# When the guns roar: how the war, reserves and exports shape Ukraine's cost of external borrowing

SERGII SHELUDKO, Ph.D.*

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Sergii SHELUDKO
State Tax University, 31 Universytetska St., Irpin, 08205, Kyiv region, Ukraine
e-mail: s.szeludko@gmail.com
ORCiD: 0000-0003-0636-4940

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PUBLIC SECTOR ECONOMICS
50 (1) 95–115 (2026)



**Abstract**

*This study examines factors shaping Ukraine's cost of external borrowing amid the 2022 Russian invasion. It focuses on the impact of the intensity of military activities, the size of central bank reserve assets, and the volume of grain and oilseed exports on sovereign bond spreads. Estimates from an ARDL model with data from September 2021 to July 2024 suggest a stable long-term relationship between the spreads, military activities and reserve assets, with escalating military actions widening the spreads and larger reserves narrowing them. The effects of exports on the spreads are not statistically significant, probably reflecting the difficulty to transport large quantities of grain and oilseeds in wartime conditions. The findings underscore the role of monetary policy in managing the cost of external borrowing, and the importance of foreign exchange reserves in mitigating sovereign debt and foreign exchange market risks in wartime conditions.*

*Keywords: external borrowing, sovereign spreads, war, international reserves, commodity exports*

## 1 INTRODUCTION

Maintaining sufficient international liquidity is one of the core responsibilities of the central bank, especially under conditions of global financial fragmentation. By securing foreign exchange for vital imports and external debt obligations, monetary authorities of small open economies ensure sovereign creditworthiness and sustain confidence in domestic price and financial stability. These tasks become critical during crises of non-economic origin such as the Covid pandemic and Russia's full-scale invasion of Ukraine. Such shocks, combined with unpredictable market reactions, create serious challenges for monetary policy and may undermine the confidence of foreign creditors if not effectively addressed. Improving the effectiveness of monetary response requires, in turn, a deeper analysis of its potential influence on external borrowing costs during extraordinary events.

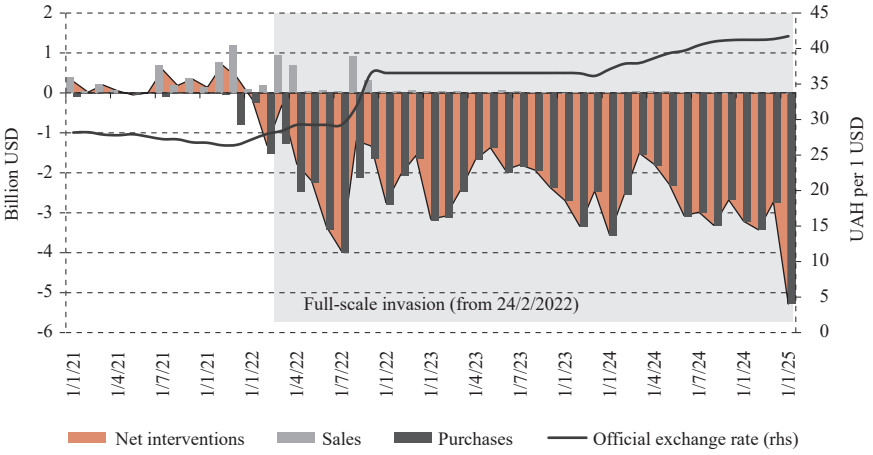
The motivation for this study stems from the need to address a key question that Russia's unprovoked military aggression against Ukraine has raised for the National Bank of Ukraine (NBU): does the central bank of a country subjected to regular attacks and partial occupation retain some degree of control over its cost of external borrowing? A clear challenge in pursuing this inquiry lies in the limited availability of empirical data and the frequency of certain variables relative to the duration of the military conflict. By utilising the maximum feasible sample, the paper nevertheless derives sufficiently reliable conclusions.

Before the full-scale invasion, Ukraine operated under an inflation-targeting framework, which was adopted in 2016. Price stability was the declared primary goal, with the policy rate as the main instrument. The hryvnia was managed under a flexible exchange rate regime. The NBU intervened occasionally to smooth volatility rather than to defend a certain level of the exchange rate. Reserves were accumulated through market purchases, external borrowing, multilateral loans, and strong export revenues from agricultural products and metals.

As can be seen in graph 1, with the war starting in February 2022, the framework was swiftly adjusted. The hryvnia was pegged to the US dollar at UAH 29.25/USD in late February to prevent capital flight and stabilise expectations. FX interventions became large and regular, but reserves increased markedly, primarily due to large-scale official external financing from international partners. At the same time, strict capital controls and cash market restrictions significantly curtailed private demand for foreign currency. As a result, foreign currency inflows systematically exceeded the amounts required to support the peg, allowing the NBU to accumulate reserves despite depreciation pressures.

**Graph 1**

*Foreign exchange interventions and official exchange rate, 2021-24*




*Source: National Bank of Ukraine (2025).*

Already by the summer of 2022, four months after the beginning of the Russian invasion, the NBU emphasised its strategic commitment to a gradual return to pre-war flexible exchange rate and inflation targeting policies. However, the continuation of hostilities and absence of progress on peace initiatives demonstrated that the wartime shocks were more persistent than initially expected. As a result, the NBU was forced to partially revert to ultra-tight monetary policy: the policy rate was raised to 25% in June 2022 and a wide set of capital and currency restrictions was prolonged. In these conditions, the cost of domestic government borrowing converged closely to Ukraine's sovereign eurobond yields. Thus, while the formal inflation-targeting regime was preserved, the war environment changed its operation fundamentally, with foreign exchange reserves turning into the principal buffer for exchange rate stability and investor confidence.

Against this backdrop, the paper investigates the short- and long-term effects of military actions, developments in NBU reserve assets, and the exports of Ukraine's primary products – grains and oilseeds – on the cost of external borrowing, as measured by the spread on Ukraine's long-term sovereign eurobonds. It finds a

positive long-run cointegration relationship between the spreads and intensified military actions, and a negative one between the spreads and reserve assets. However, no significant long-term cointegration relationship between the spreads and the volume of Ukraine's agricultural commodity exports could be established. The paper contributes to the literature on monetary and exchange rate policy in emerging market economies by analysing the adjustment of Ukraine's policy framework following the full-scale invasion. It relates to studies on the cost of external borrowing and FX interventions in emerging markets, as well as to the growing literature on macroeconomic policy under extreme shocks. The main contribution lies in the documentation and interpretation of the interaction between the intensity of military events, commodity exports, and reserve dynamics in a wartime setting characterised by severe capital controls and large official external inflows. Using a detailed dataset on FX operations and policy instruments compiled from official sources, the paper shows how the National Bank of Ukraine was able to stabilise expectations on external markets for its sovereign debt. By focusing on the mechanics of policy implementation rather than model-based counterfactuals, the analysis provides policy-relevant insights into the functioning of monetary and exchange rate policy under conditions that fall outside standard crisis episodes studied in the existing literature.

Existing studies have largely overlooked the influence of international reserves on sovereign bond spreads in a country experiencing active wartime conflict. This paper addresses that gap and offers novel insights into the FX market and sovereign debt dynamics of a major food commodity exporter navigating an unprecedented war environment. It examines the combined influence of the intensity of military actions, the volume of international reserves, and the dynamics of food commodity exports on external markets' perception of Ukraine's sovereign risk. A quantitative analysis of the relationship among these variables in the short- and long-term also sheds light on the effectiveness of the central bank's efforts to maintain the cost of external borrowing under control in conditions of escalating physical attacks and disruptions to commodity export logistics. Another contribution of the paper is the use of an ARDL model to test several hypotheses related to the main research question. One advantage of this approach is that it can yield reliable results despite limited sample size.

The remainder of the paper is structured as follows. Section 2 reviews the relevant literature. Section 3 describes the dataset and the methodological framework. Section 4 presents key estimation and diagnostic test results. Section 5 interprets the findings and relates them to previous empirical findings. Section 6 concludes.

## 2 LITERATURE REVIEW

The literature that comes closest to the subject matter of this study is the one that investigates the role of central bank reserves on a country's financial stability during crises (e.g. Lowe, 2018). Since the 1990s, emerging markets have built sizable reserves to guard against capital flow reversals and debt rollover risks.

Higher reserves are shown to reduce sovereign spreads, thereby lowering default risk and borrowing costs, although this effect weakens beyond a threshold of around 15% of GDP and is less evident in smaller economies. Fatum, Hattori and Yamamoto (2023), for example, analyse China's reserve accumulation and its unintended effects on private sector risk-taking, using CDS spreads and stock indices as proxies. They find evidence that during upswings higher reserves act as implicit insurance and correlate with increased risk appetite, thus potentially leading to moral hazard. In crisis periods, on the other hand, high reserves may strengthen the precautionary saving motive and thereby weaken the effectiveness of expansionary monetary and fiscal policies. This finding parallels Lowe's (2018) concerns about diminishing returns to reserves accumulation.

The empirical link between larger foreign exchange reserves and the lower likelihood of sovereign debt crises was also established by Hernández (2018) and Yeyati and Gómez (2019). Yeyati and Gómez (2019) and Sosa-Padilla and Sturzenegger (2023) also argued that the impact of reserves on sovereign spreads depended on how the reserves were financed: reserves backed by domestic, income-linked debt reduced default risk, while those based on external borrowing had little or even negative effect on the spreads. Kartal et al. (2023) confirmed a number of intuitively appealing bidirectional relationships: higher reserves strengthened the exchange rate, this in turn helped narrow the sovereign CDS spreads, and lower spreads facilitated additional reserves accumulation. Similarly, Tüysüz and Gül (2024) confirmed that lower bond yields and a stronger domestic currency helped narrow the CDS spreads, and Aizenman and Jinjarak (2020) argued that reserve dynamics explained much of the variation in sovereign spreads and exchange rates.

The financial impact of Russia's full-scale invasion of Ukraine has also attracted some attention in the empirical literature. Nagy and Neszveda (2025) demonstrated that, in wartime, CDS markets were the earliest indicator of sovereign vulnerability, with spreads widening at least two weeks before the stock market began to drop. Shen, Feng and Sun (2024) documented how the war in Ukraine amplified global sovereign debt risks. Assaf, Gupta and Kumar (2023) further showed that active hostilities in Ukraine unevenly affected stock prices, with net exporters in the region suffering the heaviest losses.

In terms of empirical methodology, the studies that come closest to the research question in this paper are Zhou (2021), who applied linear and nonlinear ARDL to assess the effects of macroeconomic performance on South Africa's long-term bond yield, and Sunal and Yağcı (2024), who showed that the volatility of Turkey's CDS spreads depended on the exchange rate, oil prices, and stock prices in the long term, while short-term variation is driven by lagged U.S. Treasury yields and COVID-19 dynamics.

## 3 DATA AND METHODOLOGY

For the purposes of this study, the cost of Ukraine's external borrowing is defined as:

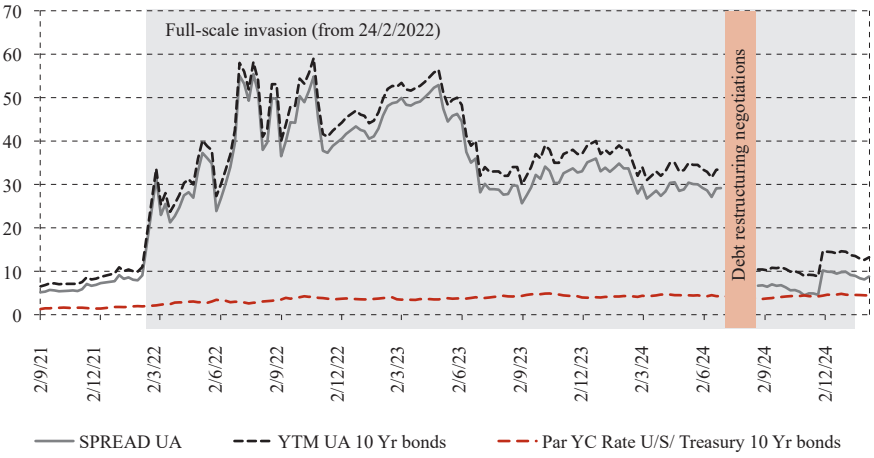
$$SPREAD^{t}_{UA} = Y^{t}_{UA\,10\,Yr\ bonds} - Y^{t}_{U.S.\ Treasury\,10\,Yr\ bonds} \quad (1)$$

where $SPREAD^{t}_{UA}$ is the spread on Ukraine's 10-year sovereign bonds at time $t$; $Y^{t}_{UA\ 10\ Yr\ bonds}$ is the interest rate on Ukraine's 10-year sovereign bonds denominated in USD at time $t$; and $Y^{t}_{U.S.\ Treasury\ 10\ Yr\ bonds}$ is the interest rate on 10-year US Treasury bonds at time $t$.

The 10-year bonds were chosen because they are the longest-maturity Ukrainian securities traded abroad. CDS spreads, often used in similar studies, were not used because the data after September 2022 are unreliable. US Treasury par yield-curve rates are assumed equivalent to yields to maturity.

**GRAPH 2**

*Sovereign bond spread of Ukraine and its components, Sep 2021 – Feb 2025 (in %)*




*Sources: US Department of the Treasury (2025); Eavex Capital (2025); author's calculations.*

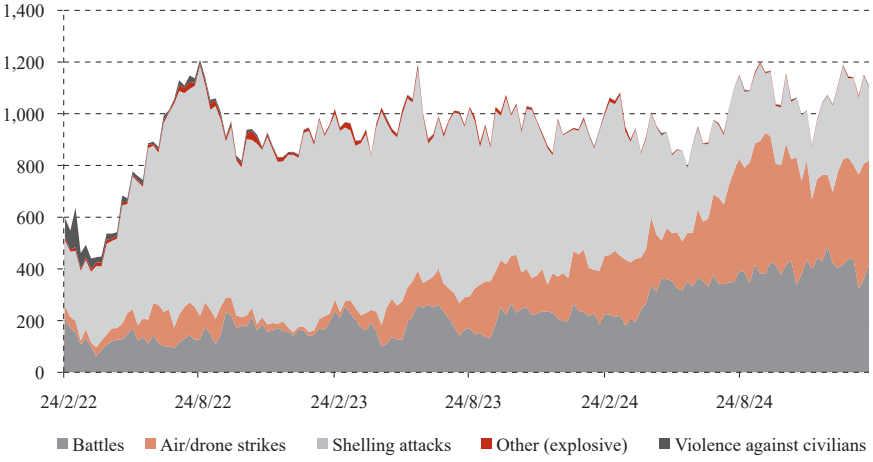
Graph 2 shows a sharp rise in Ukraine's 10-year sovereign bond yield to maturity (YTM) and spread since the full-scale invasion began, with notable volatility. A data gap in July – August 2024 reflects debt restructuring negotiations with international creditors, resulting in a new 10-year bond with a coupon rate reduced to 1.75% (from 7.38%), lowering the YTM proportionally. The data series interruption and YTM availability from September 2021 limit the sample to September 2021 – July 2024.

The explanatory variables were selected to represent the influence of military actions, measures taken by the central bank, and economic opportunities to replenishing foreign currency reserves. When accounting for the impact of military events, the objectivity of observations is critical. Given the sample's time frame and data frequency, the regularly updated Armed Conflict Location and Event Data (ACLED)

Ukraine Conflict Monitor was chosen as the indicator of the intensity of military actions. Military events in this database are shown on a weekly basis, from Saturday to the Friday of the preceding week, and classified into five categories: battles, air/drone strikes, shelling attacks, other (explosive) attacks, and violence against civilians (graph 3). Most prevalent in the first year were shelling attacks. Starting in the summer of 2023, air/drone strikes became increasingly prominent, reaching their highest relative share by the fall of 2024. Battles followed a nearly identical pattern from May 2024 through the end of the observation period. The two remaining categories were measured on a significantly smaller scale.

**Graph 3**

*Dynamics of military events in Ukraine, Feb 2022 – Feb 2025 (number of events)*




*Source: ACLED (2025).*

The paper uses the number of violent events rather than fatalities (or other metrics) as the core measure of war intensity because it is very difficult to estimate reliably the number of deaths amid ongoing hostilities. ACLED (2025) defines an "event" as a discrete instance of military violence occurring at a specific location on a given day as reported in military statements, media, and other monitoring sources. When aggregating for intensity analysis, ACLED (2025) recommends focusing on event volumes over time and space, as this provides a more consistent proxy for conflict dynamics and allows cross-event type comparisons (e.g. frontline escalations). A cumulative indicator of intensity of military conflict was calculated as a simple sum of reported military events:

$$W_t = \sum_{a \in A} a_t, A = \{B, D, S, X, V\} \quad (2)$$

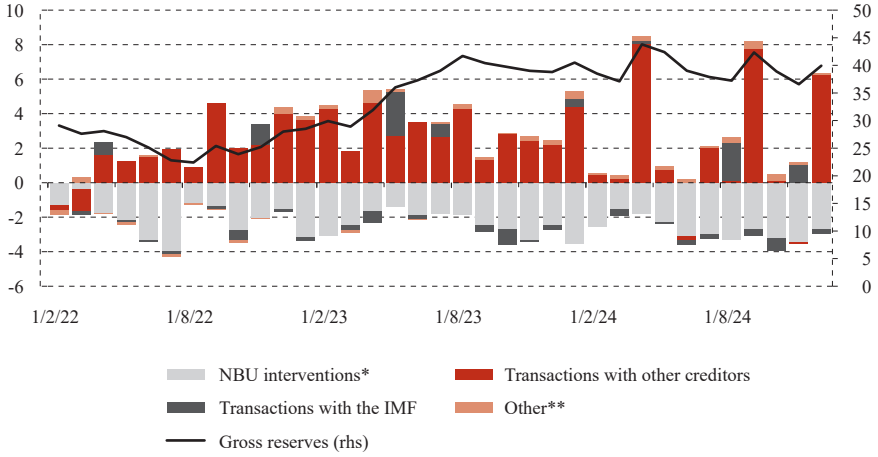
where $A$ is the set of indicators for the number of military events (battles, air/drone strikes shelling attacks, other (explosive) attacks and violence against civilians); $W_t$ is the total number of military events at time $t$; and $a_t$ is the number of specific military events at time $t$.

PUBLIC SECTOR ECONOMICS
50 (1) 95-115 (2026)



**Graph 4**

*NBU gross reserve assets, Jan 2022 – Nov 2024 (billion USD)*




** (+) refers to FX purchases to increase reserves; (-) refers to FX sales from reserves.*
*** Revaluation of financial instruments due to changes in their market value and exchange rate fluctuations, and other transactions.*

*Source: National Bank of Ukraine (2025).*

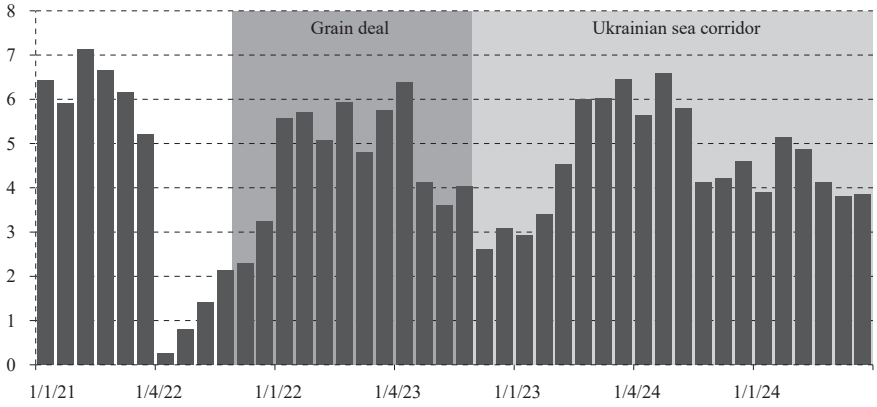
Central bank efforts to manage the cost of external borrowing are measured by the volume of its gross reserve assets (foreign exchange reserves). While net reserves could offer a more precise measure of international liquidity, the distinction between gross and net reserves is less clear under wartime conditions. A significant portion of Ukraine's external financing, formally recorded as loans, is concessional, subject to restructuring, or expected to be repaid from external sources (e.g., revenues from frozen Russian assets). These liabilities exert less market pressure on sovereign bond spreads than conventional foreign debt held by the central bank, so market participants primarily focus on gross reserves as the key liquidity buffer.

The NBU publishes data on reserves and their composition at the beginning of each month. Reserves were rising with minor interruptions from August 2022. The main contribution came from transactions with other creditors (excluding the IMF), essentially external financial assistance in the form of loans and grants, and net interventions by the NBU, which were negative throughout the period. Transactions with the IMF – both in terms of financing inflows and outflows – occasionally had a noticeable (but not decisive) influence on reserves.

Following Kovalenko et al. (2024), foreign currency inflows to Ukraine's domestic market are measured by the physical volume of grain and oilseed exports. Russia's military actions in the Black Sea disrupted export flows, redirecting logistics and intermittently halting maritime routes. Graph 5 shows a sharp decline in export volumes from March to July 2022 due to threats to civilian vessels, with sea routes previously handling 95-97% of exports. Partial restoration via the so-called Grain deal and, from August 2023, the Ukrainian sea corridor, stabilised export volumes.

**Graph 5**

*Grain and oilseed exports, Sep 2021 – Feb 2025 (in million metric tons)*




*Sources: FAO (2022); Centre for Economic Strategy (2025).*

As data on gross reserves and grain and oilseed exports are monthly, data on sovereign spreads and military events had to be transformed from weekly to monthly frequency. For spreads, the following transformation was used:

$$SPREAD^{m}_{UA} = \frac{1}{W}\sum_{t=1}^{W} SPREAD^{t}_{UA} \quad (3)$$

where $SPREAD^{m}_{UA}$ is the average monthly spread on Ukraine's 10-year sovereign bonds in month $m$; $W$ is number of weeks in a month; $t$ is the week within a month; and $SPREAD^{t}_{UA}$ is the spread on Ukraine's 10-year sovereign bonds for week $t$. Military events were also aggregated into monthly frequency using formula (2). Aggregating weekly observations on spreads and military actions into monthly frequency smooths out short-term fluctuations in these data, but so does transforming monthly data on reserves and export volumes into weekly frequency, so it is hard to argue that the latter would have been preferable.

**Table 1**

*Descriptive statistics for variables, monthly averages, September 2021 – July 2024*

| | SPREAD[1] | WAREV[2] | GRES[3] | AGRXP[4] |
|---|---|---|---|---|
| Mean | 3,132 | 3,271 | 32.915 | 4.573 |
| Median | 3,166 | 3,783 | 30.941 | 5.080 |
| Maximum | 4,965 | 5,000 | 43.767 | 7.120 |
| Minimum | 526 | 0 | 22.387 | 0.270 |
| Std. dev. | 1,361 | 1,590 | 6.400 | 1.798 |
| Skewness | -0.616 | -1.221 | 0.024 | -0.701 |
| Kurtosis | 2.501 | 3.107 | 1.605 | 2.554 |
| Jarque-Bera p-value | 0.276 | 0.013 | 0.242 | 0.207 |
| Observations | 35 | 35 | 35 | 35 |

[1] Spread on Ukraine's 10-year sovereign bonds in USD, in basis points.
[2] Number of military events.
[3] Gross reserve assets of the NBU, in billions of USD.
[4] Volume of grain and oilseed exports, in millions of metric tons.

*Source: Author's calculations.*

PUBLIC SECTOR ECONOMICS
50 (1) 95-115 (2026)



Descriptive statistics for the variables are presented in table 1. Reserve assets are closest to normal distribution, with skewness near zero, kurtosis below 3, and the Jarque-Bera statistic indicating approximate normality. Bond spreads and grain/oilseed exports display mild negative skewness and flatter-than-normal tails, yet still pass the normality test. The number of military events stands out for strong negative skewness with the Jarque-Bera statistic indicating a non-normal distribution, which is considered in diagnostics. The high mean and median values of sovereign spreads are consistent with market conditions in the aftermath of the invasion of Ukraine – market yields on 10-year Ukrainian sovereign bonds reached 40-60% (graph 2). For one-, three- and five-year bonds, yields exceeded 100% in some cases (Eavex Capital, 2025).

**Table 2**
*Correlation matrix of variables*

| | SPREAD | WAREV | GRES | AGRXP |
|---|---|---|---|---|
| SPREAD | – | 0.840 | 0.004 | -0.206 |
| WAREV | 0.840 | – | 0.352 | -0.258 |
| GRES | 0.004 | 0.352 | – | 0.170 |
| AGRXP | -0.206 | -0.258 | 0.170 | – |

*Source: Author's calculations.*

Table 2 assesses the degree of linear dependence among variables. There is a strong positive relationship between sovereign spreads and military events, suggesting a high sensitivity in external markets to the progression of hostilities. Correlation between the spreads and gross international reserves is close to zero, which is surprising in view of the empirical findings discussed above. Correlation between the spreads and grain/oilseed exports is weakly negative, consistent with expectations. Correlations among independent variables are moderate – the highest correlation coefficient of 0.35 is between reserves and military actions – suggesting that multicollinearity is unlikely to be a major modelling issue.

**Table 3**
*Augmented Dickey-Fuller test statistics*

| | Test for unit root in: | | | | Exogenous | |
|---|---|---|---|---|---|---|
| | Level | | 1st difference | | Constant | Linear trend |
| | t-stat. | Prob. | t-stat. | Prob. | | |
| SPREAD | -1.435 | 0.832 | -6.355 | 0.000 | + | + |
| WAREV | -1.764 | 0.700 | -7.875 | 0.000 | + | + |
| GRES | -1.606 | 0.769 | -5.032 | 0.001 | + | + |
| AGRXP | -2.303 | 0.177 | -5.332 | 0.000 | + | |

*Source: Author's calculations.*

PUBLIC SECTOR ECONOMICS
50 (1) 95-115 (2026)



Table 3 presents stationarity test statistics. All variables have a unit root in levels but become stationary in first differences. This suggests that an autoregressive distributed lag (ARDL) model is appropriate to estimate the relationship between sovereign bond spreads and three explanatory variables, and that there is a potential cointegrating relationship among them.

Table 4 summarises the characteristics of model variables.

**Table 4**
*Characteristics of model variables*

| | Indicator | Units | Order of integration | Expected coefficient sign | Data source |
|---|---|---|---|---|---|
| SPREAD | Spread on Ukrainian sovereign 10-year bonds in USD | Basis points | I(1) | NA | US Department of the Treasury (2025); Eavex Capital (2025) |
| WAREV | Number of military events | Thousand events | I(1) | + | Armed Conflict Location and Event Data (2025) |
| GRES | Gross reserve assets of NBU | Billion USD | I(1) | - | National Bank of Ukraine (2025) |
| AGRXP | Volume of Ukrainian grain and oilseed exports | Million metric tons | I(1) | - | FAO (2022); Centre for Economic Strategy (2025) |

*Source: Author's calculations.*

The ARDL model for this study is specified as follows:

$$SPREAD_t = \alpha + \sum_{i=1}^{p} \beta_i SPREAD_{t-i} + \sum_{j=0}^{q_1} \gamma_{1,j} WAREV_{t-j} + \sum_{j=0}^{q_2} \gamma_{2,j} GRES_{t-j} + \sum_{j=0}^{q_3} \gamma_{3,j} AGRXP_{t-j} + \epsilon_t \quad (4)$$

where $\alpha$ is a constant; $p$ is the number of lags $i=1,...p$ of the dependent variable; $j$ is the number of lags for independent variables, $j=1,...,q_k$; and $\epsilon_t$ is the random error term.

One advantage of using ARDL is its ability to produce reliable estimates despite a limited sample size, which here includes only 35 observations. According to Nkoro and Uko (2016), the error correction representation of the model becomes relatively more efficient with small or finite sample sizes when there is a long-term relationship between variables. The critical values for the bounds test calculated by Narayan (2005) for sample sizes ranging from 30 to 80 observations are used, as traditional critical values are typically derived for larger samples. The model is estimated with the EViews 13 package, but cointegration test results are interpreted manually rather than relying on the software's built-in critical value statistics for the bounds test.

## 4 ESTIMATION RESULTS

Estimation of the linear ARDL model was conducted with an unrestricted constant and no trend. During the automatic selection based on the Akaike information criterion, this limited the maximum number of lags for the dependent variable and regressors to three. After a preliminary evaluation of 192 variants (table A2), an ARDL(1,0,0,1) model was selected. Based on equation (4), this model can be expressed as follows:

$$SPREAD_t = \alpha + \beta_1 SPREAD_{t-1} + \gamma_{1,0} WAREV_t + \gamma_{2,0} GRES_t + \gamma_{3,0} AGRXP_t + \gamma_{3,1} AGRXP_{t-1} \quad (5)$$

The model was estimated using data from October 2021 to July 2024 (34 observations). Most coefficient estimates are statistically significant at the 1% level and have the expected sign (table 5). The exception is the coefficient on the volume of exports, which is negative and insignificant (current value) or significant only at the 10% level (lagged value).

**Table 5**

*Estimates of ARDL (1,0,0,1) model*[1]

| Coefficient | Estimated value | Standard error | t-statistic | Probability |
|---|---|---|---|---|
| $\alpha$ | 1,762.5 | 419.7 | 4.200 | 0.000 |
| $\beta_1$ | 0.6 | 0.1 | 6.038 | 0.000 |
| $\gamma_{1,0}$ | 348.1 | 103.4 | 3.368 | 0.002 |
| $\gamma_{2,0}$ | -55.2 | 13.8 | -4.005 | 0.000 |
| $\gamma_{3,0}$ | -85.6 | 62.7 | -1.365 | 0.183 |
| $\gamma_{3,1}$ | 121.5 | 63.4 | 1.917 | 0.065 |

[1] *Adj. R2 = 0.899, standard error of regression = 414.8, F-statistic = 59.452 (p = 0.000), Durbin-Watson statistic = 2.355.*

*Source: Author's estimates.*

Table 6 presents cointegration test results.

**Table 6**

*Bounds test statistic values for ARDL (1,0,0,1) model*

| Test statistic | Value | Sample size | Narayan (2005) critical values (case 3, k=3) | | Probability (%) |
|---|---|---|---|---|---|
| | | | I(0) | I(1) | |
| F-statistic | 6.381 | 30 | 5.333 | 7.063 | 1 |
| | | 35 | 5.198 | 6.845 | |
| | | 30 | 3.710 | 5.018 | 5 |
| | | 35 | 3.615 | 4.913 | |
| | | 30 | 3.008 | 4.150 | 10 |
| | | 35 | 2.958 | 4.100 | |

*Source: Author's estimates.*

PUBLIC SECTOR ECONOMICS
50 (1) 95–115 (2026)



The bounds test refers to a model with three cointegrating variables (k=3) and an unrestricted constant (so-called case 3). The F-statistic of 6.381 exceeds the I(1) critical value at the 5% significance level for a sample of 35 observations, as per Narayan (2005). The t-statistic calculated from the same test, at -3.796, also suggests rejecting the null hypothesis at the 5% level. This provides sufficient evidence to indicate the existence a long-term cointegrating relationship among the model's variables.

Diagnostics of residuals indicates no potential issues with autocorrelation, heteroscedasticity, or assumed normal distribution of regression residuals (table 7). Likewise, multicollinearity tests using variance inflation factors (VIF) indicate that multicollinearity does not significantly affect the estimates: the centred VIF values range from 1.519 (GRES) to 4.654 (WAREV), well below the critical threshold of 10.

**Table 7**

*Diagnostics of residuals for ARDL (1,0,0,1) model*

| Test | Statistic value | p-value | Interpretation |
|---|---|---|---|
| Breusch-Godfrey (LM) | F = 0.810 | 0.456 | No autocorrelation |
| White (cross terms incl.) | F = 1.667 | 0.174 | No heteroscedasticity |
| Skewness | -0.112 | NA | Weak negative |
| Kurtosis | 2.752 | NA | Slightly below normal |
| Jarque-Bera | 0.158 | 0.924 | Normal residuals |

*Source: Author's estimates.*

The cumulative sum of standardised residuals remained within the critical bounds at the 5% significance level, indicating the absence of structural breaks in model parameters. The cumulative sum of squares test also indicated the stability of the residual variance. Finally, the validity of the linear model was checked with the Ramsey regression equation specification error test: the F-statistic value was 0.540 with a p-value of 0.469, ruling out the presence of omitted nonlinear effects. The model was next estimated in conditional error correction form to assess the short- and long-term dynamics of model variables. The error correction coefficient SPREAD(-1) is negative and statistically significant at the 1% level, indicating the very quick adjustment of spreads to deviations from the long-term equilibrium (table 8). The immediate effects of war events (WAREV) and the size of NBU's reserves (GRES) are also statistically significant and have the expected signs. The estimated effects of grain and oilseed exports (AGRXP) exhibit alternating signs and lack statistical significance. However, this does not affect the overall significance of the error correction model, as the F-statistic value is 6.076 (p = 0.001), and the R-squared is 0.52.

**Table 8**

*Conditional error correction model for ARDL (1,0,0,1)*

| Variable | Coefficient | Standard error | t-statistic | Probability |
|---|---|---|---|---|
| SPREAD(-1) | -0.4 | 0.1 | -3.796 | 0.001 |
| WAREV | 348.1 | 103.4 | 3.368 | 0.002 |
| GRES | -55.2 | 13.8 | -4.005 | 0.000 |
| AGRXP(-1) | 35.9 | 50.1 | 0.717 | 0.479 |
| D(AGRXP) | -85.6 | 62.7 | -1.365 | 0.183 |
| C | 1,762.5 | 419.7 | 4.200 | 0.000 |

*Note: SPREAD(-1) reflects the speed of error correction.*

*Source: Author's estimates.*

Table 9 shows the long-term coefficients of the cointegrating equation, normalised with respect to the dependent variable. The coefficients on war events and gross reserves are large and statistically significant at the 1% significance level, while the one on grain and oilseed exports is not statistically significant and has the wrong sign.

**Table 9**

*Long-term cointegrating coefficients for ARDL (1,0,0,1) model*

| Variable | Coefficient | Standard error | t-statistic | Probability |
|---|---|---|---|---|
| WAREV | 901.9 | 146.1 | 6.172 | 0.000 |
| GRES | -143.1 | 41.9 | -3.413 | 0.002 |
| AGRXP | 93.1 | 124.8 | 0.746 | 0.461 |

*Note: Coefficients derived from the CEC regression.*

*Source: Author's estimates.*

Given the unique context of a wartime economy, this analysis applied to a relatively short period following the significant structural break caused by the onset of the war. Extending the sample to a pre-war period was not feasible, so the analysis effectively tested a "war cointegration" rather than conventional long-run cointegration. Nevertheless, the estimates and test results seem to be sufficiently reliable to allow their economic interpretation.

## 5 DISCUSSION

Evidence of strong cointegration between Ukraine's sovereign spreads, war events and NBU foreign reserves suggests that, despite Russia's full-scale invasion, the NBU retained some control over the country's external borrowing costs even in the most precarious wartime conditions.

Military events intensity exerts a lasting impact on Ukraine's sovereign spreads: the estimated coefficient indicates that each thousand military events add nearly 902 bps (≈9%) to the spread. This strong effect reflects the impact that destruction of infrastructure and of trade routes, among other consequences of the invasion, have on investor confidence in Ukraine's USD-denominated debt.

PUBLIC SECTOR ECONOMICS
50 (1) 95–115 (2026)



The size of the central bank's foreign reserves helps significantly narrow the spreads in both short and long term: each additional $1 billion in reserves lowers borrowing costs by 143 basis points. Reserves thus act as a strong buffer for Ukraine's external debt in wartime conditions.

The effect of the volume of grain and oilseed exports on the spreads is less clear, as the estimated coefficients are unstable and are not statistically significant. This statistically weak link probably reflects wartime disruptions to maritime logistics of grain and oilseed exports via the Black Sea, and the relatively short time span of the study, as exporters may have eventually found alternative transportation routes to ship grain and oilseeds abroad.

## 6 ROBUSTNESS CHECK AND LIMITATIONS

To check robustness of estimates to an alternative measurement of the dependent variable, the model was re-estimated by using the logarithm of spreads as the dependent variable. This transformation allows for elasticity-based interpretation. Estimates obtained from an ARDL (3,1,0,1) model confirmed the baseline results that higher reserves narrowed the spreads, war intensity widened them, while exports had no statistically significant effect (table A4).

Despite the overall reliability of baseline estimates from the perspective of model diagnostics and test results, the above analysis remains limited in several respects. One is the small sample size constrained by data availability and debt restructuring in mid-2024. Although the ARDL method is suitable for small samples and the bounds test results were adapted to the number of observations, a longer time series could reveal additional dynamics, particularly given the evolving nature of military actions. Relatedly, data on military actions may not fully capture the qualitative impact of events such as attacks on energy infrastructure or the destruction of the Kakhovka Dam, potentially underestimating their economic consequences.

Another limitation is that aggregating data on spreads and war events from weekly to monthly frequency probably resulted in some loss of information about the short-term dynamics between these variables. Separately, it was not possible to account for potential endogeneity between reserves accumulation in response to rising spreads, or between military actions and exports of grain and oilseeds. The spreads may have also been partly influenced by other exports, e.g. metallurgy products, or global factors not modelled in the paper. More generally, a bootstrap analysis to assess the accuracy of standard errors could not be implemented given the nature of the dataset.

PUBLIC SECTOR ECONOMICS
50 (1) 95-115 (2026)



## 7 CONCLUSION

The existence of a long-run cointegration relationship linking Ukraine's sovereign spreads to both military attacks and foreign reserves highlights the critical role of the central bank in maintaining liquidity during an existential crisis. Previous work established this relationship during economic and financial crises (e.g. Afonso et al., 2021), but this is perhaps the first time that it has also been confirmed for a country in wartime conditions.

For central banks of countries in potential conflict zones this is a powerful message: the preservation and, to the extent possible, accumulation of foreign exchange reserves are the key priority when the guns start to roar on a country's soil. High reserves can help mitigate perceptions of riskiness of externally held sovereign debt, particularly during escalations of hostilities, and thereby help reduce external borrowing costs. As commodity exporting countries will likely find it hard to replenish foreign reserves by increasing exports in wartime conditions, central banks would be well advised to plan for such an FX war chest in good times, and thereby enhance economic resilience in crisis situations.

**Disclosure statement**

The author has no conflicts of interest to declare.

PUBLIC SECTOR ECONOMICS 50 (1) 95-115 (2026)



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**Table A1**

*Values of model variables*

| Year/month | SPREAD Basis points | WAREV Number of events | GRES Billion USD | AGRXP Million metric tons |
|---|---|---|---|---|
| 2021/09 | 525.5 | 0 | 28.706 | 6.44 |
| 2021/10 | 554.3 | 0 | 29.654 | 5.90 |
| 2021/11 | 590.6 | 0 | 30.598 | 7.12 |
| 2021/12 | 694.0 | 0 | 30.941 | 6.65 |
| 2022/01 | 842.5 | 0 | 29.087 | 6.15 |
| 2022/02 | 836.0 | 739 | 27.553 | 5.22 |
| 2022/03 | 2,666.0 | 2,098 | 28.107 | 0.27 |
| 2022/04 | 2,405.8 | 2,342 | 26.945 | 0.80 |
| 2022/05 | 3,230.6 | 2,637 | 25.102 | 1.42 |
| 2022/06 | 2,894.0 | 3,247 | 22.802 | 2.14 |
| 2022/07 | 4,544.0 | 5,000 | 22.387 | 2.29 |
| 2022/08 | 4,671.8 | 4,534 | 25.439 | 3.25 |
| 2022/09 | 4,401.5 | 4,185 | 23.932 | 5.58 |
| 2022/10 | 4,789.4 | 4,401 | 25.246 | 5.71 |
| 2022/11 | 4,374.5 | 3,581 | 27.955 | 5.08 |
| 2022/12 | 4,038.3 | 4,189 | 28.494 | 5.93 |
| 2023/01 | 4,219.8 | 3,581 | 29.928 | 4.81 |
| 2023/02 | 4,447.8 | 3,844 | 28.870 | 5.75 |
| 2023/03 | 4,899.3 | 3,698 | 31.887 | 6.38 |
| 2023/04 | 4,903.5 | 4,608 | 35.953 | 4.13 |
| 2023/05 | 4,965.4 | 3,807 | 37.321 | 3.61 |
| 2023/06 | 4,352.3 | 4,282 | 39.027 | 4.03 |
| 2023/07 | 3,165.8 | 4,666 | 41.738 | 2.61 |
| 2023/08 | 2,829.5 | 3,975 | 40.405 | 3.08 |
| 2023/09 | 2,816.5 | 4,671 | 39.723 | 2.93 |
| 2023/10 | 3,201.6 | 4,081 | 38.987 | 3.39 |
| 2023/11 | 3,109.3 | 3,934 | 38.796 | 4.54 |
| 2023/12 | 3,366.3 | 4,517 | 40.514 | 5.99 |
| 2024/01 | 3,396.0 | 3,783 | 38.534 | 6.02 |
| 2024/02 | 3,402.0 | 3,718 | 37.060 | 6.46 |
| 2024/03 | 2,877.3 | 4,985 | 43.767 | 5.63 |
| 2024/04 | 2,847.4 | 3,695 | 42.404 | 6.60 |
| 2024/05 | 2,958.3 | 3,642 | 39.037 | 5.80 |
| 2024/06 | 2,949.8 | 4,333 | 37.896 | 4.13 |
| 2024/07 | 2,847.0 | 3,701 | 37.235 | 4.22 |

*Sources: US Department of the Treasury (2025); Eavex Capital (2025); ACLED (2025); National Bank of Ukraine (2025); FAO (2022); Centre for Economic Strategy (2025); author's estimates.*

PUBLIC SECTOR ECONOMICS
50 (1) 95–115 (2026)



**Table A2**

*Model selection criteria – summary for top 20 models*

| Model no. | LogL[1] | AIC[2] | BIC[3] | HQ[4] | Model specification |
|---|---|---|---|---|---|
| 191 | -236.038 | 15.127 | 15.402 | 15.218 | ARDL(1,0,0,1) |
| 175 | -235.173 | 15.136 | 15.456 | 15.242 | ARDL(1,1,0,1) |
| 47 | -233.554 | 15.160 | 15.572 | 15.296 | ARDL(3,1,0,1) |
| 127 | -235.810 | 15.176 | 15.496 | 15.282 | ARDL(2,0,0,1) |
| 63 | -234.948 | 15.184 | 15.551 | 15.306 | ARDL(3,0,0,1) |
| 187 | -235.982 | 15.186 | 15.507 | 15.293 | ARDL(1,0,1,1) |
| 111 | -234.996 | 15.187 | 15.554 | 15.309 | ARDL(2,1,0,1) |
| 192 | -238.001 | 15.188 | 15.417 | 15.263 | ARDL(1,0,0,0) |
| 190 | -236.030 | 15.189 | 15.510 | 15.296 | ARDL(1,0,0,2) |
| 159 | -235.126 | 15.195 | 15.562 | 15.317 | ARDL(1,2,0,1) |
| 174 | -235.158 | 15.197 | 15.564 | 15.319 | ARDL(1,1,0,2) |
| 171 | -235.165 | 15.198 | 15.564 | 15.319 | ARDL(1,1,1,1) |
| 173 | -234.181 | 15.199 | 15.611 | 15.335 | ARDL(1,1,0,3) |
| 143 | -234.416 | 15.214 | 15.626 | 15.350 | ARDL(1,3,0,1) |
| 31 | -233.528 | 15.220 | 15.679 | 15.372 | ARDL(3,2,0,1) |
| 43 | -233.546 | 15.222 | 15.680 | 15.373 | ARDL(3,1,1,1) |
| 46 | -233.554 | 15.222 | 15.680 | 15.374 | ARDL(3,1,0,2) |
| 189 | -235.582 | 15.224 | 15.590 | 15.345 | ARDL(1,0,0,3) |
| 128 | -237.584 | 15.224 | 15.499 | 15.315 | ARDL(2,0,0,0) |
| 183 | -235.767 | 15.235 | 15.602 | 15.357 | ARDL(1,0,2,1) |

*[1] Log likelihood. [2] Akaike information criterion. [3] Bayesian information criterion. [4] Hannan-Quinn criterion.*

*Source: Author's estimates.*

**Table A3**

*Multicollinearity tests – variance inflation factors (VIF)*

| Variable | Coefficient variance | Uncentred VIF | Centred VIF |
|---|---|---|---|
| SPREAD(-1) | 0.010 | 23.923 | 3.778 |
| WAREV | 10,685.3 | 28.586 | 4.654 |
| GRES | 190.1 | 42.523 | 1.519 |
| AGRXP | 3,931.1 | 18.285 | 2.430 |
| AGRXP(-1) | 4,015.5 | 19.229 | 2.562 |
| C | 176,130.1 | 34.799 | NA |

*Source: Author's estimates.*

PUBLIC SECTOR ECONOMICS
50 (1) 95-115 (2026)



**Table A4**

*Estimates of ARDL (3,1,0,1) model*

| Coefficient | Value | Standard error | t-statistic | Probability |
|---|---|---|---|---|
| $\alpha$ | -0.681 | 0.441 | -1.543 | 0.136 |
| $\beta_1$ | 0.465 | 0.168 | 2.767 | 0.011 |
| $\beta_2$ | 0.270 | 0.163 | 1.661 | 0.110 |
| $\beta_3$ | -0.250 | 0.149 | -1.678 | 0.107 |
| $\gamma_{1,0}$ | 0.097 | 0.058 | 1.676 | 0.107 |
| $\gamma_{1,1}$ | 0.106 | 0.061 | 1.751 | 0.093 |
| $\gamma_{2,0}$ | -0.019 | 0.006 | -3.185 | 0.004 |
| $\gamma_{3,0}$ | -0.088 | 0.028 | -3.195 | 0.004 |
| $\gamma_{3,1}$ | 0.085 | 0.030 | 2.871 | 0.009 |

*Source: Author's estimates.*