	–0.14338	–33.0199	–0.25274	–0.11403	–0.3276
	[–0.78539]	[6.61944]	[0.36478]	[0.02948]	[–0.39745]	[–1.28969]	[–1.65706]
CPI(–2)	–0.01592	–0.41195	0.014099	–25.3591	0.016598	0.146281	0.358045
	–0.03969	–0.1195	–0.11872	–27.341	–0.20927	–0.09442	–0.27126
	[–0.40106]	[–3.44718]	[0.11876]	[–0.92751]	[0.07931]	[1.54932]	[1.31993]
D_SERVICE(–1)	0.118714	0.538641	–0.77999	17.89323	–0.19351	–0.27967	–0.84915
	–0.07922	–0.23854	–0.23698	–54.576	–0.41773	–0.18847	–0.54147
	[1.49852]	[2.25803]	[–3.29138]	[0.32786]	[–0.46324]	[–1.48393]	[–1.56822]
D_SERVICE(–2)	0.141429	0.72489	–0.07891	–21.4664	–0.60809	–0.46647	–0.77322
	–0.08055	–0.24254	–0.24095	–55.4898	–0.42472	–0.19162	–0.55054
	[1.75584]	[2.98876]	[–0.32749]	[–0.38685]	[–1.43173]	[–2.43435]	[–1.40448]
FDI(–1)	–0.00059	0.000845	–0.00208	–0.30774	–0.00066	0.003256	0.002705
	–0.00058	–0.00174	–0.00173	–0.39763	–0.00304	–0.00137	–0.00394
	[–1.02493]	[0.48645]	[–1.20661]	[–0.77395]	[–0.21737]	[2.37122]	[0.68580]
FDI(–2)	0.000223	0.002605	–0.00187	–0.22512	0.000304	0.000998	0.002957
	–0.00046	–0.00138	–0.00137	–0.31526	–0.00241	–0.00109	–0.00313
	[0.48782]	[1.89082]	[–1.36704]	[–0.71409]	[0.12589]	[0.91633]	[0.94548]
FX(–1)	0.022652	–0.02767	0.270039	–4.28359	0.708859	0.047378	0.155159
	–0.06473	–0.1949	–0.19362	–44.5899	–0.34129	–0.15398	–0.44239
	[0.34998]	[–0.14195]	[1.39470]	[–0.09607]	[2.07697]	[0.30769]	[0.35073]
FX(–2)	0.029591	–0.22654	–0.16288	–10.794	–0.14909	–0.00588	0.066278
	–0.06855	–0.20642	–0.20507	–47.227	–0.36148	–0.16309	–0.46856
	[0.43165]	[–1.09746]	[–0.79427]	[–0.22856]	[–0.41245]	[–0.03605]	[0.14145]
IMPRT(–1)	–0.32468	–0.10447	0.17215	52.16748	0.686264	1.28726	0.407
	–0.07145	–0.21515	–0.21374	–49.2234	–0.37676	–0.16998	–0.48837
	[–4.54411]	[–0.48556]	[0.80542]	[1.05981]	[1.82149]	[7.57292]	[0.83339]
IMPRT(–2)	0.193297	–0.17077	–0.11104	–73.0505	–0.64196	–0.82834	0.223817
	–0.05668	–0.17066	–0.16955	–39.0458	–0.29886	–0.13484	–0.38739
	[3.41045]	[–1.00061]	[–0.65490]	[–1.87089]	[–2.14802]	[–6.14331]	[0.57776]
P_STAB(–1)	–0.07107	–0.03123	0.053484	–9.9701	0.002302	–0.10787	0.479981
	–0.032	–0.09636	–0.09573	–22.0465	–0.16875	–0.07613	–0.21873
	[–2.22086]	[–0.32413]	[0.55869]	[–0.45223]	[0.01364]	[–1.41693]	[2.19438]
P_STAB(–2)	–0.0734	0.046769	–0.06015	–7.29884	–0.04469	–0.05359	0.217941
	–0.02098	–0.06318	–0.06277	–14.4553	–0.11064	–0.04992	–0.14342
	[–3.49792]	[0.74022]	[–0.95826]	[–0.50493]	[–0.40390]	[–1.07350]	[1.51963]
C	1.605916	3.573768	–0.84095	286.816	0.17872	6.540261	–7.77986
	–0.59052	–1.77812	–1.76647	–406.813	–3.11378	–1.40484	–4.03615
	[2.71950]	[2.00985]	[–0.47606]	[0.70503]	[0.05740]	[4.65554]	[–1.92754]
R–squared	0.991	0.985	0.836	0.621	0.936	0.995	0.973
Adj. R–squared	0.980	0.965	0.627	0.139	0.855	0.989	0.938
Sum sq. resids	0.001	0.005	0.005	256.591	0.015	0.003	0.025
S.E. equation	0.007	0.021	0.021	4.830	0.037	0.017	0.048
F–statistic	86.357	50.624	4.007	1.288	11.490	156.782	27.846
Log likelihood	103.258	74.598	74.769	–66.654	60.031	80.725	53.285
Akaike AIC	–6.789	–4.584	–4.598	6.281	–3.464	–5.056	–2.945
Schwarz SC	–6.063	–3.859	–3.872	7.007	–2.738	–4.330	–2.219
Mean dependent	0.331	0.125	0.123	4.317	0.873	11.062	–0.510
S.D. dependent	0.049	0.113	0.034	5.205	0.097	0.157	0.192

Note: D GDP: The ratio of general government debt to GDP; D SERVICE: Debt service to total government expenditures; CPI: Consumer price index; FX: Index of the real effective exchange rate of UAH to USD; FDI: The volume of foreign direct investment; IMPRT: Imports of goods and services; P STAB: Political stability index (according to the World Bank); C: constant; (-1), (-2): time lags of the corresponding indicators. First row – the obtained coefficients of the regression equation for the respective indicator; second row – standard error; third row – test statistics.

APPENDIX D

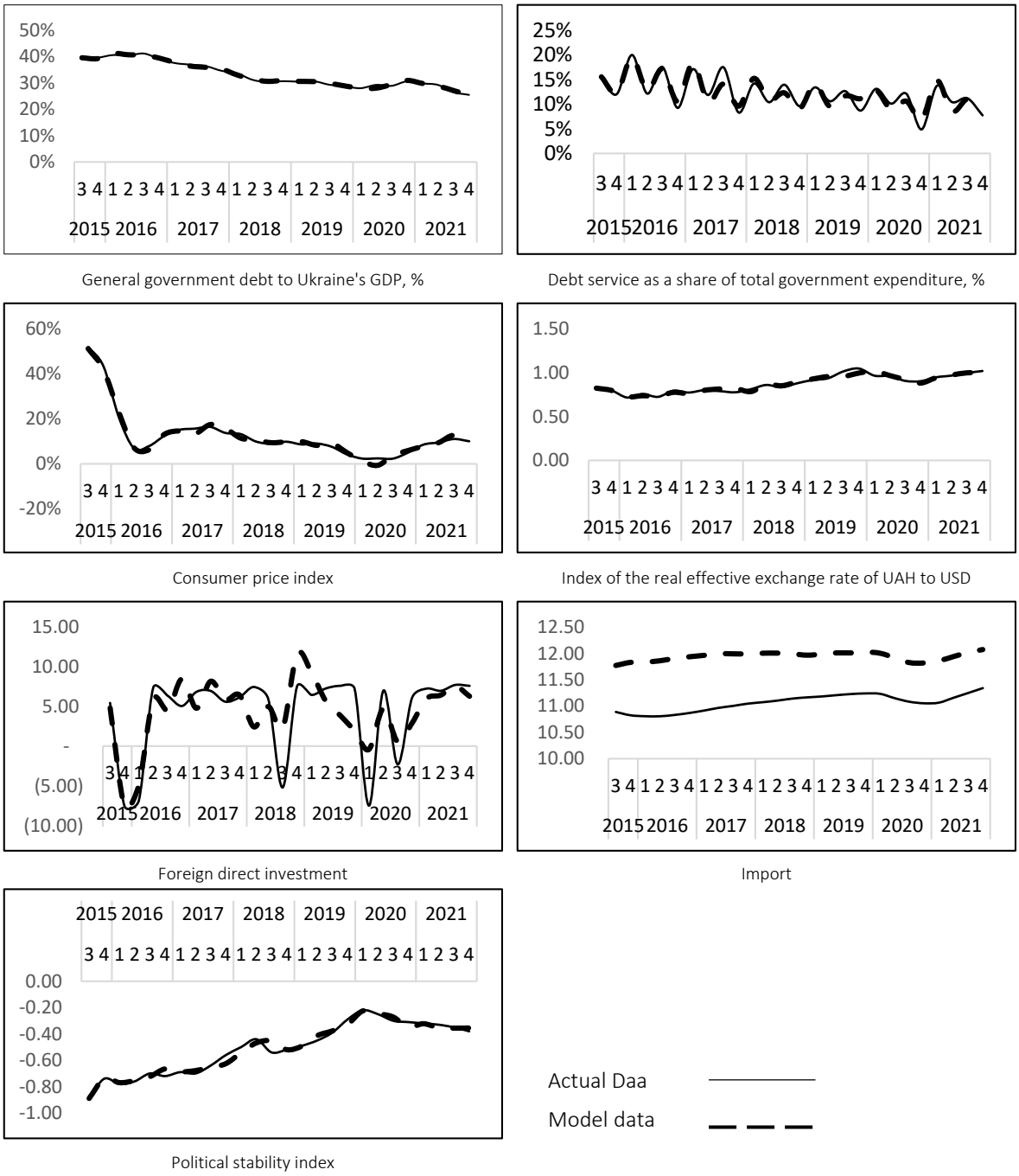

Figure D1. Comparison of real data with model values from the VAR model

http://dx.doi.org/10.21511/ppm.21(4).2023.37

APPENDIX E

Table E1. Results of VAR modeling for selected macroeconomic indicators during 2015–2021

	D_GDP	D_SERVICE	CPI	FX	P_STAB
D_GDP(–1)	1.023239	0.369221	0.413795	–0.04557	0.362006
	–0.24364	–0.39139	–0.43613	–0.7581	–1.06398
	[4.19983]	[0.94337]	[0.94879]	[–0.06011]	[0.34024]
D_GDP(–2)	–0.296372	0.031054	–0.528129	–1.111732	–0.420805
	–0.2209	–0.35486	–0.39543	–0.68735	–0.96469
	[–1.34165]	[0.08751]	[–1.33558]	[–1.61742]	[–0.43621]
D_SERVICE(–1)	0.036989	–0.801368	0.556755	–0.046571	–0.614065
	–0.13977	–0.22452	–0.25019	–0.43489	–0.61036
	[0.26465]	[–3.56921]	[2.22533]	[–0.10709]	[–1.00607]
D_SERVICE(–2)	0.068462	–0.057478	0.642669	–0.533944	–0.571694
	–0.14138	–0.22711	–0.25308	–0.43991	–0.6174
	[0.48425]	[–0.25308]	[2.53943]	[–1.21377]	[–0.92597]
CPI(–1)	–0.017708	–0.080743	1.159218	–0.070439	–0.399098
	–0.06275	–0.1008	–0.11233	–0.19525	–0.27403
	[–0.28220]	[–0.80101]	[10.3202]	[–0.36077]	[–1.45642]
CPI(–2)	0.037983	0.124564	–0.554112	–0.104864	0.111669
	–0.05628	–0.09041	–0.10075	–0.17512	–0.24578
	[0.67488]	[1.37775]	[–5.50001]	[–0.59880]	[0.45434]
FX(–1)	–0.085527	0.095131	0.018879	0.739213	0.575301
	–0.07978	–0.12817	–0.14282	–0.24826	–0.34842
	[–1.07197]	[0.74224]	[0.13219]	[2.97763]	[1.65116]
FX(–2)	0.06654	–0.039803	–0.274766	–0.095272	0.084588
	–0.08186	–0.1315	–0.14653	–0.25471	–0.35748
	[0.81287]	[–0.30269]	[–1.87513]	[–0.37405]	[0.23662]
P_STAB(–1)	0.018758	0.041153	–0.021433	–0.171968	0.247607
	–0.04618	–0.07418	–0.08266	–0.14368	–0.20165
	[0.40624]	[0.55480]	[–0.25930]	[–1.19691]	[1.22791]
P_STAB(–2)	–0.04887	–0.107081	0.126585	–0.062867	0.169282
	–0.02923	–0.04696	–0.05233	–0.09096	–0.12766
	[–1.67181]	[–2.28031]	[2.41910]	[–0.69117]	[1.32606]
C	0.07123	0.003493	0.207714	0.681684	–0.646163
	–0.10071	–0.16178	–0.18028	–0.31336	–0.4398
	[0.70728]	[0.02159]	[1.15220]	[2.17539]	[–1.46922]
R–squared	0.960331	0.79201	0.976236	0.901938	0.950712
Adj. R–squared	0.933884	0.65335	0.960393	0.836563	0.917854
Sum sq. resids	0.002379	0.006138	0.007622	0.02303	0.045364
S.E. equation	0.012593	0.020229	0.022542	0.039184	0.054994
F–statistic	36.31246	5.711886	61.61976	13.79637	28.9336
Log likelihood	83.99843	71.67419	68.85977	54.48515	45.67223
Akaike AIC	–5.615264	–4.667246	–4.450752	–3.345011	–2.667095
Schwarz SC	–5.082992	–4.134974	–3.91848	–2.81274	–2.134823
Mean dependent	0.330566	0.122501	0.125423	0.872509	–0.51
S.D. dependent	0.048975	0.034359	0.113268	0.096923	0.191875

APPENDIX F

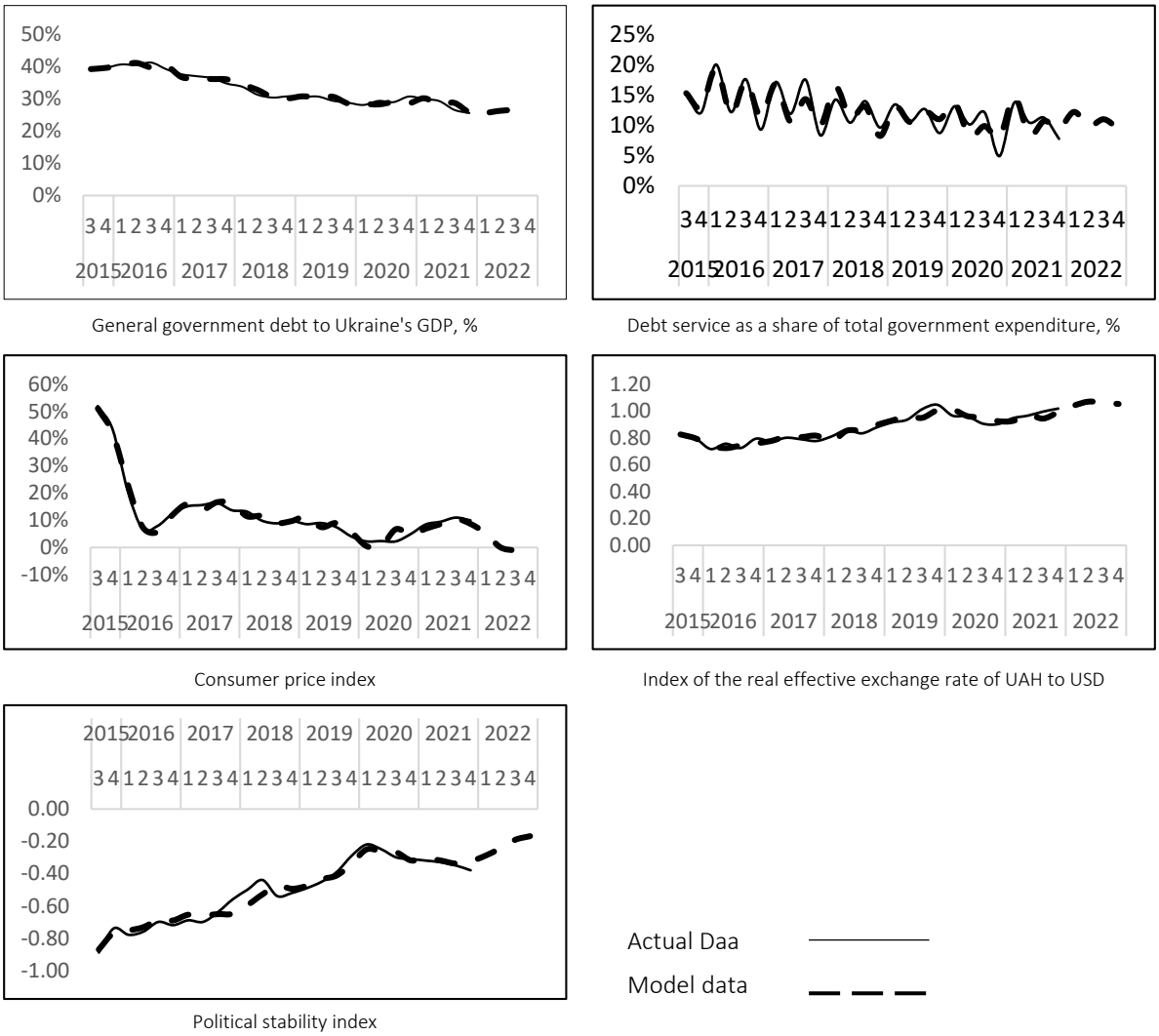

Figure F1. Comparison of actual data with model values of the VAR model

http://dx.doi.org/10.21511/ppm.21(4).2023.37

APPENDIX G

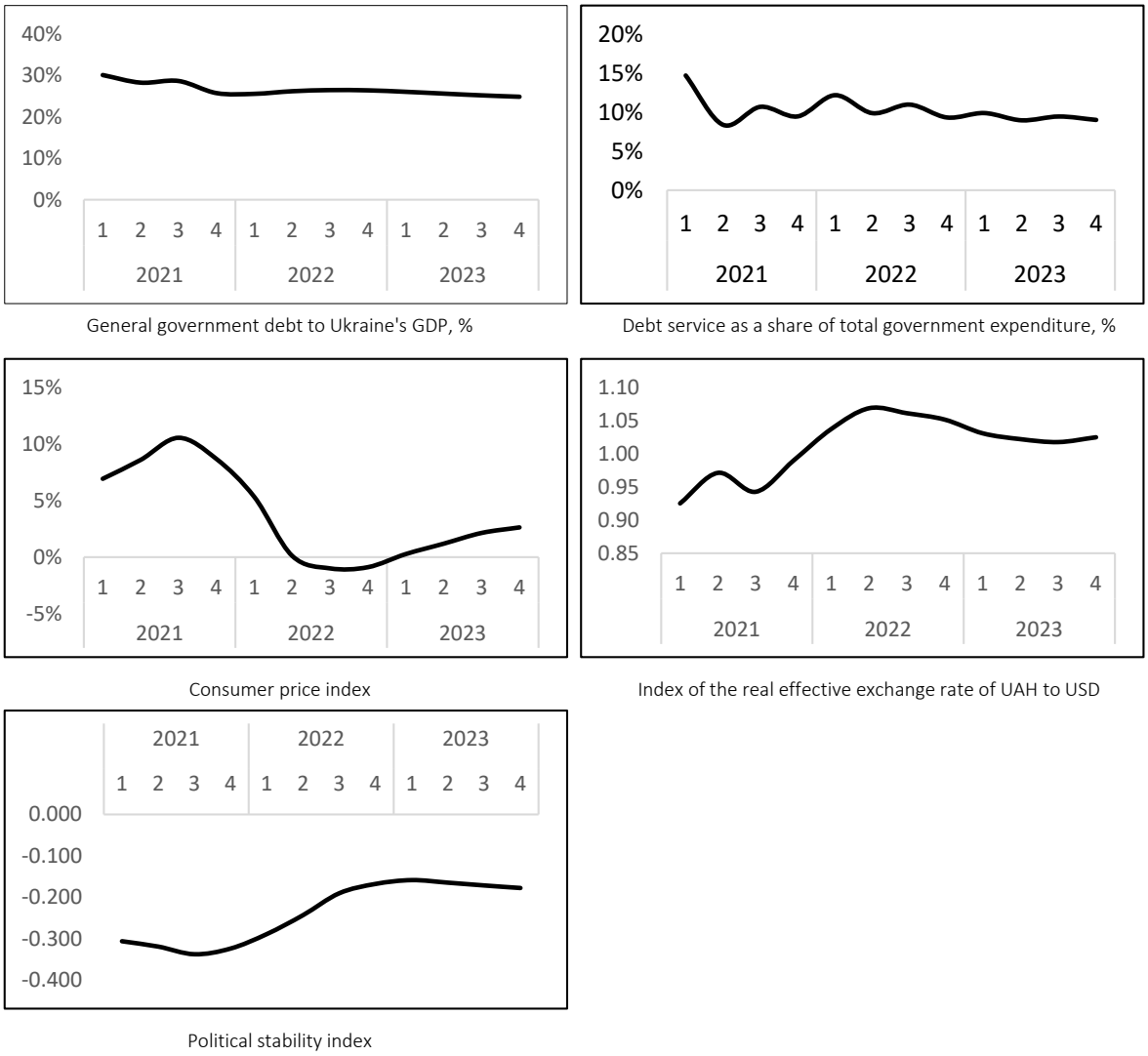

Figure G1. Projections of chosen macroeconomic indicators based on the VAR model for 2021–2023