EXTERNAL PUBLIC DEBT AND TRADE BALANCE: AN EVIDENCE FROM UKRAINE

by

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Abstract

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With limited financing options and high levels of defense spending, Ukraine relies heavily on its external borrowing. However, this brings debt-related risks to the national economy. Although Ukrainian economists highlight the importance of the issue of external debt repayment, there are few studies aimed on assessing the key factors of its accumulation.

The main objective of the thesis is to study the relationship between the external public debt Ukraine's and its trade balance, which is commonly viewed as a main source of foreign currency inflow and, thus, external public debt repayment.

The Auto-Regressive Distributed Lag (ARDL) approach was used to explore both short-term dynamics and long-term cointegration between key macroeconomic indicators.

The results show new evidence of the limited direct role of trade balance in debt accumulation for developing economies. The analysis also confirms the importance of the budget balance, reserves, and inflation in shaping external public debt in Ukraine.

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LIST OF ABBREVIATIONS

ARDL. Autoregressive Distributed Lag Model.

ECM. Error Correction Model.

EUR. Euro.

GDP. Gross Domestic Product.

GNI. Gross National Income.

GNP. Gross National Product.

IMF. International Monetary Fund.

NBU. National Bank of Ukraine.

USD. United States dollar.

Chapter 1

INTRODUCTION

External public debt is a common instrument in today's fiscal policy, mostly used to soften crises and stimulate economic growth. However, a too-high level of external debt accumulation increases the risks of default and a country's vulnerability to external shocks.

The recent "International Debt Report 2024" by the World Bank (2024) shows that the share of low- and middle-income countries with low or moderate risk of external debt distress increased in 2023, although it had a general negative tendency from 2015 to 2022. It was also noted that due to the overall improvement in GNI, these countries also strengthened their debt-to-GNI indicator. These facts show a positive tendency in the global debt sustainability situation. However, the authors also noted that some countries, including Ukraine, showed the opposite results. For instance, Ukraine was among the countries that reported the largest increase in the debt-to-export ratio in 2023.

Ukraine has experienced external public debt as a significant source of financing since achieving independence. External borrowing has been taking a high share in gross public debt for the last 15 years yet staying relatively stable till 2022 (see Figure 1 below). At the same time, the gross public debt experienced a moderate increase during this period.

With the full-scale russian invasion, the external public debt-to-public debt ratio has rapidly risen. As of December 31, 2024, it was already 72.32% (Ministry of Finance of Ukraine 2024). Such a rise is a result of the high budget deficit driven

by a sharp increase in defense expenditures. Thus, external debt became an essential instrument for supporting the Ukrainian economy during wartime.

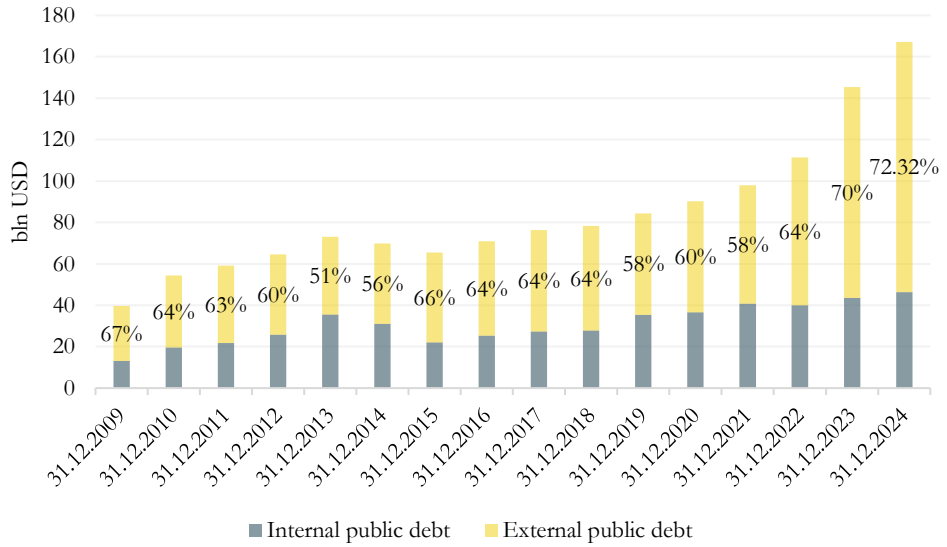

Figure 1. External public debt in Ukraine's gross public debt structure (as of December 31, 2024)

Source: Ministry of Finance of Ukraine

The key issue of using external debt as a main source of financing the war is that it must be repaid to creditors. Under the conditions of economic instability and a damaged energy system, the government has a limited number of solutions to this problem. From the start of the full-scale invasion, the Ukrainian government has been working on debt restructuring to keep as many resources in the economy as possible (Wall Street Journal 2023). However, at the end of the day, Ukraine is still obliged to repay its debt to keep credibility and foreign assistance. Therefore, the issue of the capacity of the Ukrainian economy to serve its external debt is highly important.

In literature, international trade is usually viewed as the main source of external debt repayment. For example, the debt overhang framework (Krugman 1988) assesses external debt sustainability through comparison of the debt accumulation with the present value of net exports. However, this approach gives mixed results in empirical studies (Chaudhary and Awar 2001).

Another approach to trade balance and external debt relationship associates it with cash flows. External public debt is usually denominated in foreign currency. For instance, as of December 31, 2024, only 1% of Ukrainian external debt was denominated in hryvnia (see Figure 2 below). Therefore, to repay the external loan, the Ministry of Finance has not only to ensure that the needed amount of resources is available, but also that it matches the currency in which the payment should be made.

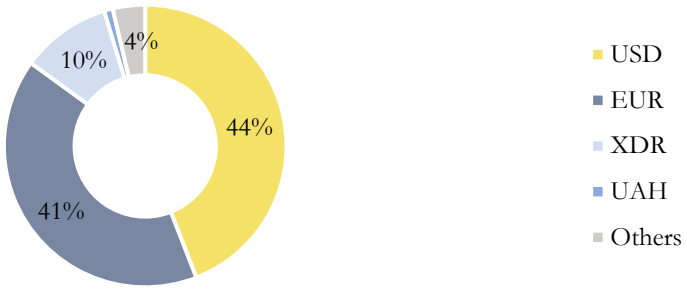

Figure 2. Currency structure of the external public debt of Ukraine (as of December 31, 2024)

Source: Ministry of Finance of Ukraine

In this perspective, the Ukrainian government is interested in the sustainable foreign currency inflow into the country, which is mainly provided by the

exporters. In the literature, this relationship is analyzed from the perspective of the currency mismatch problem, which can arise when trade balance and external debt currency structure do not align (Bussière, Fratzscher, and Koeniger 2004, Fujii 2017).

However, if the trade balance is in deficit (i.e., exports are lower than imports), this can lead to an increase in external debt. This perspective is analyzed in the two-gap model framework (Chenery and Strout 1966). The empirical papers showed its effectiveness in defining the most significant external debt determinants for developing countries (Beyene and Kotosz 2020, Sağdıç and Yıldız 2020).

For now, there are no studies on Ukrainian data aimed at assessing the relationship between trade balance and external public debt from any of the listed perspectives. A recent paper by Davydenko et al. (2023) highlights the importance of the financial security issue in Ukraine. However, it provides only a descriptive analysis of the external public debt sustainability indicators and their potential determinants. At the same time, an analysis of the Ukrainian case might bring important insights into the relationship between external debt and international trade during sharply changing circumstances of wartime. Therefore, there is a need for a study that will fill in the existing gap in econometric analysis of the issue.

This thesis contributes to the literature by bringing the evidence from Ukraine to the discussion on trade balance and the external debt relationship. I apply the two-gap model theoretical framework to Ukraine, accounting for the perspectives of debt overhang and currency mismatch theories.

Previous empirical studies use either annual (Zafar and Butt 2008, Bittencourt 2015, Harsono, Kusumawati, and Nirwana 2024) or quarterly data (Bölükbaş 2016, Nazamuddin et al. 2022). This study also contributes to the literature by giving additional insights into the monthly time series analysis.

The thesis is structured as follows. It starts with a literature review in *Chapter 2*, which briefly overviews both the theoretical foundations of trade balance and the external public debt relationship, as well as the main results of the empirical studies. In *Chapter 3*, the methodology is developed. *Chapter 4* describes the data collected for model estimation along with conducted transformations. The results of the stationarity testing, model estimation, as well as assumption tests, and robustness checks, are presented in *Chapter 5*. Finally, in *Chapter 6,* the key findings and possible policy implications are provided.

Chapter 2

LITERATURE REVIEW

The relationship between trade balance indicators and external public debt has been actively discussed in the literature. The theoretical analysis mainly has two key perspectives on this topic. The first one analyses trade as a main source of foreign currency inflow into the economy and the main source of external debt repayment. The second perspective is focused on the situation where the trade balance is negative, which is linked with an increase in external borrowing. In this section, I review theoretical papers from both perspectives to draw a general vision of the possible relationship between trade balance and external debt. I end this section with a brief discussion of the recent empirical studies on the topic with a focus on independent variables that are used.

2.1. International trade as a source of repayment of external public debt

External debt repayment is usually viewed from the perspective of two key issues: solvency and liquidity. The first one characterizes the ability of a country to generate enough resources that can be extracted and transferred to the creditors. It is usually analyzed in the context of economic growth. The second one is related to the capability of a country to convert the extracted resources into the needed form of repayment (i.e., a certain foreign currency). Both problems are important in the context of the external debt and trade balance relationship, and both have been analyzed theoretically.

One of the very first theories aimed at addressing the problem of solvency of external debt is the debt overhang theory. This concept was primarily developed

by Krugman (1988) and described a situation when the accumulated debt of a country is higher than the present value of the sum of expected repayment transfers. The framework was further developed by Aizenman (1991), who incorporated endogenous trade dependency into the debt-overhang analysis. He suggested that conditional credit relief can enhance future repayments if it is connected to the level of investment in the trade-dependent sectors of the borrowing economy.

The concept of debt overhang is also a cornerstone of the debt Laffer curve framework. Krugman (1989) showed that "debt forgiveness" will be beneficial for creditors if the borrower country's economy is on the downsloping side of the Laffer curve, i.e., when the expected total repayment value lowers with the increase of the public debt. The current debt Laffer curve framework often links international trade to the market value of external public debt as the main source of its repayment (Tatu 2014).

Empirical studies on overhang theory and debt Laffer curve show mixed results on the trade balance and external debt relationship. For instance, Claessens (1990) assessed debt Laffer curves for 29 sub-Saharan African countries and found a significant positive effect of debt-to-export value and real export growth rate on nominal public debt. This result was confirmed by a later study on 35 countries (Claessens et al. 1990), where the authors also found that the downsloping part of the Laffer curve is associated with high levels of debt-to-export ratio. On the other hand, Chaudhary and Awar (2001) found that for most South Asian Countries, the growth rate of exports and the external debt outstanding to exports rate were statistically insignificant in defining the secondary market price of external debt outstanding. The authors associated such a result with the fact that the studied countries are mostly agricultural economies with a small share of domestic products in GNP.

In contrast to solvency, the issue of external public debt liquidity is often considered to mainly appear in developing economies, which usually borrow in foreign currencies. For these countries, the currency of generated revenues or assets often misaligns with the currency in which external debt is nominated, which can lead to a currency mismatch situation. Bussière, Fratzscher, and Koeniger (2004) analyzed this issue from the perspective of the exchange rate link between trade balance and external public debt. They found that countries with more aligned currency composition for debt and trade are more likely to benefit from external borrowing and show economic growth. This relationship was further confirmed in the empirical study by Fujii (2017), which was conducted on the data from 45 middle-income and low-income countries. The significance of this issue for Ukraine is discussed by Kulyk and Spivak (2023) in the context of debt management.

2.2. International trade as a cause of external borrowing

Theories that view trade balance as a main source of external debt repayment usually assume a positive trade balance. However, for today's developing economies, it is more common to have a trade deficit, which is often financed through external borrowing. This situation is analyzed through the two-gap model, initially developed by Chenery and Strout (1966). In essence, the authors identified two interrelated gaps that can occur in the economy: savings-investment and export-import (trade gap). The main purpose of foreign assistance and external debt in the model is seen as financing these gaps to boost economic growth.

This idea was further developed by Bacha (1990), who brought the fiscal gap to the analysis, which is a difference between the government's income and expenditure.

Similarly to the two gaps discussed above, the fiscal gap directly leads to increases in external borrowing as the government uses it as a main source of financing.

Subrahmanyam and Sundararajan (1998) added central bank and monetary policy into the model and adapted it to the context of developing countries to compare gaps as possible constraints of economic growth. In the context of their research, a gap becomes a binding constraint if it makes any other government investments ineffective in terms of enhancing economic growth. The authors showed that the savings gap is binding only in the case when both domestic savings and access to foreign borrowing are constrained.

Such a perspective on the trade balance has a lot of empirical evidence. Lane and Milesi-Ferretti (2000) found that countries with persistent trade deficits tend to finance them through increasing external debt and vice versa. Sağdıç and Yıldız (2020) implemented a two-gap model to examine 7 Central Asian countries for the period from 1995 to 2017 and found a significant negative effect of the balance of payment on the external debt. Beyene and Kotosz (2020) found statistically significant impacts of the discussed gaps on the external debt of Ethiopia.

2.3. Review of empirical studies

Empirical studies aimed at assessing the strength of the relationship between external public debt and international trade can be divided into two groups. The first group of studies is concentrated on finding the key determinants of public debt. In such papers, trade balance indicators are included in regression among other explanatory variables (Bittencourt 2015, Omar and Ibrahim 2021, Harsono, Kusumawati, and Nirwana 2024, Beyene and Kotosz 2020). The second group examines specifically international trade indicators, meanwhile other

macroeconomic measures can be included as controls (Zafar and Butt 2008, Kızılgöl and İpek 2014). All papers use either time series on a specific country or panel data for groups of related countries.

In terms of empirical study, it is important to identify theoretically reasonable and practically available variables. Scholars usually have several indicators of international trade that can be included in the regression. This led to a certain variation in approaches.

The most common approach is to analyze trade openness as an indicator of involvement in international trade. For instance, Bittencourt (2015) found its significant and negative impact on external debt in the study of 9 South American democracies. On the contrary, Ayvaz Kızılgöl and İpek (2014) found significant positive effects of trade openness on external debt both in the short- and long-run using quarterly time series data in Turkey from 1990 to 2012. Another study on Turkey by Bölükbaş (2016) confirmed this relationship. Analogically, in a recent analysis of the data on 5 ASEAN countries during the 2008-2019 period, Harsono, Kusumawati, and Nirwana (2024) found a significant positive effect of trade openness. They argued that this indicator can show mixed effects as it is a sum of exports and imports, which are supposed to have opposite effects on the external debt. It is a significant limitation that has to be accounted for in such studies.

In contrast to these papers, Omar and Ibrahim (2021) applied a more direct approach by analyzing exports as an indicator of foreign currency inflow to the economy. However, the authors found no statistical significance for this variable.

In the study of the trade liberalization impact on the external debt in Pakistan, Zafar and Butt (2008) included both export-to-GDP and import-to-GDP ratios into the regression, used debt-to-GDP ratio as an independent variable, and got counterintuitive results. They argued that the significant positive effect of exports

and the significant negative effect of imports on external public debt could be a result of poor export basket composition. The authors suggested that the export of products with low value-added leads to an increase in external borrowing because of a steady decline in the world prices for these goods. Simultaneously, the import of capital goods improves productivity in the developing country, raises GDP growth, and thus lowers the debt-to-GDP share.

Finally, Beyene and Kotosz (2020) analyzed trade deficit and trade openness as determinants of external public debt in Ethiopia and found a positive effect of the trade deficit and a negative effect of the trade openness, both significant in the long run.

The reviewed literature highlights the complexity of the relationship between trade balance and external public debt. The two main perspectives are analyzed in theoretical literature: the role of international trade as a source of external debt repayment and its role as a cause of external borrowing. Empirical literature usually combines these approaches to get the most precise regression. However, the variety of compositions of independent variables in papers leads to mixed and sometimes counterintuitive results.

Chapter 3

METHODOLOGY

The objective of the research is to study the relationship between external public debt and trade balance in Ukraine. The key hypothesis is that there is a significant negative relationship between these variables. This chapter discusses the methodology applied to test it. It starts with a discussion of the variables included in the main econometric model as well as the variables used for the robustness checks. Then, the auto-regressive distributed lag (ARDL) methodology is justified as a main estimation approach. I end this section with the possible estimation challenges and the ways to address them.

3.1. Variables and key hypotheses

The dependent variable in the research is the external public debt of Ukraine. Therefore, the study applies time series analysis, and the econometric model specification takes such form:

$$ED_t = \alpha_0 + \alpha_1 \boldsymbol{x_t} + \varepsilon_t \quad (1)$$

where ED_t is external public debt in period t, α_0 is a drift term, $\boldsymbol{x_t}$ is a vector of explanatory variables, and ε_t – error term.

As reviewed in the literature section, the three-gap model framework has shown high reliability and empirical evidence in defining the relationship between external

public debt and international trade in the context of developing economies. Following this theoretical approach, the trade gap is analyzed as a key independent variable, representing the impact of international trade on Ukraine's external public debt. In the context of the research, the term "trade balance" is used for better clarity, which is calculated in the same manner as "trade gap", "trade deficit" or "net export" in other studies.

The definitions of the main model variables are summarized in Table 1 below. Most independent variables are included following Beyene and Kotosz's (2020) empirical study on the three-gap model. However, several changes were made to adjust the model to the Ukrainian context and improve the methodology and reliability of the final estimates.

For instance, Beyene and Kotosz (2020) do not use the absolute values of variables but their percentage rate of GDP. However, in this research, such data transformation is not conducted for several reasons. Firstly, this step might bring endogeneity to the model as the dependent and most independent variables are divided by the same series. Secondly, the monthly GDP has not been calculated by the State Statistics Service of Ukraine since 2015. This means that the GDP series needs additional disaggregation before being used in the analysis. Finally, as the research is conducted on time series and not panels or cross-sectional data, there is no need to account for the regional differences, which is often the main purpose of such data transformations.

Trade openness, originally used by Beine and Kotosz (2020), is not included in the main model due to its expected ambiguous effect. As discussed in *Chapter 2*, trade openness can have mixed effects on the external public debt as it combines the country's imports and exports, which have opposite effects on the country's balance of payments. In the thesis, it is replaced by the country's official reserves.

Therefore, the effect of foreign currency inflows from international trade is captured more precisely without doubling the balance of payments indicators.

Table 1. Definitions of the key variables

Variable	Definition
External public debt	Sum of the state and guaranteed public debt accumulated in the period in bn USD
Trade balance	Total exports per period minus total imports per period in bn USD
Budget balance	Government income per period minus government expenditures per period in bn USD
External debt service	Gross external debt service during the period in bn USD
Reserves	The official reserve assets of Ukraine accumulated in the period, bn USD
Inflation	Average per period inflation rate compared to the previous period
Exchange rate to EUR	Average official exchange rate of hryvnia per 1 EUR

Trade balance, budget balance, and external debt service are all flow indicators, while external public debt and international reserves are stock indicators. To bring

all variables to a common understanding, the external debt and reserves are not included in the model in their stock values but in their accumulation or change per period.

It is important to note that the final model uses the exchange rate of the hryvnia to the euro as the key exchange rate for the foreign currency. The choice is made based on the currency structure of external public debt in Ukraine (recall Figure 1.2 from *Introduction*). At the same time, the exchange rate of hryvnia to US dollars was not included in the model as it was used for data transformation (see *Chapter 4* for the details).

With all variables included, the model is formulated as follows:

$$ED_t = \alpha_0 + \alpha_1 TrBal_t + \alpha_2 BdBal_t + \alpha_3 EDServ_t + \alpha_4 Res_t + \alpha_5 Infl_t + \alpha_6 EXC_t + \varepsilon_t \quad (2)$$

where ED_t is external public debt in period t, $TrBal_t$ – trade balance, $BdBal_t$ – budget balance, $EDServ_t$ – external debt service, Res_t – reserves, $Infl_t$ – inflation and EXC_t – exchange rate to foreign currency.

This model combines the variables with positive and negative effects on external public debt that are commonly used in empirical research (Bittencourt 2015, Omar and Ibrahim 2021, Harsono, Kusumawati, and Nirwana 2024). The hypotheses on explanatory variables included in the main model are summarized in Table 2.

Table 2. Expected signs and hypotheses

Independent variable	Expected sign	Hypothesis explanation
Trade balance	–	Trade balance increases external public debt when it is negative (a trade gap occurs) and decreases it when positive.
Budget balance	–	Budget balance increases external public debt when it is negative (a budget gap occurs) and decreases it when positive.
External debt service	–	External debt service decreases external public debt as it is partially repaid.
Reserves	–	Reserves accumulation allows to avoid costly short-term loans and allows for debt repayment.
Inflation	+	Inflation reduces the purchasing power of the local currency and thus increases the external debt.
Exchange rate	+	Exchange rate increases lead to higher transaction expenditure on currency exchange and thus make external debt more costly.

At the same time, the variables with possible ambiguous effect are added in the model for the robustness testing. This includes trade openness and GDP.

As reviewed in *Chapter 2*, trade openness can show mixed effects on external public debt as it combines the country's imports and exports, which have opposite effects on the country's balance of payments. In the research, the assumption made is that

the import effect prevails. The positive effect of trade openness can also be expected as international trade might increase prices in the local economy, making government spending and individual consumption more costly (Elmendorf and Mankiw 1998).

GDP is commonly expected to have a negative impact on external public debt as it is a potential source of debt repayment. At the same time, the well-developed countries with high levels of GDP usually have a high stock of external public debt. That is why the relationship between GDP and external public debt can be ambiguous. To address this issue, one could use the GDP growth rate. Unfortunately, this option is not available for this research. The State Statistics Service of Ukraine has not gathered data on the monthly GDP for 2015. Therefore, the quarterly data was collected and simply divided by the number of months in the quarter. Thus, the monthly GDP growth rate could not be captured.

3.2. Estimation approach

The estimation approach implemented in this research is the auto-regressive distributed lag (ARDL) methodology. It was proposed by Pesaran et al. (2001) and allows for running regression of variables with different integration orders with no issues on small or highly volatile series. It also works with endogeneity issues, which is beneficial for macroeconomic and national accounts time series.

Although the ARDL methodology does not require all variables to be at the same level of integration, it assumes they are either I(0) or I(1) stationary. Therefore, the first stage of the estimation process implies conducting unit root tests. For this purpose, both the Augmented Dickey-Fuller (ADF) by Dickey and Fuller (1979) and Phillips-Perron (PP) by Phillips and Perron (1988) tests are used. Furthermore, to cross-check the result the Kwiantkowski-Phillips-Schmidt-Shin (KPSS) test is

applied. Oppositely to ADF and PP tests, the null hypothesis for the KPSS test is that the time series is stationary, and the alternative is that it has a unit root (Kwiatkowski et al. 1992).

After conducting unit root tests, the lag choice is decided on either Akaike information criterion (AIC) or Schwarz-Bayesian information criterion (SBIC). SBIC is considered as more precise in the context of small sample and possible breakpoints. It imposes a stronger penalty for adding more parameters and therefore accounts for possible overfitting. In the research SBIC is used as a main criterion with also considering AIC results.

After the lag structure is decided, the unrestricted error correction model (UECM) is estimated as follows:

$$\begin{aligned} \Delta ED_t = \alpha_0 &+ \sum_{i=1}^{p} \beta_i \Delta ED_{t-i} + \sum_{j=0}^{q_1} \delta_j \Delta TrBal_{t-j} + \sum_{j=0}^{q_2} \gamma_j \Delta BdBal_{t-j} \\ &+ \sum_{j=0}^{q_3} \mu_j \Delta EDServ_{t-j} + \sum_{j=0}^{q_4} \lambda_j \Delta Infl_{t-j} \\ &+ \sum_{j=0}^{q_5} \phi_j \Delta Infl_{t-j} + \sum_{j=0}^{q_6} \eta_j \Delta EXC_{t-j} + \theta_1 ED_{t-1} \\ &+ \theta_2 TrBal_{t-1} + \theta_3 BdBal_{t-1} + \theta_4 EDServ_{t-1} \\ &+ \theta_5 Res_{t-1} + \theta_6 Infl_{t-1} + \theta_7 EXC_{t-1} + \varepsilon_t \end{aligned} \tag{3}$$

Here, the operator Δ denotes the first difference, and the summation terms represent the effect of lagged changes in each independent variable on the current

period's external public debt growth (ΔED_t). The chosen lags are denoted as p for the dependent variable and q_n for the independent variables. Consequently, the coefficients $\beta_i, \delta_j, \gamma_j, \mu_j, \lambda_j, \phi_j, \eta_j$ capture short-term effects of the explanatory variables. At the same time, the long-term effects are estimated as θ_n coefficients.

The estimation results of UECM are primarily used to perform the Wald test for cointegration, initially proposed by Wald (1943). If the test rejects the null hypothesis of no-cointegration, the levels equation can be estimated as a long-run equilibrium condition. The short-run coefficients are interpreted from the UECM results. Finally, the error-correction term (ECT) is obtained with a restricted error correction model (RECM) as a sum of lagged effects.

Although its flexibility, the ARDL approach still requires limitation of maximum lag allowed in the model. Pesaran et al. (2001) argue that as long bounds test for cointegration is used to determine the long-run relationship, it may fail to do so with too many lags included. On the other hand, too restrictive approach might fail to capture the effects of independent variables appropriately and lower the explanatory power of the model. The common approach is to use no more than two lags on the annual data (Abdullahi, Abu Bakar, and Hassan 2015, Beyene and Kotosz 2020, Omar and Ibrahim 2021). At the same time, Baniata, Alnawasreh, and Nsairat (2023), while assuring that the analyzed time series are stationary at the first two lags, still use the third lag to improve model fit and address possible serial correlation. Moreover, in the initial paper Pesaran et al. (2001) apply the proposed methodology to data with the quarter frequency and allow seven lags at maximum. The monthly time series used in the research might reflect seasonality and thus also require higher integration levels. The two approaches are applied: allowing four and twelve lags at maximum. The resulting models are compared by explanatory power and reliability.

In addition to an adequate choice of the lag structure, Pesaran et al. (2001) identify other important assumptions of the ARDL approach. No serial correlation in the error terms is assumed. Violation of this assumption might result in misleading standard errors and cointegration test results. Following Nazamuddin et al. (2022) Breusch-Godfrey test is applied to check for serial correlation (Breusch 1978, Godfrey 1978). It is based on the Lagrange multiplier statistics and detects serial correlation in residuals. Homoskedasticity is also important and checked by the Breusch-Pagan test (Breusch and Pagan 1979).

The model is also assumed to be dynamically stable. For the detection of structural breaks in the model, CUSUM and CUSUMSQ tests by Brown, Durbin, and Evans (1975) are used, as is commonly done for the ARDL approach.

Finally, it is assumed that there is no perfect collinearity. Following Akinwalere (2017), the correlation matrix analysis is applied to confirm this assumption.

For all estimations and visualizations below, the R-4.4.2 is used. Natsiopoulos and Tzeremes (2022) showed its power in applying ARDL methodology by fully replicating Pesaran et al. (2001) approach using this analytical tool.

Chapter 4

DATA

In this research, secondary data from official web pages of Ukrainian institutions is used. The data on external public debt, budget balance, and external debt service are collected from the reports by the Ministry of Finance of Ukraine. The inflation, reserves, and exchange rate data are collected from statistics of the National Bank of Ukraine (NBU), and the trade balance series is calculated on the NBU's external sector database.

The descriptive statistics of the dataset are provided in Table 3 below.

Table 3. Descriptive statistics

Variable	Obs.	Mean	Std. Dev	Min	Max
External public debt (in bn USD)	144	0.56	1.66	-3.48	7.99
Trade balance (in bn USD)	144	-1.05	1.15	-4.27	1.69
Budget balance (in bn USD)	144	-0.24	0.52	-2.28	1.09
External debt service (in bn USD)	144	0.37	0.48	0.01	3.16
Reserves (in bn USD)	144	-0.13	1.67	-6.71	3.80
Inflation (MoM %)	144	1.07	1.75	-1.40	13.97
Exchange rate to EUR	144	29.17	8.89	10.36	45.79

Note: see the extended results in Table 12 in Appendix A.

The time-series data was collected over the last 11 years (from 2013 to 2024), monthly. The idea behind taking monthly data is to get fresh insights into short-term external debt fluctuations. This also allows for deeper analysis in the sharply changing context of wartime.

The data on external public debt, trade balance, reserves, and external debt service are measured in USD and do not require currency transformation. The original series on the budget gap in millions of UAH was changed to billions of USD for consistency. To do so, it was divided by the average official exchange rate to USD. The series on external state debt and external state-guaranteed debt were summarized to obtain the external public debt stock. The analyzed series on external public debt and reserves were differenced to capture the accumulation or reduction in the analyzed period. Inflation is taken as a percentage rate over the previous month, and exchange rate data is measured in hryvnas per euro.

The decomposition of external public debt and trade balance series showed that both variables' trends have changed sharply after the beginning of full-scale russian invasion.

The trend line of the external public debt series (see Figure 3) reflects the increases in Ukraine's external public debt accumulation dynamics in 2014, 2020, and 2022 in response to external shocks. This confirms that the Ukrainian government leads the anti-cyclical fiscal policy. One can also note that the full-scale russian invasion to Ukraine was a severe external shock in terms of external public debt accumulation, even in comparison to other shocks covered by the analyzed period. At the same time, the dynamics of external public debt accumulation tend to decrease after reaching its peak in 2024.

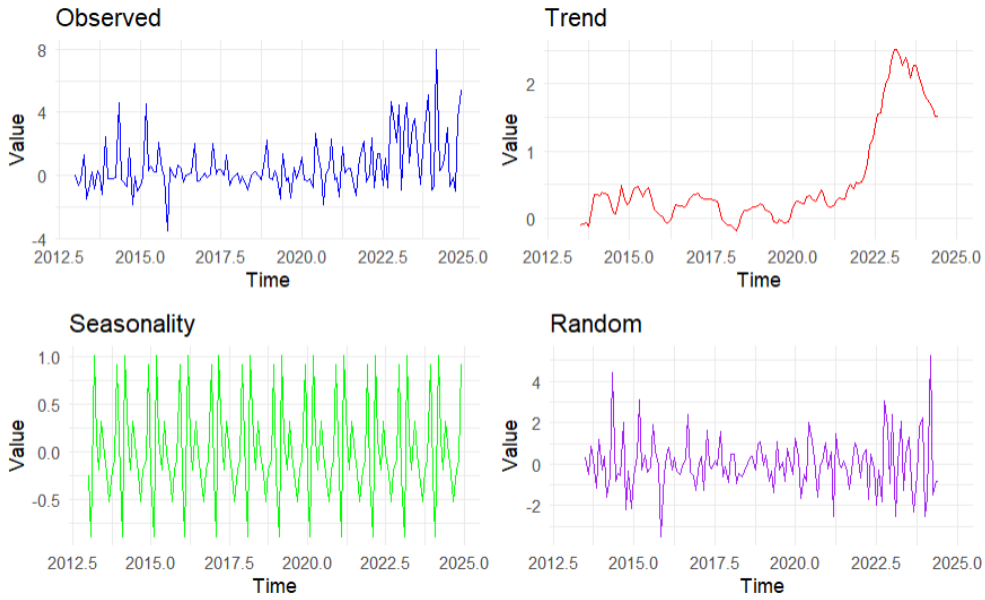

Figure 3. External public debt accumulation per period (bn USD) time series decomposition

The trade balance series is characterized by higher volatility (see Figure 4). The seasonal component is mostly caused by a business cycle, which is in turn connected to the season and month.

The trend line moves in the opposite direction to the external public debt trend line, except for the 2013-2015 period. Despite the substantial external shocks (Revolution of Dignity and beginning of the russian-Ukrainian hybrid war), trade balance showed a positive dynamic during this period. This can be potentially related to the intensification of international trade. However, during this period, external borrowing still grew due to other factors.

The correlation matrix of analyzed variables (see Table 13 in Appendix A) shows a negative correlation between trade balance and external public debt. It also reveals a high positive correlation between the exchange rate variables (0.99). This can be

a result of the National Bank of Ukraine's policy: official exchange rates to foreign currencies might be established with a fixed cross-rate. This is an additional reason to include only one exchange rate for a foreign currency in the model. Because of the reasons discussed before (see *Chapter 3*), the exchange rate to euro was chosen to be included in the further analysis.

Figure 4. Trade balance (bn USD) time series decomposition

The correlation analysis also shows that there is no high correlation coefficient among the variables considered in the main model (above 0.8), which could indicate multicollinearity. This means that the assumption of no multicollinearity is satisfied, and the ARDL estimation approach can be implemented in the main model specification.

However, there is a high positive correlation (0.82) between trade openness and GDP. This aligns with the mainstream theoretical idea that international trade boosts economic growth. To prevent possible multicollinearity the controls were included into the model separately.

The signs of correlation coefficients of independent variables with external public debt are in line with the hypothesis made in *Chapter 3*. The trade balance, budget balance, external debt repayment, and reserves show a negative correlation with external public debt, while inflation, exchange rates, GDP, and trade openness – are positive. There is also a small negative correlation between trade balance and trade openness. This might reflect that the overall intensification of international trade in Ukraine is often associated with the rise in imports rather than exports.

To summarize, the preliminary analysis of key variables supports the initial research hypothesis and lays the ground for further ARDL model implementation.

Chapter 5

ESTIMATION RESULTS

The results of implementation of the ARDL methodology are presented in this chapter. It starts with stationarity testing of the analyzed series. Then the optimal lag structure is determined and the cointegration test is conducted. After confirmation of the cointegration existence both short- and long-term coefficients are estimated, and the model diagnosis is performed. Finally, the robustness checks are presented and discussed.

5.1. Stationarity testing

Stationarity tests' results indicate that all the variables (both included in the main model and used for the robustness checks) are stationary at level or at first difference (see Table 4 below).

The results of the ADF and PP tests confirm the stationarity of the public external debt at level. However, the KPSS test rejects the null hypothesis of stationarity at level and suggests stationarity at first difference. This might signal possible structural breaks in the time series. To test this hypothesis, Zivot-Andrews and Bai-Perron tests have been conducted.

The Zivot-Andrews test confirmed stationarity with a structural break of the external debt time series at the 1% significance level (with test statistics of -13.4611 and suggested breakpoint in September 2021). Therefore, the external public debt time series may be I(0) stationary with a break.

Table 4. Stationarity tests results

Variable	ADF		PP		KPSS		Conclusion on stationarity
	Level	1st Diff	Level	1st Diff	Level	1st Diff	
External public debt	-3.38*	-7.67**	-139.91**	-165.33**	0.28***	0.03	I(1)
Trade balance	-2.13	-5.35**	-24.41**	-146.77**	0.22***	0.08	I(1)
Budget balance	-4.68**	-8.91**	-160.35**	-187.03**	0.08	0.02	I(0)
External debt service	-3.00	-5.37**	-21.14**	-162.53**	0.24***	0.04	I(1)
Reserves	-4.78**	-6.64**	-128.55**	-160.93**	0.05	0.03	I(0)
Inflation	-4.05**	-7.25**	-52.96**	-119.01**	0.08	0.02	I(0)
Exchange rate to EUR	-2.27	-4.65**	-7.67	-139.59**	0.34***	0.11	I(1)
Trade openness	-3.49**	-8.75**	-156.73**	-188.43**	0.10	0.02	I(0)
GDP	-3.85**	-10.37**	-20.11*	-137.8**	0.28***	0.02	I(0)

Note: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. The reported numbers are t-values.

The Bai-Perron test confirmed the results of Zivot-Andrews test suggesting one brake point in the same period (see Table 5 below). To account for the identified breakpoint, model with the respective break dummy is discussed in the robustness check section.

Table 5. Bai-Perron multiple breakpoints test for the external public debt results

Number of breaks	Suggested break dates	RSS	BIC
0 (no breaks)	—	391.8	562.7
1	Sep 2022	303.5	535.9
2	May 2020, Sep 2022	301.1	544.7
3	Sep 2017, May 2020, Sep 2022	299.9	554.1
4	Feb 2015, Sep 2017, May 2020, Sep 2022	297.5	562.9
5	Jan 2015, Oct 2016, Aug 2018, May 2020, Sep 2022	299.1	573.5

The general conclusion of the stationarity testing is that the ARDL methodology can be applied. Furthermore, as the analyzed dataset shows mixed levels of integration, the chosen approach is the most suitable in the given case.

5.2. Lag selection and short-run effects

With the maximum allowed lag of 4, the number of all possible specifications is equal to $4^7 = 16\,384$, and with the maximum allowed lag of 12, it increases to $12^7 = 35\,831\,808$. Based on SBIC and AIC, twenty lag structures were proposed for each case (see Table 14 in Appendix B).

The top 6 lag orders are the same for both approaches. This means that allowing more lags in the model does not significantly improve its explanatory power. Table 6 presents the model specifications that estimated and compared in further

analysis. These include top 6 model specifications by both approached and the recommended specification that suggests non-zero lags for all variables.

Table 6. Selected lag structures

Suggested lag order	SBIC	AIC
ARDL(1,0,0,0,0,0,0)	416.8	390.1
ARDL(2,0,0,0,0,0,0)	419.0	389.5
ARDL(1,0,0,0,0,0,1)	419.3	389.6
ARDL(2,0,0,0,0,0,1)	421.4	388.9
ARDL(3,0,0,0,0,0,0)	421.8	389.4
ARDL(1,0,0,0,0,1,1)	423.6	391.0
ARDL(1,1,1,1,1,1,1)	441.4	397.0

As the logic behind lag structure selection process is to minimize information criteria value, the best of the chosen model specifications are ARDL(1,0,0,0,0,0,0) by SBIC and ARDL(2,0,0,0,0,0,1) by AIC. However, all chosen models show close results and are worth considering.

Following Pesaran et al. (2001), the respective ARDL models were estimated. While the coefficients are not usually interpreted, they are used in the estimation of long-run coefficients if the cointegration is detected. Therefore, it is important to ensure that there is no serial correlation in the residuals. For this purpose, the BG test was applied. It confirmed that there is no serial correlation for all model specifications (see Table 7). As the serial correlation in ARDL estimations has not been detected, the cointegration test can be conducted.

Table 7. Breusch-Godfrey test results

Suggested lag order	p-value
ARDL(1,0,0,0,0,0,0)	0.9257
ARDL(2,0,0,0,0,0,0)	0.9300
ARDL(1,0,0,0,0,0,1)	0.8140
ARDL(2,0,0,0,0,0,1)	0.8294
ARDL(3,0,0,0,0,0,0)	0.8825
ARDL(1,0,0,0,0,1,1)	0.8587
ARDL(1,1,1,1,1,1,1)	0.7962

The Wald test results are presented in Table 8. They confirm the presence of cointegration at the 1% level of significance for all considered model specifications for both cases with restricted and unrestricted intercept.

Table 8. Cointegration (Wald) test results

Restricted intercept			Unrestricted intercept		
Specification	F-statistics		Specification	F-statistics	
ARDL(1,0,0,0,0,0,0)	83.68	***	ARDL(1,0,0,0,0,0,0)	95.60	***
ARDL(2,0,0,0,0,0,0)	63.14	***	ARDL(2,0,0,0,0,0,0)	72.09	***
ARDL(1,0,0,0,0,0,1)	84.66	***	ARDL(1,0,0,0,0,0,1)	96.74	***
ARDL(2,0,0,0,0,0,1)	63.84	***	ARDL(2,0,0,0,0,0,1)	72.93	***
ARDL(3,0,0,0,0,0,0)	49.83	***	ARDL(3,0,0,0,0,0,0)	56.87	***
ARDL(1,0,0,0,0,1,1)	84.10	***	ARDL(1,0,0,0,0,1,1)	96.10	***
ARDL(1,1,1,1,1,1,1)	21.70	***	ARDL(1,1,1,1,1,1,1)	24.80	***

Note: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

The respective UECMs were estimated and diagnosed (see UECM estimation results in Table 15 in Appendix B). The results of the conducted statistical testing are presented in Table 9.

Table 9. UECM diagnosis results

Respective ARDL specification	Test				
	BG	BP	RESET	JB	CUSUM
ARDL(1,0,0,0,0,0,0)	0.926	0.070	0.082	0.000	0.298
ARDL(2,0,0,0,0,0,0)	0.930	0.095	0.089	0.000	0.275
ARDL(1,0,0,0,0,0,1)	0.814	0.056	0.108	0.000	0.252
ARDL(2,0,0,0,0,0,1)	0.829	0.076	0.116	0.000	0.230
ARDL(3,0,0,0,0,0,0)	0.882	0.105	0.092	0.000	0.301
ARDL(1,0,0,0,0,1,1)	0.859	0.025	0.116	0.000	0.331
ARDL(1,1,1,1,1,1,1)	0.796	0.038	0.236	0.000	0.789

Note: the reported numbers are p-values.

The conducted tests did not confirm serial correlation, misspecification or structural breaks for all model specifications. However, Breusch-Pagan test rejected the null hypothesis of homoskedasticity for ARDL(1,0,0,0,0,1,1) and ARDL(1,1,1,1,1,1,1) specifications. This was addressed in further analysis by applying robust standard errors.

The hypothesis of normality was also rejected by Jarque-Bera test. Pesaran et al. (2001) argue that it is not a harmful violation if the number of observations is not too small. The best way to address non-normality is to log-transform the dataset. However, this method is not applicable in this case, as analyzed variables can take negative values. The possible issue is partially addressed by applying robust standard errors.

As the UECM models are validated by the conducted tests, they can be used to capture the short-run coefficients (see Table 10). In the ARDL approach these coefficients are simply extracted from the respective UECM with applying robust standard errors, where needed.

Table 10. Short-run coefficients estimates on external public debt

	ARDL model specification		
Variable	(1,0,0,0,0,0,0)	(2,0,0,0,0,0,1)	(1,0,0,0,0,0,1)
(Intercept)	-0.021	0.046	-0.034
	(0.297)	(0.307)	(0.296)
Trade balance	-0.116	-0.103	-0.105
	(0.101)	(0.104)	(0.101)
Budget balance	-0.489***	-0.495***	-0.496***
	(0.068)	(0.069)	(0.068)
External debt service	-0.163	-0.144	-0.158
	(0.162)	(0.162)	(0.161)
Reserves	-0.661***	-0.673***	-0.663***
	(0.048)	(0.050)	(0.048)
Inflation	0.114**	0.114**	0.113**
	(0.045)	(0.045)	(0.045)
Exchange rate to EUR	-0.005	0.092	0.094
	(0.010)	(0.066)	(0.065)

Note: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. The estimations are presented for the three chosen specifications. See the extended results in Table 16 in Appendix B.

The estimation results fail to reject the null hypothesis on the trade balance coefficient. However, the budget balance and reserves show highly significant negative coefficients. Inflation coefficient is significant at 10% level in all models.

The signs of the resulting coefficients are mostly in line with the initial hypothesis. Both trade balance and external debt service coefficient reflect a relatively low impact on external public debt compared to statistically significant coefficients. However, the coefficient on the exchange rate to euro gives ambiguous results. This may signal that the selected variable is not suitable for capturing the effect of currency volatility on external public debt. One might address the issue by reframing the model to a currency mismatch approach, as reviewed in *Chapter 2*.

The coefficients on statistically significant variables do not vary a lot among the specifications. The highest input to the expected public debt accumulation in a certain period is expected from the reserves. At the same time, the high coefficient on budget balance is expected in Ukrainian context.

5.3. Long-run effects

As the cointegration test confirmed the existence of the long-run relationship for all analyzed specifications, the long-run coefficients can be estimated. Before this final step the respective RECM are analyzed in terms of ECT.

For all estimated models the ECT coefficient is negative and significant at 1% level (see Table 17 in Appendix B). This confirms the long-run relationship existence. As RECT includes short-term coefficients only for the variables with non-zero lag, the coefficients on independent variables are available only for ARDL(1,1,1,1,1,1,1)

specification. The results further confirm the conclusions made in the previous section.

The long-run relationship is defined with the level equation. The coefficients are derived from the models estimated above, and the standard errors are estimated using the delta method. The results are presented in Table 11.

Table 11. Long-run coefficients estimation results

	ARDL model specification		
Variable	(1,0,0,0,0,0,0)	(3,0,0,0,0,0,0)	(1,1,1,1,1,1,1)
(Intercept)	-0.02	0.11	-0.07
	(0.28)	(0.33)	(0.29)
Trade balance	-0.11	-0.12	-0.08
	(0.11)	(0.12)	(0.12)
Budget balance	-0.46***	-0.48***	-0.51***
	(0.09)	(0.10)	(0.09)
External debt service	-0.15	-0.15	-0.01
	(0.14)	(0.16)	(0.21)
Reserves	-0.62***	-0.66***	-0.65***
	(0.07)	(0.11)	(0.07)
Inflation	0.11***	0.11***	0.12***
	(0.03)	(0.04)	(0.04)
Exchange rate to EUR	-0.00	-0.01	-0.01
	(0.01)	(0.01)	(0.01)

Note: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. The estimations are presented for the three chosen specifications. See the extended results in Table 18 in Appendix B.

The results of the long-run relationship estimations are consistent with the short-run estimation results. Coefficients on budget balance and reserves are still highly significant and do not differ greatly from the short-run estimates. At the same time, the inflation coefficient appears to gain statistical significance in the long run.

Unfortunately, the conducted estimations fail to reject the null hypothesis on trade balance coefficient. However, one should not conclude that this variable has no impact on the external public debt accumulation. The possible reason the coefficient is not significant is the relatively small effect of the trade balance on external public debt in comparison to other factors. The same conclusion can be provided for the external public debt service.

5.4. Robustness checks

The conducted robustness checks were performed not only to verify the reliability of the used approach but also to address possible issues identified during the estimation process. Therefore, the break dummy was included in the model to test whether the break points identified in the external public debt time series by Zivot-Andrews and Bai-Perron tests has significant impact on model estimations. Also, trade openness and GDP were included in the model to test the key explanatory variables.

The whole ARDL procedure was repeated for the models with dummy and controls. The lag structure was decided as best model by SBIC. The resulting ARDLs showed no evidence of serial correlation, and the Wald test confirmed the cointegration for all three specifications (see Table 19 in Appendix B). As a result, the estimated short-run and long-run coefficients are presented in Table 20 in Appendix B.

Although the break dummy coefficient is significant at 10% level in short-term, it does not influence the significance or value of the main model estimates. The coefficient on break dummy reflects high positive effect (0.77).

Both trade openness and GDP coefficients show no statistical significance in short- or long-term and do not change the model results.

The overall conclusion of the robustness checks is that the main model shows robust and significant results. The key explanatory variables maintain their statistical significance in models with additional controls.

At the same time, further robustness checks with GDP growth rate or log-transformation of the dataset would be beneficial but are not applicable in the context of the current study.

Chapter 6

CONCLUSIONS AND POLICY RECOMMENDATIONS

In the thesis the relationship between external public debt of Ukraine and its trade balance was analyzed using monthly time series data and ARDL estimation approach. Although the results did not confirm a strong negative between the variables, the estimation results provide several important insights on external public debt accumulation process in Ukraine.

The analysis includes several variables related to international trade that could affect a country's external public debt. Trade openness, discussed in the robustness checks section, showed no statistical significance while suggesting a positive effect on the dependent variable. On the contrary, the trade balance coefficient reflected a negative relationship with the external public debt, although it is also not statistically significant. The negative correlation coefficient between these two variables further confirms that they might have opposite effects on external debt accumulation. The result confirms that the intensification of international trade in Ukraine is often characterized by prevailing import increases and decreases in net exports.

The general conclusion is that international trade while bringing benefits to local consumers, does not influence external public debt accumulation significantly. This means that while enhancing international trade is still an important objective, the government should not focus on simply reaching the positive trade balance. Such an implication might be common for most developing economies with trade deficits.

At the same time, international trade should not be ignored as a possible source of debt repayment. In the thesis, a significant negative relationship between reserves and external public debt is determined. In Ukraine, the reserves are managed by NBU and are mostly formed from internal currency exchange transactions and foreign aid. They can be used to repay the external public debt if the government fails to accumulate the needed resources on time. The high level of reserves also allows government to avoid costly short-term loans and secure the sustainability of external public debt. This conclusion essentially implies that while the trade balance might not influence the external debt accumulation directly, the currency inflows generated by the local exporters might play an essential role in reserves accumulation and thus lower debt risks.

Thus, enhancing Ukraine's producers' participation in the international trade still takes place as a policy implication of the thesis. This includes working with formal and informal barriers such as tariffs, international regulations, licensing etc. The role of Ukrainian government is to negotiate bilateral trade agreements as well as further integration with the European Union.

The analysis also showed a positive impact of inflation on external public debt which became even more significant in the long-term. This highlights the importance of internal monetary policy in the context of external public debt management. While NBU is not responsible for the fiscal and debt policy, its objectives of price and currency stability are tightly connected to external public debt security.

A significant negative coefficient of budget balance suggests that this is the main cause of external public debt accumulation in Ukraine. The budget deficit increases in response to major external shocks. Thus, the full-scale russian invasion, while causing skyrocketing government expenditures, led to alarming external public

debt levels. An obvious recommendation would be to maintain stricter budget discipline. However, in the context of the wartime economy, this solution might not be applicable. A more holistic approach should include the development of internal borrowing instruments. The Ukrainian government has already implemented the mechanism of war bonds. However, it takes a small share in overall public debt and thus does not allow to reduce external borrowing.

In the context of World War II, John M. Keynes proposed his solution to this issue in the paper "How to Pay for the War: A Radical Plan for the Chancellor of the Exchequer" (Keynes, 1940). A general idea is to "delay" part of the consumption to the post-war period. Such a solution was a response to alarming inflation, which took place in the UK at that time. Although Ukraine experienced uncontrollable inflation rates in the first several months of the full-scale invasion, the situation has stabilized. However, the damages and territory occupation caused by russians still influence the macroeconomic situation and households' welfare, therefore not allowing the accumulation of the needed resources internally. In the Ukrainian context, the Keynesian idea can be implemented as "victory bonds" with guaranteed high post-war yields or bonuses indexed to GDP growth. However, foreign financing, both in grant and loan form, still plays the most significant role in the macroeconomic stability of wartime Ukraine.

The estimation results fail to confirm the statistical significance of external debt service, exchange rate to foreign currency, and GDP in the process of external public debt accumulation in Ukraine. However, analogical to the trade balance, these indicators should still be considered when shaping the county's debt policy.

WORKS CITED

Abdullahi, Muhammad Mustapha, Noraznin Abu Bakar, and Sallahuddin Hassan. 2015. "Determining the Macroeconomic Factors of External Debt Accumulation in Nigeria: An ARDL Bound Test Approach." *Procedia – Social and Behavioral Sciences* 211: 745–752. https://doi.org/10.1016/j.sbspro.2015.11.098.

Aizenman, Joshua. 1991. "Trade Dependency, Bargaining, and External Debt." *Journal of International Economics* 31, no. 1–2: 101–120. https://doi.org/10.1016/0022-1996(91)90058-E.

Akinwalere, Susan Nwadinachi. 2017. *An Empirical Analysis of the Determinants of Nigeria's Inward Foreign Direct Investment (FDI) Flows: A Cointegration Analysis*. PhD diss., Oxford Brookes University.

Ayvaz Kızılgöl, Özlem, and Evren İpek. June 2014. "An Empirical Evaluation of the Relationship Between Trade Openness and External Debt: Turkish Case". *International Econometric Review* 6, no. 1: 42-58. https://doi.org/10.33818/ier.278030.

Bacha, Edmar L. 1990. "A Three-Gap Model of Foreign Transfers and the GDP Growth Rate in Developing Countries." *Journal of Development Economics* 32 (2): 279–296. https://doi.org/10.1016/0304-3878(90)90039-e.

Baniata, Atef, Ahmad Alnawasreh, and Faten Nsairat. 2023. "Macroeconomic Determinants of Jordan's External Debt in the Period 1980–2022 Using ARDL." *Investment Management and Financial Innovations* 20 (3): 152–165. https://doi.org/10.21511/imfi.20(3).2023.13.

Beyene, Sisay Demissew, and Balázs Kotosz. 2020. "Macroeconomic Determinants of External Indebtedness of Ethiopia: ARDL Approach to Co-integration." *Society and Economy* 42, no. 3: 313–332. https://doi.org/10.1556/204.2020.00013.

Bittencourt, Manoel. 2015. "Determinants of Government and External Debt: Evidence from the Young Democracies of South America." *Emerging Markets Finance and Trade* 51 (3): 463–72. https://doi.org/10.1080/1540496X.2015.1025667.

Bölükbaş, Mehmet. 2016. "The Relationship Between Trade Openness and External Debt in Turkey: A Cointegration Analysis." *Journal of Balkan and Near Eastern Studies* 2, no. 4: 43–48. https://www.ibaness.org/bnejss/2016_02_04/05_bolukbas_new.pdf.

Breusch, Trevor S. 1978. "Testing for Autocorrelation in Dynamic Linear Models." *Australian Economic Papers* 17 (31): 334–355. https://doi.org/10.1111/j.1467-8454.1978.tb00635.x.

Breusch, Trevor S., and Adrian R. Pagan. 1979. "A Simple Test for Heteroscedasticity and Random Coefficient Variation." *Econometrica* 47 (5): 1287–1294. https://doi.org/10.2307/1911963.

Brown, R. L., J. Durbin, and J. M. Evans. 1975. "Techniques for Testing the Constancy of Regression Relationships over Time." *Journal of the Royal Statistical Society: Series B (Methodological)* 37 (2): 149–192. https://www.jstor.org/stable/2984889.

Bussière, Matthieu, Marcel Fratzscher, and Winfried Koeniger. November 2004. "Currency Mismatch, Uncertainty, and Debt Maturity Structure." *ECB Working Paper Series* no. 409. 10.2139/ssrn.601029.

Butt, Muhammad Sabihuddin, Sabahat Zafar. 2008. "Impact of Trade Liberalization on External Debt Burden: Econometric Evidence from Pakistan." *MPRA Paper* No. 9548,. https://mpra.ub.unimuenchen.de/9548/.

Chaudhary, Muhammad Aslam, and Sabahat Awar. 2001. "Debt Laffer Curve for South Asian Countries." *Pakistan Development Review*, 40, no. 4II (December 1): 705–20. https://doi.org/10.30541/v40i4iipp.705-720.

Chenery, Hollis B., and Alan M. Strout. 1966. "Foreign Assistance and Economic Development." *The American Economic Review* 56, no. 4: 679–733. http://www.jstor.org/stable/1813524.

Claessens, Stijn. 1990 "The Debt Laffer Curve: Some Estimates." *World Development* 18, no. 12: 1671-1677. 10.1016/0305-750X(90)90062-3.

Claessens, Stijn, Ishac Diwan, Kenneth A. Froot, and Paul R. Krugman. 1990. "Market-Based Debt Reduction for Developing Countries: Principles and Prospects". *Policy and Research Series* No. 16. Washington, DC: The World Bank. https://documents1.worldbank.org/curated/pt/449951468739262216/pdf/Market-based-debt-reduction-for-developing-countries-principles-and-prospects.pdf.

Davydenko, Nadiia, Mykola Mykhaylichenko, Zoia Titenko, and Liudmyla Tsiukalo. 2023. "External Debt Management in the System of Financial Security of the State." *WSEAS Transactions on Business and Economics* 20: 144–153. https://doi.org/10.37394/23207.2023.20.15.

Dickey, David A., and Wayne A. Fuller. 1979. "Distribution of the Estimators for Autoregressive Time Series with a Unit Root." *Journal of the American Statistical Association* 74 (366): 427–431. https://doi.org/10.2307/2286348.

Elmendorf, Douglas W., and N. Gregory Mankiw. 1998. "Government Debt." *Handbook of Macroeconomics*. Working Paper w6470. National Bureau of Economic Research. https://www.nber.org/system/files/working_papers/w6470/w6470.pdf.

Fujii, Eiji. 2017. "External Debt and International Trade: Another Mismatch." In *International Currency Exposure*, edited by Yin-Wong Cheung and Frank Westermann, 241–263. Cambridge, MA: MIT Press. 10.7551/mitpress/10939.003.0011.

Godfrey, Leslie G. 1978. "Testing for Higher Order Serial Correlation in Regression Equations When the Regressors Include Lagged Dependent Variables." *Econometrica* 46 (6): 1303–1310. https://doi.org/10.2307/1913830.

Harsono, Edi, Andi Kusumawati, and Nirwana Nirwana. 2024. "External Debt Determinants: Do Macroeconomic and Institutional Ones Matter for Selected ASEAN Developing Countries?" *Economies* 12, no. 1: 7. https://doi.org/10.3390/economies12010007.

J. M. Keynes. 1940. "How to Pay for the War: A Radical Plan for the Chancellor of the Exchequer". *International Affairs Review Supplement*, 19, № 1(June): 34. https://doi.org/10.2307/3026171.

Krugman, Paul. 1989. "Market-Based Debt-Reduction Schemes". *NBER Working Papers* 2587, National Bureau of Economic Research, Inc. https://www.nber.org/papers/w2587.

Krugman, Paul. 1988. "Financing vs. Forgiving a Debt Overhang." *NBER Working Paper Series*, no. 2486. https://www.nber.org/system/files/working_papers/w2486/w2486.pdf.

Kulyk, Svitlana, and Inna Spivak. 2023. "Debt Burden of Central and Eastern European Countries: Are There Risks for Ukraine?" *VoxUkraine*. https://voxukraine.org/en/debt-burden-of-central-and-eastern-european-countries-are-there-risks-for-ukraine.

Kwiatkowski, Denis, Peter C. B. Phillips, Peter Schmidt, and Yongcheol Shin. 1992. "Testing the Null Hypothesis of Stationarity Against the Alternative of a Unit Root: How Sure Are We That Economic Time Series Have a Unit Root?" *Journal of Econometrics* 54 (1–3): 159–78. https://doi.org/10.1016/0304-4076(92)90104-Y.

Lane, Philip R., and Gian Maria Milesi-Ferretti. 2000. "The Transfer Problem Revisited: Net Foreign Assets and Real Exchange Rates." *IMF Working Paper*, no. WP/00/123. International Monetary Fund. https://www.imf.org/en/Publications/WP/Issues/2016/12/30/The-Transfer-Problem-Revisited-Net-Foreign-Assets-and-Real-Exchange-Rates-3671.

Ministry of Finance of Ukraine. 2024. "State Debt and Guaranteed Debt of Ukraine." Accessed October 4, 2024. https://mof.gov.ua/en/derzhavnij-borg-ta-garantovanij-derzhavju-borg.

Nazamuddin, B. S., Sri Sukma Wahyuni, F. Fakhruddin, and F. Fitriyani. 2022. "The Nexus Between Foreign Exchange and External Debt in Indonesia: Evidence from Linear and Nonlinear ARDL Approaches." *Journal of the Asia Pacific Economy*. https://doi.org/10.1080/13547860.2022.2054153.

Omar, Zahir Mohamed, and Mohamed Isse Ibrahim. 2021. "Determinants of External Debt: The Case of Somalia." *Asian Development Policy Review* 9, no. 1: 33–43. https://doi.org/10.18488/journal.107.2021.91.33.43.

Sağdıç, Ersin Nail, and Fazlı Yıldız. 2020. "Factors Affecting External Debt in Transition Economies: The Case of Central Asia and the Caucasus." *International Journal of Management Economics and Business* 16, no. 4: 891–909. https://doi.org/10.17130/ijmeb.853521.

Subrahmanyam, Ganti, and Srinivasa Sundararajan. 1998. "The Three-Gap Theory of Investment and Growth." *Indian Economic Review, New Series* 33 (1): 31–51. http://www.jstor.org/stable/29794150.

Phillips, Peter C. B., and Pierre Perron. 1988. "Testing for a Unit Root in Time Series Regression." *Biometrika* 75 (2): 335–346. https://doi.org/10.2307/2336182.

Tatu, Ştefania. 2014. "An Application of Debt Laffer Curve: Empirical Evidence for Romania's Case." *Romanian Journal of Fiscal Policy* 5, no. 1: 29–38. 10.32996/jefas.2022.4.1.6.

Wald, Abraham. 1943. "Tests of Statistical Hypotheses Concerning Several Parameters When the Number of Observations Is Large." *Transactions of the American Mathematical Society* 54: 426–482. https://doi.org/10.1090/S0002-9947-1943-0012401-3.

Wall Street Journal. August 30, 2023 "Ukraine Secures Financial Reprieve, Agrees $20 Billion Debt Restructuring." *The Wall Street Journal.* https://www.wsj.com/finance/ukraine-secures-financial-reprieve-agrees-20-billion-debt-restructuring-f86a105b.

World Bank. 2024. *International Debt Report 2024*. Washington, DC: International Bank for Reconstruction and Development / The World Bank. https://hdl.handle.net/10986/42444.

APPENDIX A

DESCRIPTIVE STATISTICS

Table 12. Descriptive statistics (extended)

Variable	Observations	Mean	St. Dev.	Minimum	Maximum
External public debt (bn USD)	144	0.56	1.66	- 3.48	7.99
Trade balance (bn USD)	144	- 1.15	1.14	- 4.27	0.78
Budget balance (bn USD)	144	- 0.97	1.55	- 7.72	2.01
External debt service (bn USD)	144	0.37	0.48	0.01	3.16
Inflation (MoM index)	144	1.07	1.75	- 1.40	13.97
Reserves (bn USD)	144	-0.13	1.67	- 6.71	3.80
Exchange rate to EUR	144	29.17	8.89	10.36	45.79
Exchange rate to USD	144	25.85	8.82	7.99	41.75
Trade openness (bn USD)	144	11.22	2.27	5.93	17.50
GDP (bn USD)	144	12.37	3.50	5.11	21.87

Table 13. Correlation matrix of analyzed variables

Variable	External public debt	Trade balance	Budget balance	External debt service	Inflation	Reserves	Exchange rate to EUR	Exchange rate to USD	Trade openness	GDP
External public debt	1									
Trade balance	-0.4***	1								
Budget balance	-0.5***	0.7 ***	1							
External debt service	-0.16*	0.04	-0.04	1						
Inflation	0.11	0.14*	0	-0.03	1					
Reserves	-0.7***	0.13	-0.01	0.19**	0	1				
Exchange rate to EUR	0.32***	-0.5***	-0.4***	-0.02	-0.03	-0.21***	1			
Exchange rate to USD	0.35 ***	-0.6***	-0.4***	-0.05	-0.01	-0.22***	0.99***	1		
Trade openness	0.11	-0.4***	-0.26 **	0.17**	-0.25***	0	-0.1	-0.12	1	
GDP	0.18**	-0.5***	-0.4***	0.17**	-0.3***	-0.05	0.21**	0.2**	0.82 ***	1

Note: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

APPENDIX B

ESTIMATION RESULTS

Table 14. Lag order selection results

Maximum 4 lags allowed			Maximum 12 lags allowed		
Suggested lag order	SBIC	AIC	Suggested lag order	SBIC	AIC
ARDL(1,0,0,0,0,0,0)	416.8	390.1	ARDL(1,0,0,0,0,0,0)	416.8	390.1
ARDL(2,0,0,0,0,0,0)	419.0	389.5	ARDL(2,0,0,0,0,0,0)	419.0	389.5
ARDL(1,0,0,0,0,0,1)	419.3	389.6	ARDL(1,0,0,0,0,0,1)	419.3	389.6
ARDL(2,0,0,0,0,0,1)	421.4	388.9	ARDL(2,0,0,0,0,0,1)	421.4	388.9
ARDL(3,0,0,0,0,0,0)	421.8	389.4	ARDL(3,0,0,0,0,0,0)	421.8	389.4
ARDL(1,0,0,0,0,1,1)	423.6	391.0	ARDL(1,0,0,0,0,1,1)	423.6	391.0
ARDL(3,0,0,0,0,0,1)	424.3	388.9	ARDL(4,0,0,0,0,0,0)	423.6	388.3
ARDL(2,0,0,0,0,1,1)	426.0	390.5	ARDL(3,0,0,0,0,0,1)	424.3	388.9
ARDL(1,0,0,0,1,1,1)	428.4	392.9	ARDL(5,0,0,0,0,0,0)	425.4	387.3
ARDL(3,0,0,0,0,1,1)	428.9	390.5	ARDL(4,0,0,0,0,0,1)	425.6	387.4
ARDL(2,0,0,0,1,1,1)	430.7	392.3	ARDL(2,0,0,0,0,1,1)	426.0	390.5
ARDL(1,0,0,1,1,1,1)	433.0	394.5	ARDL(5,0,0,0,0,0,1)	427.5	386.4
ARDL(3,0,0,0,1,1,1)	433.5	392.2	ARDL(1,0,0,0,1,1,1)	428.4	392.9
ARDL(2,0,0,1,1,1,1)	435.3	393.9	ARDL(3,0,0,0,0,1,1)	428.9	390.5
ARDL(1,0,1,1,1,1,1)	436.5	395.0	ARDL(4,0,0,0,0,1,1)	430.2	389.0
ARDL(3,0,0,1,1,1,1)	438.0	393.8	ARDL(2,0,0,0,1,1,1)	430.7	392.3
ARDL(2,0,1,1,1,1,1)	438.9	394.5	ARDL(5,0,0,0,0,1,1)	432.2	388.1
ARDL(1,1,1,1,1,1,1)	441.4	397.0	ARDL(1,0,0,1,1,1,1)	433.0	394.5
ARDL(3,0,1,1,1,1,1)	441.6	394.4	ARDL(3,0,0,0,1,1,1)	433.5	392.2
ARDL(2,1,1,1,1,1,1)	443.8	396.5	ARDL(4,0,0,0,1,1,1)	434.8	390.7

Table 15. UECM estimation results

	Model specification						
Variable	(1,0,0,0,0,0,0)	(2,0,0,0,0,0,0)	(1,0,0,0,0,0,1)	(2,0,0,0,0,0,1)	(3,0,0,0,0,0,0)	(1,0,0,0,0,1,1)	(1,1,1,1,1,1,1)
(Intercept)	-0.02	0.06	-0.03	0.05	0.12	-0.07	-0.07
	(0.30)	(0.31)	(0.30)	(0.31)	(0.33)	(0.31)	(0.33)
Trade balance$_t$	-0.12	-0.12	-0.11	-0.10	-0.12	-0.11	
	(0.12)	(0.12)	(0.12)	(0.12)	(0.12)	(0.12)	
Budget balance$_t$	-0.49***	-0.49***	-0.50***	-0.49***	-0.49***	-0.49***	
	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)***	
External debt service$_t$	-0.16	-0.15	-0.16	-0.14	-0.16	-0.14	
	(0.16)	(0.16)	(0.15)	(0.15)	(0.16)	(0.16)	
Reserves$_t$	-0.66***	-0.67***	-0.66***	-0.67***	-0.67***	-0.66***	
	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	
Inflation$_t$	0.11***	0.11***	0.11***	0.11***	0.11***		
	(0.04)	(0.04)	(0.04)	(0.04)	(0.04		
Exchange rate to EUR$_t$	-0.00	-0.01			-0.01		
	(0.01)	(0.01)			(0.01)		
External public debt$_{t-1}$	-1.07***	-1.03***	-1.07***	-1.03***	-1.02***	-1.07***	-1.14
	(0.05)	(0.07)	(0.05)	(0.07)	(0.11)	(0.05)	(0.08)
Trade balance$_{t-1}$							-0.09
							(0.13)
Budget balance $_{t-1}$							-0.58***
							(0.12)
External debt service $_{t-1}$							-0.01
							(0.24)
Inflation $_{t-1}$						0.13***	0.14***
						(0.05)	(0.05)

TABLE 15 – Continued

	Model specification						
Variable	(1,0,0,0,0,0,0)	(2,0,0,0,0,0,0)	(1,0,0,0,0,0,1)	(2,0,0,0,0,0,1)	(3,0,0,0,0,0,0)	(1,0,0,0,0,1,1)	(1,1,1,1,1,1,1)
Reserves $_{t-1}$							-0.74***
							(0.10)
Exchange rate to EUR $_{t-1}$			-0.00	-0.01		-0.00	-0.01
			(0.01)	(0.01)		(0.01)	(0.01)
ΔExternal public debt $_{t-1}$		-0.03		-0.04	-0.04		
		(0.05)		(0.05)	(0.08)		
ΔExternal public debt $_{t-2}$					-0.01		
					(0.06)		
ΔTrade balance $_{t}$							-0.09
							(0.15)
ΔBudget balance$_{t}$							-0.49***
							(0.10)
ΔExternal debt service$_{t}$							-0.09
							(0.17)
ΔReserves$_{t}$							-0.67***
							(0.07)
ΔInflation$_{t}$						0.09	0.09
						(0.06)	(0.06)
ΔExchange rate to EUR$_{t}$			0.09	0.09		0.10	0.10
			(0.08)	(0.08)		(0.08)	(0.08)
R^2	0.8321	0.8332	0.835	0.8362	0.8338	0.8357	0.838

Table 16. Short-run coefficients estimation results (extended)

	ARDL model specification					
Variable	(1,0,0,0,0,0,0)	(2,0,0,0,0,0,0)	(2,0,0,0,0,0,1)	(1,0,0,0,0,0,1)	(3,0,0,0,0,0,0)	(1,0,0,0,0,1,1)
(Intercept)	-0.021	0.056	0.046	-0.034	0.115	-0.072
	(0.297)	(0.309)	(0.307)	(0.296)	(0.324)	(0.300)
Trade balance	-0.116	-0.115	-0.103	-0.105	-0.120	-0.112
	(0.101)	(0.104)	(0.104)	(0.101)	(0.108)	(0.101)
Budget balance	-0.489***	-0.488***	-0.495***	-0.496***	-0.486***	-0.492***
	(0.068)	(0.069)	(0.069)	(0.068)	(0.069)	(0.069)
External debt service	-0.163	-0.149	-0.144	-0.158	-0.156	-0.140
	(0.162)	(0.163)	(0.162)	(0.161)	(0.165)	(0.163)
Reserves	-0.661***	-0.670***	-0.673***	-0.663***	-0.671***	-0.663***
	(0.048)	(0.050)	(0.050)	(0.048)	(0.050)	(0.048)
Inflation	0.114**	0.114**	0.114**	0.113**	0.113**	0.089
	(0.045)	(0.045)	(0.045)	(0.045)	(0.045)	(0.056)
Exchange rate to EUR	-0.005	-0.008	0.092	0.094	-0.010	0.101
	(0.010)	(0.011)	(0.066)	(0.065)	(0.012)	(0.066)

Note: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 17. RECM estimation results

Variable	ARDL model specification						
	(1,0,0,0,0,0,0)	(2,0,0,0,0,0,0)	(1,0,0,0,0,0,1)	(2,0,0,0,0,0,1)	(3,0,0,0,0,0,0)	(1,0,0,0,0,1,1)	(1,1,1,1,1,1,1)
ΔBudget balance							-0.49***
							(0.06)
ΔExchange rate to EUR			0.09	0.09		0.10	0.10
			(0.07)	(0.07)		(0.08)	(0.08)
ΔExternal debt service							-0.09
							(0.10)
ΔInflation						0.09*	0.09*
						(0.05)	(0.05)
ΔL(External public debt$_{t-1}$		-0.03		-0.04	-0.04		
		(0.04)		(0.04)	(0.05)		
ΔL(External public debt $_{t-2}$					-0.01		
					(0.05)		
ΔReserves							-0.67***
							(0.04)
ΔTrade balance							-0.09
							(0.15)
ECT	-1.07***	-1.03***	-1.07***	-1.03***	-1.02***	-1.07***	-1.14***
	(0.05)	(0.05)	(0.05)	(0.05)	(0.06)	(0.05)	(0.08)
R2	0.83	0.83	0.84	0.84	0.83	0.84	0.84
Adj.R2	0.83	0.83	0.83	0.83	0.83	0.83	0.83

Note: * p < 0.10, ** p < 0.05, *** p < 0.01.

Table 18. Long-run coefficients estimation results (extended)

	ARDL model specification						
Variable	(1,0,0,0,0,0,0)	(2,0,0,0,0,0,0)	(1,0,0,0,0,0,1)	(2,0,0,0,0,0,1)	(3,0,0,0,0,0,0)	(1,0,0,0,0,1,1)	(1,1,1,1,1,1,1)
(Intercept)	-0.02	0.05	-0.03	0.05	0.11	-0.07	-0.07
	(0.28)	(0.30)	(0.28)	(0.30)	(0.33)	(0.29)	(0.29)
Trade balance	-0.11	-0.11	-0.10	-0.10	-0.12	-0.10	-0.08
	(0.11)	(0.12)	(0.11)	(0.12)	(0.12)	(0.12)	(0.12)
Budget balance	-0.46	-0.47	-0.46	-0.48	-0.48	-0.46	-0.51
	(0.09)***	(0.09)***	(0.09)***	(0.09)***	(0.10)***	(0.09)***	(0.09)***
External debt service	-0.15	-0.14	-0.15	-0.14	-0.15	-0.13	-0.01
	(0.14)	(0.15)	(0.14)	(0.15)	(0.16)	(0.15)	(0.21)
Reserves	-0.62	-0.65	-0.62	-0.65	-0.66	-0.62	-0.65
	(0.07)***	(0.09)***	(0.07)***	(0.09)***	(0.11)***	(0.07)***	(0.07)***
Inflation	0.11	0.11	0.11	0.11	0.11	0.12	0.12
	(0.03)***	(0.04)***	(0.04)***	(0.04)***	(0.04)***	(0.04)***	(0.04)***
Exchange rate to EUR	-0.00	-0.01	-0.00	-0.01	-0.01	-0.00	-0.01
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)

Note: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 19. Breusch-Godfrey and Wald tests results for models with controls included

Control included	ARDL specification	Wald test with restricted intercept F-statistics	Wald test with unrestricted intercept F-statistics	Breusch-Godfrey test p-value
Sep 2022 dummy	(1,0,0,0,0,0,0,0)	76.35 ***	85.87 ***	0.90
Trade openness	(1,0,0,0,0,0,0,0)	73.83 ***	83.03 ***	0.92
GDP	(1,0,0,0,0,0,0,0)	74.10 ***	83.34 ***	0.94

Table 20. Short- and long-term coefficients for the models with controls included

Variable	ARDL model specification		
	ue_D	ue_gdp	ue_tropen
	Short-run coefficients		
(Intercept)	0.325	0.181	-0.067
	(0.343)	(0.432)	(0.596)
Trade balance	0.031	-0.132	-0.113
	(0.125)	(0.104)	(0.108)
Budget balance	-0.464	-0.499	-0.488
	(0.069)***	(0.070)***	(0.069)***
External debt service	-0.153	-0.141	-0.166
	(0.160)	(0.166)	(0.166)
Reserves	-0.658	-0.663	-0.661
	(0.048)***	(0.048)***	(0.048)***
Inflation	0.113	0.104	0.115
	(0.044)**	(0.047)**	(0.046)**
Exchange rate to EUR	-0.015	-0.005	-0.004
	(0.012)	(0.011)	(0.011)
D2022	0.771		
	(0.395)*		
Trade openness			0.004
			(0.040)
GDP		-0.018	
		(0.027)	
	Long-run coefficients		
(Intercept)	-0.062	0.170	0.299
	(0.567)	(0.409)	(0.286)
Trade balance	-0.106	-0.124	0.029
	(0.117)	(0.111)	(0.106)
Budget balance	-0.458	-0.467	-0.427
	(0.089)***	(0.089)***	(0.094)***
External debt service	-0.155	-0.132	-0.141
	(0.146)	(0.142)	(0.146)
Reserves	-0.620	-0.621	-0.604
	(0.074)***	(0.072)***	(0.070)***
Inflation	0.108	0.098	0.104
	(0.035)***	(0.034)***	(0.031)***
Exchange rate to EUR	-0.004	-0.005	-0.013
	(0.010)	(0.008)	(0.009)
D2022	0.003		
	(0.034)		
Trade openness		-0.017	
		(0.022)	
GDP	-0.062	0.170	0.299
	(0.567)	(0.409)	(0.286)

Note: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.