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Forecasting The Budget Deficit as A Method of Ensuring the Financial Security of the State

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ABSTRACT:
Budget deficit represents a crucial measure of the country's economic health while having important geopolitical meaning in the modern world. The importance of the topic under consideration comes from the demand for efficient management of public finances to make a country financially resilient. This study sets out the objective of predicting Ukraine's budget deficit based on exponential advection and acceleration analysis methods. The statistics to use are provided by the State Statistics Service of Ukraine and the Ministry of Finance of Ukraine. The findings revealed that the increase in Ukraine's budget deficit due to incorrect and unsystematic actions can have fatal consequences for international economic activity. The study's practical significance lies in outlining recommendations for using forecast results in the management of public finance to minimise the negative impact of the deficit on the economy. The models proposed can be implemented in current fiscal planning structures to measure accuracy in forecasts.

Keywords: budget deficit, forecasting, exponential smoothing, acceleration analysis, foreign economic activity, financial stability

1. Introduction

The budget deficit is an important measure of a country's economy. Managing the budget deficit is a significant challenge for governments worldwide as they work to align expenditures with earnings. A continued imbalance of being in the 'red' values can result in an upswing in national debt, which can impact interest rates, inflation and general economic stability, which was mentioned back in the 1970s by Blinder & Solow (1972) and Herber (1971) and later confirmed by recent studies (Hidayat et al., 2019). With nations dealing with global power struggles and economic risks, predicting budget deficits has become important in formulating effective fiscal policy.

It should be mentioned that alarming trends in the public finances of Ukraine began to be observed back in early 2018. Even then, four out of 11 fiscal imbalances indicators in Ukraine exceeded the maximum permissible values, namely: the coefficient of variation of the real GDP growth rate; the size of the general government debt, reaching 75.6% with the maximum permissible value of 42.8%; the share of debt denominated in foreign currency, amounting to 67.8% with the maximum permissible value of 60%; the yield on foreign loan bonds, which amounted to 690 basis points at the end of the first half of the year, exceeding the maximum permissible value by 90 basis points (Bogdan, 2018). Start Budget revenue indicators improved somewhat in 2024, and expenditures slowly declined. However, budget imbalances remained significant, and Ukraine's public

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debt continued to grow. Continued significant international support for Ukraine fuelled consumer and investment spending in the budget. However, the flow of this support was extremely uneven and complicated the planned budget implementation. In the first quarter of 2024, the budget received $10.2 billion in foreign loans and grants, but their delays in January-February 2024 prompted the government to under-finance planned budget expenditures and withdraw funds from treasury accounts (Bogdan, 2024). In fact, after years of large-scale support for Ukraine by official creditors and donors, the country's financial position continues to depend on attracting external official financing, as the structural imbalances of the real sector have not been overcome and the balance of payments has not been improved. It should be noted that setting too high interest rates on domestic public debt in Ukraine clearly worsens the country's economic stability and defence capability during war. The Ukrainian economy has been operating in a regime of abnormally high interest rates for three years now, and the situation is only getting worse. The real National Bank of Ukraine (NBU) discount rate at the end of 2023 was 9.9% per annum, and in 2025 the Board of NBU decided to increase the discount rate to 15.5%. The IMF predicts that in 2025, Ukraine's public debt to GDP will increase to 106.6%, and in 2026 – to 107.6% (Verstiuk, 2025).

According to Ukrainian scholars Shykina and Kotsiurubenko (2020), the foundation for developing the defence of Ukraine's national interests and the long-term growth of the national economy is sufficient financial security. The authors point out that when examining the overall state of public finances as well as the nominal volumes and dynamics of changes in the state budget deficit as a percentage of GDP, it is relatively easy to trace the overall effect of all threats latent, explicit, potential, direct, and indirect to Ukraine's national security. Based on the data on U.S. debt dynamics, American scientists also emphasise that large and growing national debt poses long-term economic and security risks (Canofari et al., 2020; Hernandez, 2024).

For Ukraine, deficits are more urgent in light of the continuing geopolitical tensions and economic transformations. Afonso et al. (2024) utilized Dario Caldara and Matteo Iacovello's Geopolitical Risk Index (Caldara & Iacoviello, 2022) to assess how growing geopolitical risk affects nations' budget deficits and trade balances. The authors focused solely on European nations between 2001 and 2022, a set of countries with minimal exposure to geopolitical risk. They illustrated that the only notable rises in geopolitical risks during that time period were the 9/11 terror attacks, the commencement of the Iraq War, the London Bombings, the Russian invasion of Ukraine, and the Bataclan terror attacks in France in late 2015. The findings of Afonso et al. (2024) show that despite this relatively benign climate, there is a definite link between geopolitical concerns, budget deficits, and trade balances. When geopolitical risks rise, investment activity falls and uncertainty rises, slowing GDP growth and, more significantly, tax collections, resulting in a higher fiscal imbalance for the government. This negative impact on government finances is substantially greater if the nation is already in a recession or has a poor economy when the geopolitical shock occurs (Afonso et al., 2024). That is exactly what is happening in Ukraine right now, and it warrants further investigation and attention.

Given these challenges, strong forecasting capabilities are critical to Ukraine's financial management. Recent statistics show that Ukraine's budget deficit is on the rise. For example, in 2023, the deficit exceeded UAH 1,330,000 million, while in December

2024, the state budget deficit of Ukraine significantly increased due to the recovery of expenditures, and at the end of the year, amounted to about 1.771 trillion hryvnias (Mykhaylov, 2025). Such a growing deficit indicates the need for effective fiscal policies to prevent possible negative impacts on the economy and foreign economic activity (Baldi, 2016).

This paper aims to solve this crucial issue of national financial security by developing forecasting models of Ukraine's budget deficit using modern forecasting methods, such as exponential smoothing and acceleration analysis. It provides valuable insights for fiscal policymakers to strengthen financial stability.

2. Theoretical Background

For decades, countries have developed practices of presenting a fiscal deficit as a matter of domestic concern; over the years, such deficits have crept into global concern, mainly due to their significance in the present-day global system (Proaño, 2017; Saleh & Harvie, 2005). Recent studies show a turn to advanced methods, especially hybrid forecasting approaches, that have changed the construction of econometric models. Machine learning has been much better than traditional econometric methods in predicting the emergence of fiscal crises, changing how budget deficits are likely to be managed (Hellwig, 2021).

Nwanne (2014) conducted an empirical investigation that identified a strong negative correlation between deficit financing and economic stability, suggesting policymakers adopt a flexible model of expenditure forecasting. This holds considering how emerging economies such as those explored by Rahman and Pujiati (2021) are faced with questions about legitimate adaptive expectations for their forecasting models.

Wasserbacher and Spindler (2022) use natural language processing in conjunction with traditional financial forecasting methodologies, suggesting a hybrid approach of both methodologies alongside machine learning techniques to improve the accuracy of prediction models within unpredictable economic climates. These hybrid methods capture linear and non-linear relationships in fiscal data and remain powerful forecasting tools. Policy uncertainty leads policymakers to focus on short-term value.

According to Vitlinsky and Makhanets (2011), there is a significant need for developing fiscal stress early warning systems; the authors suggest broad monitoring systems that encapsulate both backwards-looking indicators and systematic measures to capture the economy's "forward-looking features."

All these methodologies are supported in the works of Baum, Poplawski-Ribeiro, and Weber (2020), who study how economic states influence the effectiveness of fiscal policy, and Dil (2017), who highlights the benefits of machine learning within financial forecasting.

In summary, the literature indicates a move towards more integrated and sophisticated forecasting models, employing traditional and contemporary techniques to navigate the complexities of fiscal forecasting in varying economic conditions.

The aim was to develop a forecasting model for Ukraine's budget deficit and test it using exponential smoothing and acceleration analysis, highlighting the possible implications of the forecasted budget deficit for foreign economic activity.

3. Methods

The study analyses budget deficit forecasting using a combined exponential smoothing and acceleration analysis approach.

Due to the nature of time series, which gives more weight to recent observations, exponential smoothing was chosen as the primary forecasting technique explained in Blanchard and Leigh (2013). It uses a smoothing coefficient to give different weights to observations in the final model. This method mathematically can be formalised in a recurrent formula, in which the new value of the exponential average is computed based on the previous smoothed value and the current input observation.

The choice of exponential smoothing was based on recommendations from a variety of sources. Khan & Khan (2020) and Erkekoglu et al. (2020) argue that there is no definite answer when deciding between exponential smoothing and ARIMA models since it is dependent on the data properties, forecasting objective, and analyst choice. In general, exponential smoothing may be more appropriate for data that is noisy, irregular, or contains missing values or outliers. Furthermore, if the data has a clear and consistent trend, level, and seasonality, exponential smoothing may be an appropriate choice. On the other hand, if the data is complicated, non-stationary, or contains various patterns and characteristics, ARIMA may be more suited. Exponential smoothing models update projections more rapidly when fresh data becomes available. Because of their flexibility, they can react swiftly to modifications in the underlying data patterns, which is essential when working with small datasets where trends can change quickly. This is especially significant given the unstable political, economic, and geopolitical circumstances that Ukraine is currently facing.

We employ the provisions suggested by Baum, Poplawski-Ribeiro, and Weber (2020), who analyse fiscal multipliers and the impact of economic states on the effectiveness of fiscal policy, a significant issue related to managing the budget deficit.

An acceleration-type analysis derived from economics was implemented to improve forecast accuracy. We were able to do this by looking out not just for the indicator's absolute value and rate of change but also for the temp of the change over time. Acceleration, in mathematical terms, is the second derivative of the primary function reflecting the dynamics of the deficit budget.

The functional dependence, which more accurately characterises the dynamics budget deficit, was determined using the software package SPSS. It compares different kinds of curves (linear, Quadratic, Cubic Model, etc.). Statistical criteria were used to select the third-degree polynomial as the more adequate model to describe the process under study. Dil (2017) describes the advantages of using machine learning for forecasting.

The study's information base was data on Ukraine's budget deficit for 1995-2024. The time series consists not only of historical data but also of planned indicators for 2024, which enables estimating long-term trends and contemporaneous performance of the indicators.

A validation procedure was performed to compare forecasted values to real data from the control period to ensure the model's accuracy in predicting future events. Standard statistical measures of forecasting accuracy were used to evaluate the quality of the forecasts.

This approach provides the opportunity to receive quantitative estimates of future values of the budget deficit and analyse the nature of its changes. This task is important when developing meaningful fiscal policy measures.

4. Results and Discussion

The budget deficit is an important macroeconomic indicator that reflects the state of any country's economy, especially in the context of many complex geopolitical challenges and transformation processes (Kurt & Witt, 2012). Moreover, several interconnected mechanisms and channels of influence reflect the effect of the budget deficit on the viability of business entities' foreign economic activity.

Budget deficits lead to macroeconomic instability, which immediately impacts the exchange rate. Deficit slippers generally take their toll on paper money, resulting in a double hit on foreign economic actors (Wilburn, 2014). Meanwhile, exporters benefit temporarily by lowering their products' prices in foreign markets. For importers, however, costs are going up, which can have a devastating impact on their financials.

Budget deficits also impact credit costs. Typically, higher government borrowing to finance the deficit drives up interest rates in the financial market. This complicates business financing of foreign economic activities and raises the costs of servicing existing debts.

One key factor in the impact is the climate shift in investment. A high budget deficit indicates economic risks in the macro sphere, which yields the outflow of foreign investments and makes international cooperation more difficult. This is especially important for businesses based on long-term cooperation with foreign counterparties.

Deficit expenditure is often accompanied by tighter fiscal policy, which may be expressed as a heavier tax burden, stricter customs control, and currency regulation. These changes require more resources from business entities to reshape and can make them less competitive (Perotti, 1999).

It could also spill over into the balance of payments, leading to further restrictions on economic activity for foreigners in the country. This creates uncertainty for business entities and complicates their activity planning.

Forecasting the budget deficit has utilised statistical, econometric, and anutilised information technologies. Scientists and practitioners use a variety of methodological approaches, and time series, regression analysis, and machine learning methods hold a special place among them.

Key tools like exponential smoothing underpin mathematical forecasting. The algorithm we use below is similar in casting the most weight into recent observations when building a forecast model. In its mathematical formulation, the method is represented by a formula that uses the current indicator value, previous forecast, and smoothing coefficient:

$$\hat{y}_n(t) = \alpha(y_n + (1-\alpha)y_{n-1} + (1-\alpha)^2 y_{n-2} + ...)\,,\, 0 < \alpha < 1 \quad (1)$$

where the sum of all weights is 1, and α is the smoothing parameter

In practice, the exponential average is calculated using a recurrent formula:

$$\hat{y}_t(1) = \alpha y_t + (1-\alpha)\hat{y}_t \text{ or } \hat{y}_t(1) = \hat{y}_t + \alpha(y_t - \hat{y}_t), \quad (2)$$

The new exponential average calculation takes the previous exponential average and the share (α) of the difference between the previous observation and its smoothed value, that is, the error $e_t = y_t - \hat{y}_t$. Thus, with the arrival of a new observation y_n, the forecast $\hat{y}_n(1)$ is calculated as an exponential average $\hat{y}_{n+1}$ of the following value y_{n+1}; the parameter α is chosen based on the condition of minimising the minimising.

Exponential smoothing is one of the key benefits of analysing complex systems, such as budgetary indicators.

The primary benefit of the method is its high flexibility about dynamic changes in the economic environment. In contrast to static forecasting models, exponential smoothing enables the ability to react to new trends quickly, thereby weighting the most recent observations the most. This is vital for Ukraine, whose economy is constantly metamorphosed (Kharlamov, 2024).

The mathematical nature of the method achieves the smoothing of these random fluctuations and statistical anomalies. It represents the application of a special smoothing coefficient that allows smoothing unrelated to a systemic vision of budgetary processes regarding short-term fluctuations. This boosts the representativeness of the forecast models.

Another significant benefit of exponential smoothing is its robust implementation. The approach does not need advanced computing power and can be applied even in low-tech environments. It has also benefited from a large cadre of researchers and analysts covering public finance.

For example, we can quickly modify the forecast model, which is a significant benefit. If new statistics are available, the researcher can receive information almost instantly and re-compute the forecast, just changing the smoothing factor. This adaptability is vital in an unpredictable economy.

The sound practical effect shows that this method is highly efficient in predicting indicators with moderate volatility. Budgetary indicators have certain inertia and depend on macro indicators, so they are indeed well-suited to the conditions for applying exponential smoothing.

It should be stressed that the method can account for time lags and trend components of economic processes. It enables the creation of a more precise and realistic deficit model that accounts for not only value at the moment but also past developing tendencies.

Another advantage is that exponential smoothing can be usefully combined with other forecasting methods. This approach, especially when combined with machine

learning or regression analysis methods, can help to build a hybrid model with even better forecast accuracy.

The lack of subjectivity vs expert assessment methods is also key. The algorithm is based on mathematics, making forecasting more objective and reducing the human factor's influence.

Researchers should, however, also be mindful of the method's limitations. Exponential smoothing does not adequately capture complex non-linear dependencies and can become imprecise following radical structural transformations of the economic system (Gardner, 1985; Lima et al., 2019). Thus, future studies might address this gap by combining non-linear methods like neural networks with exponential smoothing for greater forecasting accuracy, such as a hybrid synergy model integrating exponential smoothing and neural network for financial time series prediction, suggested by Lai et al. (2006), which aims to blend the linear properties of an exponential smoothing model and the nonlinear patterns of neural networks to build a "synergetic" model using the linear programming approach.

Thus, exponential smoothing seems to be a powerful, flexible, and relatively simple tool for forecasting the budget deficit, with important advantages over alternatives.

Below, we will attempt to predict Ukraine's budget deficit trend using exponential smoothing.

Initial statistical data for analysis are presented in Table 1.

Table 1: Ukraine's budget deficit dynamics

Year	Budget deficit (-budget surplus), UAH million	Year	Budget deficit (-budget surplus), UAH million
1995	3600	2010	64265.5
1996	4000	2011	23557.6
1997	6200	2012	53445.2
1998	2300	2013	64707.6
1999	1900	2014	78052.8
2000	-1000	2015	45167.5
2001	600	2016	70130.2
2002	-1600	2017	47849.6
2003	500	2018	59247.9
2004	11000	2019	78049.5
2005	7800	2020	217096.1
2006	3700	2021	197937.4
2007	4767	2022	914701.7
2008	12500.7	2023	1330000
2009	35517.2	2024 (plan)	1572000

Source: Calculated by the authors based on indicators of the State budget execution of Ukraine (2023)
Smoothed series data and forecast data are shown in Table 2.

Table 2: Smoothed a series of budget deficit

Case	Exponential smoothing: S0=164E3 (3_1) No trend, no season; Alpha = ,800		
	Budget deficit	Smoothed series	Resids
1	3600	163600	-160000
2	4000	35600	-31600
3	6200	10320	-4120
4	2300	7024	- 4724
5	1900	3245	-1345
6	-1000	2169	-3169
7	600	-366	966
8	-1600	407	-2007
9	500	-1199	1699
10	11000	160	10840
11	7800	8832	-1032
12	3700	8006	-4306
13	4767	4561	206
14	12501	4726	7775
15	35517	10946	24571
16	64266	30603	33663
17	23558	57533	-33975
18	53445	30353	23093
19	64708	48827	15881
20	78053	61531	16521
21	45168	74749	-29581
22	70130	51084	19046
23	47850	66321	-1847
24	59248	51544	7704
25	78050	57707	20342
26	217096	73981	143115
27	197937	188473	9464
28	914702	196045	718657
29	1330000	770970	559030
30	1572000	1218194	353806
31		1501239	
32		1501239	
33		1501239	
34		1501239	
35		1501239	
36		1501239	
37		1501239	
38		1501239	
39		1501239	

Source: Calculated by the authors based on statistical data

According to the forecast (levels of rows 31-39), Ukraine's budget deficit will increase, all other things being equal (Figure 1).

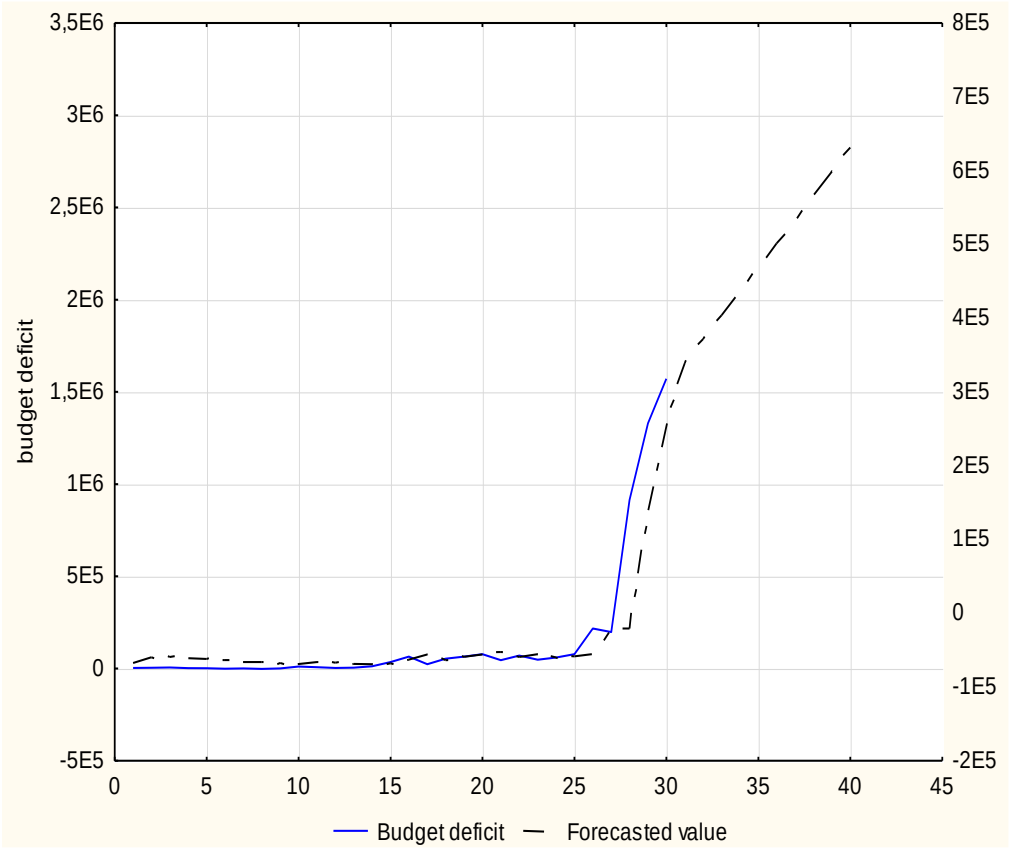

Figure 1. Dynamics and forecast of Ukraine's budget deficit
Source: Built by the authors based on statistical data

To determine the growth rate of the budget deficit, we propose using the fundamental concept of classical mechanics and economic - acceleration. This conceptual approach views budgetary processes through the lens of dynamic systems, combining economic analysis with mathematical modelling, particularly in the context of econophysics, an interdisciplinary research field that applies theories and methods developed by physicists to solve economic problems, typically those involving uncertainty or stochastic elements and nonlinear dynamics. Modern econophysics, a fast expanding field, suggests using approaches from statistical physics, physics of complex systems, and network science to macroeconomic modelling, financial market analysis, and social concerns (Ayoama et al., 2017). Indeed, an extended contemporary definition of econophysics defines this new science as an interdisciplinary research field that applies physicist-developed theories and methods to solve economic problems involving uncertainty or stochastic elements, as well as nonlinear dynamics. Its application to the study of financial markets is often known as statistical finance, owing to its roots in statistical physics (Richmond et al., 2013).

The forecasting mechanism is based on the analogy between physical motion and economic transformations. Just as in physics, one can predict the trajectory of a body's movement by having initial parameters and a quantitative estimate of acceleration, in economic research, one can predict the dynamics of the budget deficit. This method is described in several works, particularly in Vitlinsky & Makhanets (2011).

Acceleration is considered a quantitative characteristic of the change in the speed of economic processes per unit of time. Mathematically, it is the second derivative of coordinates or the first derivative of velocity. This approach allows for the consideration of the dynamic budget deficit not as a static value but as a dynamic system with its development parameters.

First, let us plot the trend of the budget deficit. To do this, we will use the SPSS programme to fit the curve. Possible curves describing the trend of the budget deficit are shown in Figure 2.

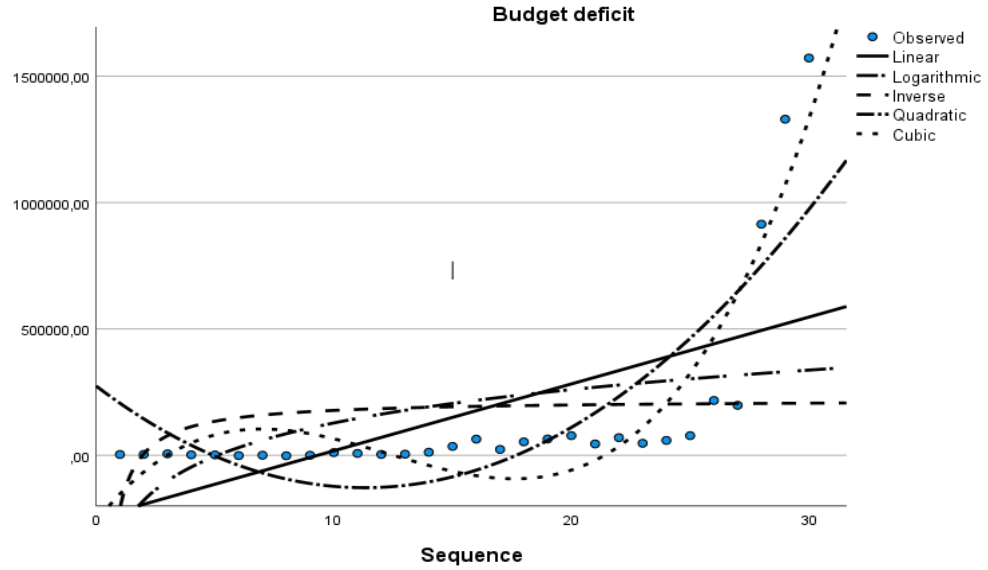

Figure 2. Selection of the curve
Source: Built by the authors based on statistical data
The parameters of the curves are shown in Table 3.

Table 3: Curve parameters

	Model Summary					Parameter Estimates			
Equation	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	,358	15,582	1	28	,000	-246411,572	26452,346		
Logarithmic	,173	5,854	1	28	,022	-310294,177	190425,323		
Inverse	,045	1,330	1	28	,259	220820,823	-429696,301		
Quadratic	,660	26,241	2	27	,000	274310,559	-71183,054	3149,529	
Cubic	,848	48,321	3	26	,000	-261898,435	120820,912	-12083,681	327,596

Source: Built by the authors based on statistical data

According to the research, the trend of the budget deficit is best described by a polynomial of degree 3:

$$D = -261898,435 + 120820,912t - 12083,681t^2 + 327,596t^3, \quad (3)$$

where t is the period number.

The following formula can describe the rate of increase in the budget deficit

$$V_D = 120820,912 - 24167,36t + 982,788t^2, \quad (4)$$

and acceleration

$$a_D = -24167,36 + 1965,576t. \quad (5)$$

Accordingly, the budget deficit of Ukraine in 2025 should increase by UAH 36765.31 million.

In summary, forecasting Ukraine's budget deficit is a complex, multidimensional process that must be approached comprehensively, considering a wide range of internal and external factors and adapting to changing economic conditions.

The study's findings show a slow and constant upward trend in the budget deficit, which is validated by the exponential smoothing technique and the third-degree polynomial model. Especially relevant is a marker identified that shows this trend of increasing deficit growth, which reflects a possible deficit increase of UAH 36765.31 million in 2025.

Using the combined exponential smoothing and acceleration analysis model, we have obtained the most complete picture of budget deficit dynamics. This is especially critical in designing appropriate fiscal policy responses and managing public finance.

Given that the trends have been worrisome since October 2023 regarding how the growing deficit affects the foreign economic activity of business entities, the expected widening of the deficit may heighten pressure on the exchange rate and complicate access to credit. There are also risks of the country's declining investment attractiveness and a potential rise in fiscal pressure on business.

5. Conclusion

From the study findings, the proposed forecasting methodology, which is based on the combination of exponential smoothing and acceleration analysis, is highly effective in modelling the dynamics of the budget deficit in light of the given country's specifics. The forecast calculations show a clear upward trend in the budget deficit, corroborated by a third-degree polynomial that fits very well. Thus, there is a noticeable acceleration of the deficit's growth, posing additional risks to financial stability and foreign economic activity. The influence of the budget deficit on foreign economic activity is multidimensional. It is manifested through several channels of transmission between the budget deficit and foreign economic activity.

To reduce the adverse effects of the increasing budget deficit, a national strategy for managing the budget deficit and an alarm system for critical deficit thresholds should be implemented. Sources of deficit financing should be diversified, and the coordination between fiscal and monetary policies should be reinforced.

Additional studies should aim to create tools for evaluating the influence of geopolitical trends on budget deficit dynamics and enhance forecasting techniques in an

environment of considerable uncertainty. Geopolitical risk has not unexpectedly received fresh attention in recent years. Geopolitical risk, unlike other categories of risk (such as credit risk), is multifaceted and not clearly measurable since it is caused by a complex web of interwoven political, economic, and social elements that span borders and sectors. When geopolitical risk materializes in its most extreme form (war), it can result in company defaults, the destruction of tangible assets, and human casualties, all of which can cause significant financial losses. Less severe occurrences, though, may also have an impact on the budget. For instance, geopolitical risk events have the potential to raise the price of energy and oil, which would raise interest rates and inflation while decreasing economic activity. Furthermore, significant disruptions to global commerce brought on by conflicts or growing political division in an area might lower stock market values and significantly lower the potential GDP. Financial stability concerns may arise as a result of such changes, or they may exacerbate already-existing vulnerabilities. Thus, the current high level of geopolitical risk has important ramifications for fiscal and macroprudential policy as well as financial stability. In light of this, multidisciplinary adaptable multi-tool models that can account for all the intricacies of the modern interweaving of geopolitical and economic realities and security paradigm landscapes are required.

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