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Томіліна Марія Сергіївна

Керівник: Галицька Е.В.
кандидат економічних наук, професор

Рецензент _Приказюк Н. В._____
(прізвище та ініціали)

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INTRODUCTION

Numerous countries have the objective of preserving the value of their national currencies by maintaining low and stable inflation rates over the medium term, and the central bank of Ukraine shares this aim. The negative consequences of inflationary pressure include reduced income and savings for economic agents, higher production costs, increased loan costs, and servicing expenses, among others. Additionally, unstable inflation patterns create challenges in attracting long-term investments into the economy, thereby adversely affecting economic growth [1].

During the past decades, the Ukrainian economy experienced volatility and unpredictable inflation, which led to a loss of confidence in its currency. This situation resulted in high-interest rates for loans and deposits, widespread use of the US dollar, and an overall unstable economic environment. The fixed exchange rate policy was responsible for this unbalanced macroeconomic situation [1]. As a response, the Ukrainian National Bank introduced de facto inflation targeting in 2016 to ensure the stability of the monetary unit. The monetary policy has been gradually reducing inflation rates to achieve the medium-term inflation target of 5% with a permissible deviation of 1% [2].

The russian invasion of Ukraine had a significant impact on the country's monetary policy framework. Firstly, the exchange rate of the Ukrainian hryvnia to the US dollar was fixed, and the most effective tools for maintaining macro-financial stability became FX interventions and capital controls. During the initial months of the full-scale war, market-based monetary instruments lost their significance in the functioning of the money and foreign exchange markets due to the strong psychological shock. Consequently, the policy rate became a complementary tool, and the inflation-targeting regime underwent significant modifications [3].

To secure households from income and savings losses in hryvnia, make hryvnia assets more attractive, and ease pressure on the FX market, the NBU raised the key policy rate by 25% and resumed active monetary policy in June 2022 [4]. Despite this resolute

step, the effectiveness was limited due to the significant level of liquidity in the banking system and the uneven distribution of liquidity among the banks [5].

Given the modified inflation-targeting regime that Ukraine has been following during the active phase of the Russian-Ukrainian war, the question arises as to what could be done to improve monetary transmission. The NBU has already taken some steps in this direction, but the results have yet to be observed due to time lags.

Therefore, the objective of this thesis is to identify which instruments could reduce inflation in Ukraine with the least amount of GDP losses. Additionally, the thesis aims to develop recommendations for the NBU with the development of the policies using the system of simulative equations to make a short-term forecast of the main macroeconomic indicators, which influence the level of the key policy rate, and the System Dynamics (SD) model that accurately represents the current inflation targeting regime's functioning through the interest rate, and inflation expectations channels.

The tasks of the study are to:

- examine the functioning of the inflation-targeting regime before the full-scale invasion of Ukraine;
- analyze the monetary policy experiences of other countries that have undergone military conflicts during the active phase of the war and post-war periods;
- identify the steps that have been taken to address the factors that have the most significant impact on inflation levels in Ukraine through the transmission mechanism;
- build a valid system of simulative equations to make a short-term forecast of key macroeconomic indicators;
- develop a System Dynamics model that illustrates the inflation-targeting framework in Ukraine before the full-scale invasion and during the active phase of the war;
- generate short- and medium-term forecasts of the inflation rate in Ukraine;
- propose policies that the NBU could adopt to lower inflation to its target rate;

- provide recommendations to the NBU on the effectiveness of decisions and actions in the monetary policy domain.

The focus of this study is on the inflation level in Ukraine, with the subject of analysis being the various factors that impact it. The research will rely on the system of simulative equations and SD modeling as the main methods, with data collected from various sections of the NBU website such as "Macroeconomic Indicators", "Business Surveys", "Statistics of Financial Markets", and "External Sector".

The structure of the work reflects a comprehensive approach to analyzing the inflation-targeting regime in Ukraine, considering both theoretical considerations and practical challenges that the country faced before and after the military invasion. It is divided into an introduction, three main chapters, a conclusion, a list of sources, and appendices. The first chapter provides a thorough overview of the inflation-targeting regime in Ukraine, highlighting its evolution over time and its performance in the face of external shocks. The chapter also draws on comparative analysis, examining the experiences of other countries that have faced similar challenges.

The second chapter takes a more quantitative approach, presenting historical and short-term projected data on key economic indicators. The chapter employs a system of simulative equations, which allows for a rigorous analysis of the factors driving inflation and exchange rate dynamics in Ukraine. This chapter serves as a foundation for the third chapter, which presents the results of a scenario analysis based on the System Dynamics model.

The third chapter presents a set of policy recommendations, considering the trade-offs between short-term and long-term goals, and the potential risks and uncertainties associated with different policy options. The work concludes with a list of sources and appendices, providing readers with additional background information and technical details. Overall, the work provides a rigorous and comprehensive analysis of the challenges facing Ukraine's inflation-targeting regime, offering valuable insights to policymakers.

PART 1 INFLATION TARGETING AS THE MAIN TOOL OF MONETARY POLICY IN UKRAINE

1.1. The foundation and development of the inflation-targeting regime in Ukraine

In 2015, the National Bank underwent a massive transformation by adopting an inflation-targeting framework for conducting its monetary policy. This transition was one of the most significant reforms that Ukraine has ever implemented. However, the adoption of inflation targeting was not without its challenges. Ukraine's economic conditions at the time of the transition were far more adverse than those faced by other countries that had already adopted this framework. Despite these obstacles, Ukraine successfully made the shift to inflation targeting, and it has continued to be a crucial element of its monetary policy ever since.

The fixed exchange regime kept inflation under control for an extended period until 2014, which marked a turning point for Ukraine [6]. The country faced several significant challenges, including an economic crisis, military conflict in the East, and the annexation of Crimea by russia. As a result, the real GDP declined by 6.8% due to falling domestic and weak external demand. This led to a sharp increase in demand for foreign currency, coupled with a drop in exports, resulting in a rapid devaluation of the hryvnia [7]. In 2015, the IMF intervened to rescue Ukraine, and one of the reforms implemented was the transformation of the NBU to an inflation-targeting regime [8].

In the Monetary Policy Fundamentals for 2015, the NBU prioritized achieving and maintaining price stability in the country. To ensure predictability in long-term economic planning and managerial decision-making, it is necessary to maintain low and stable inflation rates over three to five years. The NBU aimed to reduce inflation to 5% per year as a medium-term objective, with an acceptable deviation of one percentage point [9].

Figure 1.1. The timeline of Inflation Targeting regime adoption in Ukraine

Stage I – Set up of technical preconditions	
Before 2015	▪ Development of macroeconomic models; ▪ Implementation of a quarterly forecasting cycle; ▪ The initiation of the reform in the NBU.
Stage II – Set up of institutional preconditions	
1st half of 2015	▪ Modifications to the decision-making process for monetary policy; ▪ Establishment of the Monetary Policy Committee; ▪ Release of the Inflation Report; ▪ The Draft of Monetary Policy Strategy for 2016-2020.
Stage III – Implementation of the inflation targeting regime	
2nd half of 2015 - 2016	▪ Adoption of the Road Map for IT Implementation in Ukraine; ▪ Pursuing monetary policy to ensure price stability; ▪ Decision-making based on a predetermined schedule; ▪ Establishment of a systemic approach to communicating monetary policy; ▪ New operational design of market interest rates management.
The NBU Council officially approved the Inflation targeting regime in December 2016	

Source: made by the author based on information provided by the NBU [2]

In March 2016, the NBU released a roadmap for implementing inflation targeting over the next 12-18 months. The Monetary Policy Guidelines established inflation targets for the consumer price index, starting at a 12% annual increase with a 3% deviation and ending at a 5% annual increase with a 1% deviation by the end of December 2019. The NBU emphasized that the inflation target is unchanging, unlike inflation forecasts which are subject to revision based on actual economic developments. The central bank would use monetary policy instruments to keep inflation projections on track.

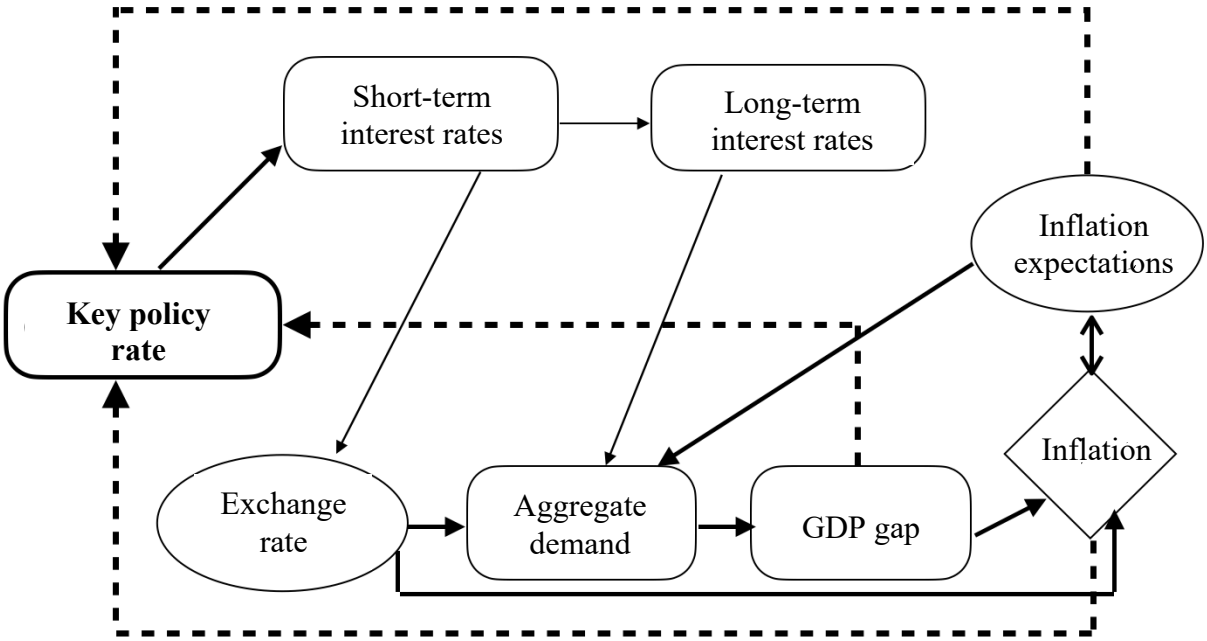
The NBU has been working on implementing inflation targeting since 2015, focusing on building macroeconomic models, designing quarterly forecasts, and modifying monetary policy decision-making mechanisms. The third stage of reform, the implementation of inflation targeting, began in the second half of 2015. The NBU also affirmed its independence in selecting monetary policies to achieve price stability and ensured that there would be no fiscal dominance [10].

The NBU employs the key policy rate as its primary tool for controlling inflation. This rate is regularly reviewed, and decisions may involve leaving it unchanged, increasing it, or decreasing it [6]. The NBU adjusts the key policy rate to align with its inflation targets. Unlike the prevailing trend in inflation, the regulator uses inflation forecasts to determine the key policy rates for the next six weeks [11].

In addition to using the key policy rate to control inflation, the NBU employs foreign exchange (FX) market interventions as an extra monetary policy tool. These interventions aim to maintain international reserves at sufficient levels, reduce exchange rate volatility, and support key policy rate transmission. However, it is worth noting that FX interventions cannot guarantee a specific exchange rate due to the flexible exchange rate regime in Ukraine. The NBU may also use other methods, including banks' required reserves, repo, and swap transactions, and purchasing or selling government bonds, to achieve its goals [12].

The monetary transmission mechanism in Ukraine operates through several channels, with varying degrees of intensity [13]. Changes in the NBU's key policy rate impact interbank interest rates, which then affect aggregate demand and inflation, primarily through changes in household and business expectations. The transmission process takes time, typically 9 to 18 months, which is why the regulator bases its policy decisions on future expectations rather than past events. To enhance monetary policy transmission, the NBU implements a consistent inflation-targeting policy that effectively manages expectations [6]. Figure 1 provides a summary of the information discussed, highlighting the functioning of monetary policy in Ukraine.

Figure 1.2. The transmission mechanism of the NBU's monetary policy



Source: made by the author based on information provided by the NBU [6]

As the interest rate is the primary tool of the central bank, we begin our analysis by focusing on the interest rate channel. The initial step of it is the impact of a modification in the key policy rate on short-term money market rates, specifically the interbank market. Central banks usually succeed in regulating short-term rates by managing bank liquidity. In the event of a liquidity surplus, they absorb excess liquidity. It is possible to achieve this by either selling the deposit certificates or government securities from the NBU`s portfolio or carrying out reverse repo transactions. In case of a liquidity deficit, they inject funds into the banking system by providing loans to commercial banks and accepting liquid collateral. Furthermore, the NBU may also purchase government securities for its portfolio or engage in repo transactions [6].

The NBU communicates its preferred rate level for achieving its monetary policy objectives by setting the key rate. It conducts its transactions based on this key rate to align market rates closer to the desired level. Specifically, when there is a liquidity surplus, the NBU's primary operation involves selling two-week certificates at the same rate as the

key policy rate. Moreover, to mitigate market volatility, the NBU also utilizes standing facilities such as certificates of deposit and overnight loans (1 percentage point below/above the key policy rate).

Besides, the central bank can exert prompt and effective control over short-term interbank rates if it does not impose any additional limitations when attracting or issuing short-term facilities. Commercial banks can engage in transactions with either the NBU or with each other, causing short-term interbank rates to generally fall between the central bank's rates for deposit certificates and overnight loans and remain near the key rate [6].

Nevertheless, medium- and long-term interest rates play a crucial role in influencing economic processes by directing temporarily free funds to where they are needed within the banking system. These rates depend on various factors, including short-term interbank rates, competition within the banking system, inflation expectations, demand for loans, etc.

After the NBU adjusted the short-term rate management system in 2016–2017, the relationship between short-term interbank rates and rates on bank loans and deposits strengthened considerably, leading to decreased volatility of short-term rates, and providing banks with a reliable indicator of money value in the market [6].

Besides, the change in interest rates on bank loans and deposits leads to a shift in economic agents' preferences for current consumption, investment, and savings. Rising interest rates tend to encourage savings and reduce investments, which could result in a slowdown of inflation and/or deflation due to a decrease in aggregate demand [13]. This has been supported by the experience of developed countries and developing economies, including a study of the MTM in the Czech Republic, Poland, and Hungary that points out the specifics of transitional economies that switched from a fixed exchange rate to inflation targeting [14].

Some methods can be used to assess the effect of changes in market rates on the components of aggregate demand. For example, the National Bank of Poland uses vector autoregression (VAR) models and semi-structural and structural models [15]. While most

models show the existence of transmission, the quantitative results vary. Another way to study the effect of changes in market interest rates on their investment decisions is the usage of data from companies' balance sheets (this method is embraced by the Central Bank of Hungary [16]). In the case of Ukraine, it is worth assessing the effect of the monetary transmission mechanism using several models, including macro models and micro analyses of individual transmission chains. At the same time, the short data sample since the country`s transition to inflation targeting complicates the use of econometric models, and the problem of a short data sample can be mitigated somewhat with assumptions for how the relationship between some variables had been changing after the launch of inflation targeting [13].

In addition to the information mentioned above, the short-term interest rates also impact long-term rates on the financial market, particularly yields on government securities, which are the safest debt instruments, and whose yields serve as a benchmark for investors to assess the return and risk of investing in other securities. The maturity of domestic government bonds varies from several months to years and yields on these bonds of different maturities from the yield curve, which illustrates the relationship between yield and investment term [6].

In the research of Oleksandr Zholud, Volodymyr Lepushynskiy, and Sergiy Nikolaychuk, "The Effectiveness of the Monetary Transmission Mechanism in Ukraine since the Transition to Inflation Targeting," there was a model that estimates the pass-through level of interest rate changes to short-term business loans in Ukraine. The authors of this paper discovered that there is a significant relationship between short-term business loan rates and overnight and key rates (0,92). Moreover, the model indicated a weekly pass-through level of 19%, while the expected long-term transmission should be 15%, suggesting that other factors also impact interest rates. When the researchers used only 2017 data, the model represented a more significant short-term effect, but with lower statistical significance for most coefficients. Nevertheless, market interest rates still have a weak impact on aggregate demand and, therefore, on inflation in Ukraine due to factors

such as lower financial depth and high volatility in nominal and real interest rates during a long period of high and volatile inflation [13].

If we look at the research conducted on monetary transmission in Poland via the interest rate channel, it has been discovered that the key policy rate fully transmitted to money market rates in all cases except short-term interbank rates, which were affected by the global financial crisis of 2008-2009. The further transmission of money market rates to interest rates on business and individual deposits indicated full long-term transmission for all except short-term deposits, which was also affected by the crisis. There was incomplete transmission to interest rates on property loans for individuals, while the transmission to loan interest rates for businesses was statistically higher than one [17].

Moreover, the paper "The Effectiveness of the Monetary Transmission Mechanism in Ukraine since the Transition to Inflation Targeting" emphasized the yield curve concept that lies at the intersection of the interest rate and expectations channels. In Ukraine, the NBU handles the short end of the yield curve, which includes overnight deposits and 14-day certificates of deposit, while the Finance Ministry handles the DGBs with maturities ranging from 6 months to several years [13].

While the government securities market has grown in volume and liquidity over the past few years, it remains relatively shallow. Therefore, the key interest rate is transmitted quickly and completely to government security yields. Despite this, there is still a significant gap between the yield on government securities and the interest rates on individual deposits due to the low level of engagement. In the future, there will no longer be any arbitrage opportunity for the DGB market as it grows.

International experience shows that the establishment of the first stage of monetary transmission and the adoption of inflation targeting both help increase the sensitivity of aggregate demand to interest rate changes. Gradual resumption of lending, further expansion of the DGB market, and lower dollarization are important factors that can also help strengthen the effect of changes in market interest rates on aggregate demand and inflation [13].

The second monetary transmission channel is the key policy rate transmission via the exchange rate. In general, in economies with open capital flows, the exchange rate channel enables borrowing at lower interest rates in one country and investing in another with higher yields. If the key policy rate increases, it can attract foreign currency inflows, increase demand for domestic currency, and strengthen it. The issuance of government bonds with different yields in hryvnia and foreign currency in Ukraine means that rate changes can affect the balance between supply and demand for both types of bonds, as well as influence the choice between domestic and foreign currency deposits. This, in turn, can impact the exchange rate [6].

The CPI in Ukraine includes imported and domestically produced goods that compete with imports. When the hryvnia strengthens against the dollar, the cost of imported goods decreases, while local products become more expensive in dollar terms, making them less competitive on global markets. As a result, inflation may decrease, but the trade balance could worsen [6].

Even though no studies have been conducted on the effects of changing interest rates or foreign currency interventions on exchange rates in Ukraine, there seemed to be a strong correlation between monetary policy decisions and exchange rate trends, as was observed in the rate hike cycle in 2017-2018.

After exceeding the inflation targets for 2017 and 2018, the NBU began a cycle of tightening monetary policy by increasing the key rate in October 2017. As a result of the increase in the key rate, yields of domestic government bonds (DGBs) went up in early 2018. Before the rate increase in January-November 2017, DGBs with a one-year term accounted for less than 600 million UAH per month in average placements. During January-February 2018, DGB placements increased by more than ten times, with yields increasing by around 1.6 percentage points. Foreign currency inflows strengthened the Ukrainian currency's exchange rate between 1 January and 28 February [13].

Analyzing the second stage of this transmission channel, historically, the exchange rate and inflation have had the strongest correlations and fastest transmissions in Ukraine.

It is partly due to the country's long history of hard currency pegs that the public pays so much attention to exchange rates. In contrast, the Ukrainian economy is characterized by high levels of openness and dollarization, and it has also an impact on the existence of this strong correlation between inflation and changes in the value of Ukrainian hryvnia to USD [13].

As for inflation transmission, the study was conducted by Oleksandr Faryna, and the researcher used a panel autoregressive model with distributed lags to study the nonlinearity of transmission effects. The results of his study demonstrated that significant devaluations (more than 16% per quarter) lead to a high pass-through (0.2-0.3 during 12 months). Nevertheless, mild exchange rate fluctuations (between 3 and 16%) pointed out no significant impact on inflationary processes. At the same time, inflation was found to have very low elasticity under conditions of strengthening exchange rates [18].

In another research, the effects of anticipated and unanticipated changes in the exchange rate were compared. The industrial and agricultural sectors were observed, and there were found no reactions to expected changes in the nominal effective exchange rate (NEER) and unanticipated changes in NEER had a negative effect. The currency floating, as it has been in Ukraine before the full-scale invasion, also strengthens the impact of unanticipated changes in exchange rates [19].

A foreign currency's role in the assets and liabilities of economic agents is another important aspect of the exchange rate channel. As household and company assets and liabilities are mostly held in foreign currencies, primarily US dollars and Euros, exchange rate fluctuations impact balance sheets significantly [13].

During times of economic growth and crisis, the hryvnia's real exchange rate has been observed to strengthen and weaken, respectively. These trends are primarily driven by capital flows and foreign currency loans used for capital and production financing. When capital inflows increase, the hryvnia strengthens in real terms, reducing foreign-currency loan costs and increasing corporate assets. This balance sheet effect leads to increased investment and production activity, as well as lower costs for imported

investment goods and increased household purchasing power. However, this strengthening weakens price competitiveness and reduces net exports, resulting in a widening foreign trade deficit during periods of economic growth. Conversely, during crisis periods, the opposite trend occurs. Despite these fluctuations, the impact of exchange rate changes on economic activity in Ukraine is limited due to the offset effect of other channels [13].

Another monetary transmission channel, which plays a significant role in Ukraine, is the expectations channel. The transition to inflation targeting has resulted in a significant and rapid decline in inflation expectations after the crisis, with clear and irrevocable inflation targets declared in mid-2015. The NBU has still been viewed with low trust considering its history and the experiences of the most recent currency crisis in 2014-2015, and, as a result, inflation expectations remain much higher than its targets. Based on Coibion and Gorodnichenko's study, inflation expectations are significantly influenced by currency exchange rates [20].

Since mid-2016, inflation expectations have remained largely stagnant, despite a temporary but significant increase in actual inflation. To sum it up, if the public trusts the NBU's monetary policy, it is possible to anchor them at a lower level [13].

Interest rate hikes by the NBU in October 2017 - March 2018 increased trust in monetary policy and enhanced the capacity of the expectations channel, despite their unpopular nature. Another factor in the success of the NBU's communication strategy regarding monetary policy was its use of best communication practices. The following elements have been introduced since 2015 as standard features for inflation reduction:

- Public meetings by the NBU Board on monetary policy are held eight times a year since 2018;
- Announcing each monetary decision via a press release or press briefing featuring the regulator's members;
- Issuing of the Inflation Report along with the macroeconomic forecasts by the NBU;

- Release of Monetary Policy Committee discussion summaries [13].

In the research "The Effectiveness of the Monetary Transmission Mechanism in Ukraine since the Transition to Inflation Targeting", to determine the rationality of economic agents in Ukraine, the following hypotheses were tested:

1) *A central bank's key rate changing unanticipatedly harms long-term forward rates* according to Rezessy [21]. When the regulator raises its key rate to respond to rising inflation, government securities' yield curves tend to slope upward. Consequently, central banks lower long-term forward yields by taming inflation in this manner.

The analysis of this hypothesis is based solely on anecdotal evidence due to the limited availability of data. A four-step increase in the key rate was carried out by the NBU in the period from October 2017 - March 2018. There were no expectations for the first two hikes among financial analysts. As a result, the market learned the National Bank is prepared to defend its inflation target, despite not expecting a tightening of policy in the past. This resulted in a rise in current yields on DGBs whilst forward rates remained flat or declined. The market considers the NBU's behavior when determining whether this channel is effective [13].

2) *There is no consideration for current price trends in inflation expectations, or they are unbiased.*

To examine this hypothesis, the inflation expectations for the following year in the division of months were compared with actual values of inflation in 12 months, using the mean forecast error (ME), the mean absolute percentage error (MAPE), and the root mean square error (RMSE). According to Ranchhod, bias might exist when forming expectations, as indicated by the mean error that considers the deviation sign [22].

Understatement of expectations is suggested by a negative error, which was observed for all respondent groups except firms, where it is positive but nearly zero. This tendency towards underestimating inflation was a consequence of unforeseen shocks that hastened inflation during the survey period, especially in 2015 and to a lesser extent in 2017. Despite this, the results were encouraging as the expectations had not been anchored

at high levels of actual inflation and were expected to decrease. Those expectations can be anchored more closely to the inflation target as we gain experience with inflation targeting. Moreover, it was found that respondents consider factors other than current inflation when forming their expectations [13].

3) *The inflation expectations are influenced by forward-looking inflation, not backward-looking.*

First of all, it is necessary to mention that some quantitative analyses suggest that inflation expectations are not rational not only in developed countries like Sweden but also in developing countries like India [23-24].

Based on the results of the research, it was discovered that there is a future-oriented component to the expectations of all economic agents. It is no surprise that financial analysts are highly future-oriented, as they associate future inflation expectations with future inflation rates. Their forecasting skills are better, and they already know the NBU's monetary policy goals. In contrast, current inflation indicators primarily determine other economic agents` expectations [13].

A thorough examination of the expectations channel would have been possible but isn't available right now due to the lack of detailed studies of Ukraine's wage and pricing mechanisms and the effects of monetary policy on them. Additionally, short survey periods (especially for inflation targeting periods) would permit accurate estimates of expectations.

Based on the available data on inflation expectations, Ukrainian researchers found that these expectations are a function of not only current and backward-looking inflation but also future inflation expectations. It is also necessary that economic agents are better at making predictions than simply using naïve forecasts. This mainly applies to skillful analysts, who already have a superior level of understanding of regulator goals and the way it conducts its monetary policy. Enterprises and households still have weak links to the NBU's inflation target in terms of their inflation expectations. It is due to the initial

low level of trust, the short time of inflation targeting regime work in Ukraine, and considerable inflation shocks of recent years [13].

Taking a consistent monetary policy for a long time can lead to inflation expectations anchored near the NBU's inflation target, according to the study's results. A more comprehensive analysis would be possible with more data, especially for timeframes during which the NBU used inflation targeting as a basis for monetary policy [13].

Moreover, it is necessary to mention that there are two monetary transmission channels, which don`t have such power in Ukraine as the three previous ones. They include credit and asset channels.

In general, the credit channel theory suggests that tighter monetary policy increases the premium for external financing due to imperfections in the credit market, such as the principal-agent problem and information asymmetry. Borrowers have a better understanding of their investment project's success chances than creditors, leading to a risk premium on all types of external financing. This results in adverse selection and moral hazard, causing a gap between the cost of external and internal funds. Therefore, an increase in the central bank's key rate decreases aggregate demand and loan supply.

A credit channel consists of two components: the lending channel and the balance sheet channel. They operate differently. In the lending channel, credit resources in the banking sector are reduced by tighter monetary policy. On the other hand, the balance sheet channel relies on the financial accelerator principle, where changes in interest rates have a direct impact on cash flows and collateral values. Hence, as interest rates increase, net worth decreases, and external financing premiums increase [13].

However, the credit channel's contribution to the monetary transmission mechanism in Ukraine is not outstanding, as evidenced by recent studies. Commercial banks prefer to finance reliable borrowers despite monetary conditions, particularly those affected by the armed conflict [25]. Additionally, institutional factors, such as poor creditor rights protection, restrict the fast resumption of lending. As well, large corporations can borrow from their parent companies and issue Eurobonds instead of

borrowing from banks. Moreover, the corporate sector's dependence on bank lending has reduced in recent years, financing only 5.3% of investments in 2017 [13].

Another monetary transmission channel is the asset one. In theory, it works the following way: a central bank's key rate hike leads to a decline in asset prices, particularly bonds (yield increase), stocks, financial derivatives, and commodity futures. These prices serve as the foundation for consumer prices, collateral appraisal (especially real estate), and real estate prices themselves. As a result, asset prices affect consumption through the wealth effect and liquidity of households [26].

However, the asset price channel works best in countries with developed stock and commodity markets, like the US, and has limited capacity in Ukraine. The main reason for it is that the stock market in Ukraine is still in an early stage, with stocks playing no significant role in household financial assets. Similarly, government securities account for only UAH 36,1 billion in the circulation of individuals (2,5% of total DGBs outstanding) and UAH 115,7 billion – legal entities (8,1% of total DGBs outstanding) as of May 1, 2023 [27]. Real estate plays a more significant role in household assets, but the almost non-existent commercial bank activity in mortgage lending limits the asset price channel's capacity via real estate prices [13].

The asset price channel's effect may be noticeable to some extent via substantial amounts of foreign currency held by households as savings. A tighter monetary policy that strengthens the hryvnia exchange rate reduces the real value of household savings in foreign currency. This may affect households' long-term consumer and investment decisions.

In summary, the NBU has been successful in implementing the inflation-targeting regime and resolving the banking system crisis since 2016. Research conducted by Ukrainian scholars has shown that the interest rate, exchange rate, and expectations channels have been effective. However, the credit channel remains ineffective, and the asset price channel is underdeveloped. The reasons for this include an underdeveloped financial system, low stock market development, and the limited role played by long-term

investment institutions such as pension funds, as well as historical factors such as high and volatile inflation, low trust in the central bank, and structural changes.

1.2. The foreign experience of monetary policy during armed conflicts

During a crisis, the objectives of a monetary policy shift to address the unique challenges presented by a military economy (see Appendix A). In such an economy, government expenditure rises, and the state's role in the economy becomes more prominent. Furthermore, economic decisions are dominated by security concerns, and the economic multiplier effect is limited due to the destruction caused by war [28].

If we look at the Federal Reserve System of the U.S. when World War II outbroke, the challenges for dealing with a considerable surge in the federal deficit due to increased war expenditures occurred even though the Treasury depended more on taxes than it did during World War I and even with the rise in tax revenue due to the significant growth in industrial production [29].

To promote stable financial markets and reduce interest rates on financing large deficits, the FRS controlled government bond prices and established a maximum yield. The FRS`s commitment to maintaining low yields resulted in the purchase of a significant volume of government securities, producing a substantial expansion of the Federal Reserve System’s balance sheet and the monetary base (by 149% from August 1939 to August 1948). Moreover, the outbreak of war in Europe led to an acceleration of gold inflows as Britain and other allies paid for domestically produced war materials and supplies by shipping gold to the United States. This, along with another contributing factor, resulted in a strong expansion of the monetary base and the money supply. As a result, inflation rose significantly during the war despite price and wage controls, and consumer credit controls were imposed to curb inflation [29].

The Federal Reserve System used various tools to control private sector spending and curb inflation during the government bond support program. They imposed direct

controls on consumer credit and increased the reserve requirements of commercial banks. The controls on consumer credit aimed to reduce the demand for consumer durable goods, while the increase in reserve requirements aimed to restrain credit growth and expansion of bank liabilities, but it had only a minor effect on the money supply and the price level. And it took six years after the war ended for monetary policy to regain its independence from the Treasury through the Treasury-Federal Reserve Accord [29].

For many years, reserve requirements were an important part of US monetary policy, but since the Treasury-Federal Reserve accord, more emphasis was placed on open market operations. Selective credit controls, except on stock exchange securities, were not a permanent part of monetary control. However, the US did not face the same reconstruction or payment difficulties as other countries, and its simple monetary policy techniques combined with budget surpluses facilitated steady economic growth and high employment. Although there had been no direct controls for most postwar years, the US experienced moderate price increases compared to other countries [30].

If we look deeper into the foreign experience of countries who took part in World War II, Belgium was one of those that the fastest returned to economic liberalism by using monetary policy, which was consistent with the country's prevalent liberal philosophy. The government employed the orthodox method of changing the discount rate to great effect. Belgium undertook a monetary purge in October 1944 to reduce the money supply by blocking part of the currency and bank deposits. Besides, the banking system's liquidity was attacked to avoid excessive expansion of bank credit. Banks were required to keep 50 to 65% of their demand deposits as cash or government securities, and this provision has remained in force with minor modifications. The use of the discount rate technique began in January 1945 when the rate was lowered from 2 to 1.5% to promote the revival of production and the replenishment of stocks. The rate was gradually raised as the economy recovered and lowered during an economic recession in 1949. The central bank also set up a system of certified bank acceptances for imports and exports, which had been

developed considerably and become the basis for charging different discount rates for different types of bank paper [30].

Analyzing the Netherlands and its experience with monetary policy after World War II, the country faced latent inflation with a money supply four times larger than in 1938, and wholesale prices 80% higher than prewar levels in May 1945. The government tried to tackle the problem in September 1945 by withdrawing and blocking all currency and deposit money. The idea was to gradually deblock old accounts to provide means of payments for current contributions to production. However, the deblocking of old money and assets together with the creation of new money led to the re-emergence of latent inflation in the early postwar years. Control over bank credit was exercised, with banks not allowed to give credit to anyone still holding blocked accounts. The discount rate remained at the 1941 level of 2,5%, and banks were not subject to reserve requirements. The mainstay of credit control was direct quantitative control. By 1949, the ratio of the money supply to national income had been restored to the 1938 level, and the excess money supply had been worked off with the help of rising prices and import surpluses [30].

Looking back at Germany after World War II, Germany demonstrated economic achievements since the currency reform of 1948, attributing them to a combination of monetary policy and generous U.S. assistance. Employment in industries has increased by over 20% and industrial production has more than doubled since then, while real wages have increased along with productivity. Germany achieved a small balance of payments surplus and a commanding cumulative surplus with EPU by 1952. Despite a remaining unemployment rate of 1.1 million people, the country's progress should be judged against the backdrop of a rise in employment and real wages and the influx of millions of refugees from Eastern Germany.

France pursued an active monetary policy since World War II but faced unique economic challenges including persistent budget deficits, political instability, and social tensions. To combat inflation, France implemented an elaborate system of quantitative

and qualitative controls over credit. However, as inflationary pressures continue to be generated, massive wage and price increases become inevitable. French monetary policy in the early 1950s was characterized by periodic attempts to patch up loopholes in existing credit controls while acknowledging the need to raise the lid on credit in response to inflation [30].

After World War II the United Kingdom's monetary policy changes represent a more complete return to monetary orthodoxy compared to other countries. The new monetary policy relied on controlling bank liquidity to restrict the availability of bank credit, without using statutory reserve requirements or keeping interest rates low. The fear of increasing the cost of government debt had been set aside for a flexible monetary policy. Besides, short-term government paper interest rates increased to encourage banks to hold short-term government investments. Qualitative credit controls were used along with indirect pressure on banks during refinancing operations [30].

It is common and effective to peg the exchange rate at the start of military activities to stabilize macro-financial conditions. For instance, in 2008, the Georgian central bank stabilized the foreign exchange market by fixing the lari to the USD during the summer and autumn months. However, to achieve this, they had to devalue the domestic currency by 16% and stabilize the exchange rate at a new level through foreign exchange market intervention [31]. Similarly, Israel used various forms of pegging the shekel with varying degrees of success since 1985 but only introduced a floating exchange rate in June 2005 [32]. However, keeping the exchange rate fixed for an extended period can result in accumulating macroeconomic imbalances, as the effect of stabilizing the exchange rate diminishes over time. This fact is exemplified by the negative experiences of Libya (between 2016-2020) and Lebanon (in 2020) [33-34]. It is also worth noting that foreign exchange crises can occur even in peacetime if the exchange rate remains fixed for too long, as was the case in Chile, Mexico, and Thailand [35-37].

It is important to consider the link between war financing and monetary policy. War can be financed through various means, including tax increases, borrowing from domestic

and foreign markets, receiving financial aid from other countries, and borrowing from the banking system. However, when central banks finance a large portion of the budget deficit, it often results in hyperinflation, high levels of dollarization, and, in some cases, the loss of monetary sovereignty. This was demonstrated after the First World War in countries such as Germany (where inflation reached 29,500% month-over-month in October 1923), Austria (which experienced 129% month-over-month inflation in August 1922), Poland (with 275% month-over-month inflation in October 1923), and others [38]. Similar experiences occurred after the Second World War in Japan, Hungary, and again in Germany and Austria. South Korea also experienced high inflation during the Korean War (213% year-over-year in 1951), and Israel experienced a surge in inflation after the Lebanon War (480% year-over-year in November 1984) [39].

To recover from wartime crises, many countries have found success in abandoning monetization and adopting a more independent monetary policy, fiscal consolidation, and market financing. Two examples of successful programs were implemented in Israel and Croatia [3]. Israel's program, for instance, significantly reduced annual inflation from 480% to 18% in the mid-1980s through a combination of fiscal consolidation (such as subsidies reduction, new tax introduction, and limiting civil servants), tight monetary policy, and structural reforms [40]. Similarly, Croatia introduced a comparable program in 1993 after annual inflation surpassed 1000%, implementing measures such as tight monetary policy, fiscal adjustments (such as increasing tax revenue and reducing state budget expenditures), and structural reforms (such as accelerating privatization and demonopolizing the economy) [41]. Both countries limited the central bank's financing of the government and, with the collaboration of the government and central bank, successfully controlled inflation and stabilized inflationary expectations, leading to economic growth [42].

Therewith, natural disasters have effects like military conflicts, causing a loss of capital and productivity. Macroeconomic modeling shows that the optimal response of a central bank to a rise in inflation caused by natural disasters is monetary policy tightening.

Empirical evidence also shows that central banks of developed countries and those pursuing inflation or other monetary targets tend to react to natural disasters by raising their interest rates, which is more successful in stabilizing output and inflation after a disaster than countries with other monetary regimes [3].

1.3. The peculiarities of monetary policy during the war in the example of Ukraine

Based on the information provided above, Ukraine followed a similar path to other countries when the NBU chose to peg the exchange rate of hryvnia to USD during the onset of the invasion. This move was made by the regulator to maintain stability in economic agents' expectations and thereby ensure macro-financial stability during the war. In addition, the fixed exchange rate played a vital role in controlling inflation [3].

FX interventions have become the main monetary policy instrument in Ukraine during the war. By imposing FX restrictions and intervening in the interbank market to cover the remaining FX deficit, the NBU was able to fix the exchange rate [4]. Also, certain restrictions were imposed on some FX transactions and capital movements (see Table 1.1). In such a way, NBU has wanted to prevent nonproductive capital outflows, thereby limiting foreign exchange demand.

At the same time, in the first several months of the full-scale invasion, the regulator decided to postpone its decisions regarding the key policy rate and left it unchanged at 10% till the beginning of June 2022, when the Board of the NBU raised the key policy rate to 25% [4, 44].

Table 1.1. Restrictions imposed on FX transactions and capital movements

	Operations	Feb.24	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct till now
Individuals	FX cash withdrawals from FX accounts	**X** Full ban	UAH 30K/day → UAH **100K/day**							
	Cash withdrawals abroad from UAH accounts	**V** No limit	**cap** → UAH 100K/month		**cap** → UAH 50K/month		**cap** → UAH **12,5K/month**			
	Settlements abroad with hryvnia cards	**V** No limit					**cap** → UAH **100K/month**			
	P2P card transfers	**V** No limit	**cap** → UAH 100K/month				**cap** → UAH 30K/month			**X** Full ban
	FX cash purchases from banks	**X** Full ban		**cap** → cash currency purchased by banks			+ **50%** of noncash FX purchased from individuals		**+ 100%** of noncash FX purchased from individuals	
	Online FX purchases	**X** Full ban					**cap** → UAH 50K/month + deposit for 3 months			**cap** → UAH **100K/month** + deposit for 3 months
	ER for card payments	**cap** → official + 1%		**cap** → official + 10%	**cap** → **no restrictions**					
	Swift payments abroad	**X** Full ban								
Corporates	Import payments	List of critical imports:	Goods ~ 65% Services 0%	→ **allowed** →		Goods ~ 90% Services ~ 30%	Goods → **100%** (no restrictions) Services → ~ **50%**			
	Deadline for settlement of export-import transactions	365 days		→ 90 days		→ 120 days	→ **180 days**			
	Repayments of debts	X Full ban							Interest payments are **allowed**	
Banks	FX open position	15% → **5%**								
	Repayments of loans to non-residents	Early payments are **prohibited**								

Source: Inflation Report, October 2022 [43]

At the beginning of the extensive russian aggression, the NBU chose not to make any significant decisions regarding the key policy rate. The reasoning behind this decision was the immense psychological pressure caused by the full-scale invasion. As a result, altering the key policy rate was unlikely to have a positive impact on stabilizing expectations and encouraging the retention of hryvnia assets, particularly in support of the fixed exchange rate. Instead, the NBU focused its monetary policy efforts primarily on guaranteeing the uninterrupted functioning of the banking system and payments within the economy [4].

The situation with inflation was worsening, as it was accelerating from February to May (from 10,7% to 18% respectively) due to the disruption of production and logistics [45]. Moreover, the persistently high global energy prices exerted significant inflationary pressure on consumer inflation, both directly and indirectly, through increased production costs. Furthermore, global inflation rates also recorded high values, exceeding 8% in the United States and euro area countries, which was further fueling the rise of domestic prices. Despite the gradual economic recovery, the upward inflation trend was expected to persist in the upcoming months. This may have worsened inflation expectations, leading depositors to convert their hryvnia savings into foreign currency. To mitigate these negative effects, the NBU returned to an active interest rate policy [4].

This decisive action to return to active monetary policy, in conjunction with other measures, was intended to safeguard the earnings and savings of households in hryvnia, increase the appeal of hryvnia-based assets, alleviate the burden on the foreign exchange market, and consequently bolster the NBU's capacity to sustain the stability of the exchange rate and control inflation amid the war [4].

The NBU's governing board has opted to maintain the key policy rate at 25% per year for ten months consequently while also raising the required reserves ratios for banks. These actions were expected to promote greater appeal for hryvnia-based assets, reinforce the stability of the exchange rate, and gradually mitigate inflationary pressures [46]. Furthermore, the choice to maintain the key policy rate at its current level is motivated by

the need to uphold exchange rate stability. Additionally, it creates suitable circumstances for the persistent reduction of inflation and the alleviation of the most oppressive foreign exchange constraints [47].

As the Ukrainian economy was gradually adapting and the psychological shock of the conflict subsided, there was a need to change the approach to monetary policy. With low yields on hryvnia assets, there was an increased risk of dollarization of the economy and the financial system losing valuable resources. The depreciation expectations of households and businesses were also unstable and vulnerable to changes in the war situation, especially those on the frontline and other situational factors. To address these issues, the NBU decided to intensify its interventions to sell foreign currency. However, the difference in the cash market exchange rate and the official exchange rate widened, exacerbating the negative effects on the economy caused by multiple exchange rates and restrictions on foreign exchange transactions and cross-border transfers [4].

The NBU admitted that the fixation of the exchange rate at USD/UAH 29,25 had a restraining effect on the cost of goods and services and influenced inflation and exchange rate expectations. Economic agents were adapting to the war, and consumer imports recovered faster than exports due to restrictions on seaports that were till July. During that period, The U.S. dollar strengthened markedly against most currencies, including reserve currencies, and the fixed exchange rate caused more imbalance in the economy and high pressure on international reserves. As a result, the members of the Monetary Policy Committee agreed that maintaining the exchange rate at pre-war levels was unjustified and that improvements in export logistics and imports justified a policy change. However, returning to a floating exchange rate was seen as premature, so a one-time adjustment of 25% was made to fix the exchange rate at a new level of USD/UAH 36,56 per USD. This adjustment was expected to reduce demand for noncritical imports, improve the competitiveness of domestic production, and stimulate exports. External financing and the exchange rate adjustment allowed international reserves to be maintained at a sufficient level (as of May 1, 2023, Ukraine had reached its historical value of USD 35,9 billion in

international reserves, covering 4,9 months of future imports), strengthening the NBU's ability to control the exchange rate and inflation trends [48-49].

According to the recent situation with inflation in Ukraine, it has been decreasing at a great rate than predicted for the third consecutive month (as of April 2023, the annual consumer inflation dropped to 17,9%, which was much lower than in December 2022 – 26,6%; the rates of price growth were also lower than the trajectory outlined in the NBU`s Inflation Report published in January 2023). This decline is attributed to the significant supply of food, sufficient fuel reserves, and improvements in inflation and exchange rate expectations. The latter is mainly due to the NBU's consistent monetary policy that seeks to maintain exchange rate stability and increase the appeal of hryvnia savings.

The decrease in inflation is anticipated to persist, mainly because of the reduced expense of energy resources in the worldwide market, limited internal demand, and the influence of the monetary policies implemented by the National Bank of Ukraine. Considering the collective impact of these factors, alongside the significantly improved situation in the energy sector, the National Bank of Ukraine has modified its inflation projection for 2023, lowering it from 18.7% to 14.8% [50-51].

At the same time, the notable decline in inflation every year is mainly due to the elevated reference point of the previous year, coupled with the mild winter climate that reinforced this pattern. Nevertheless, the strain on production expenses for businesses remains prominent, including the challenges of managing operations and adapting logistics networks amidst the ongoing conflict. As a result, the ongoing conflict remains a major source of uncertainty, which poses a significant risk to future inflation trends. That`s why NBU highlights the necessity to keep the key policy rate at a high value to bolster the impact of previous measures by the regulator and facilitate additional growth in the investment appeal of hryvnia savings [47, 52-53].

In addition to it, the NBU has taken steps to strengthen the monetary transmission and increase interest rates on hryvnia deposits, including tightening reserve requirements (RR) for current accounts and demand deposits [54]. Moreover, starting from February

11, 2023, banks can use a wider range of domestic government debt securities to cover up to 50% of their total required reserves. The NBU implemented this measure to encourage banks to actively participate in auctions held by the Ministry of Finance and help revive the domestic debt market, thereby avoiding direct funding of the budget deficit by the NBU in 2023 [55].

At the same time, these measures taken to immobilize liquidity may not be sufficient due to constant inflows of foreign exchange and government debt securities returning to the banking system. So, the question arises of what additional tools to protect hryvnia retail and corporate deposits from inflation and optimize the operational design of monetary policy to make hryvnia assets more attractive could be implemented. The members of the MPC also believe that NBU's measures to stimulate hryvnia term deposits and stabilize the FX market should create conditions for easing FX market restrictions, which adversely affect business activity [53].

Summary of Part 1:

The study of post-World War II monetary policies provided valuable insights into the effectiveness of different tools and approaches in stabilizing financial markets and reducing inflation. The use of open market operations, selective credit controls, adjusting discount rates, and controlling bank liquidity have been employed by various countries with varying degrees of success. However, it is important to note that the effectiveness of these policies can depend on a variety of factors, such as the state of the economy and the underlying institutional framework.

One approach that has proven effective in stabilizing macro-financial conditions is fixing exchange rates. However, it is important to recognize that maintaining fixed exchange rates may lead to accumulating macroeconomic imbalances over time. Therefore, policymakers must carefully consider the trade-offs between short-term stabilization and long-term sustainability.

Turning to the specific case of Ukraine, we identified successful actions that have helped maintain macro-financial stability and control inflation during the active phase of the russian-Ukrainian war. Firstly, the NBU pegged the exchange rate of hryvnia to USD, and it played a vital role in controlling inflation and maintaining macro-financial stability. To prevent nonproductive capital outflows and limit foreign exchange demand, FX restrictions were imposed, and FX interventions became the main monetary policy instrument. The NBU initially postponed its decisions regarding the key policy rate due to immense psychological pressure caused by the invasion but later returned to an active interest rate policy to mitigate negative effects on inflation expectations. The NBU maintained the key policy rate at 25% per year for ten months, raised the required reserve ratios for banks, and intensified its interventions to sell foreign currency to address the dollarization risk of the economy. Also, it re-pegged the exchange rate to reduce demand for noncritical imports, improve the competitiveness of domestic production, and stimulate exports. Recently, inflation has been decreasing at a greater rate than predicted. It is attributed to several factors including an ample supply of food, adequate fuel reserves, and positive changes in exchange rates and inflation projections. This positive trend is further bolstered by the unwavering monetary policy of the National Bank of Ukraine, which aims to promote exchange rate stability and encourage domestic savings.

PART 2
MODELLING OF THE KEY MONETARY POLICY INDICATORS USING A SET OF SIMULATION EQUATIONS

2.1. The theoretical and methodological principles involved in creating macroeconomic models using a set of simulation equations

Macroeconomic models are commonly used to address socioeconomic issues, providing a comprehensive understanding of dynamic relationships and their impact on a country's development. The econometric analysis evaluates complex hierarchical relationships within socio-economic systems, considering internal and external shocks. Developing macroeconomic models of different complexity levels based on various theoretical approaches and mathematical tools is a vital task for many countries, including Ukraine.

Western and Ukrainian research institutions, international organizations, and independent analysts use a variety of macroeconomic models for forecasting, scenario analysis, decision support, and strategic economic development. Central banks worldwide also rely on these models to form and justify monetary policy decisions. The International Monetary Fund uses a sophisticated analytical toolkit to evaluate the economic development of different countries and provide expert recommendations. Therefore, these institutions typically have multiple macro-econometric models at their disposal to solve specific problems and provide scientifically justified recommendations for decision-making at various hierarchical levels [56].

The evolution of mathematical tools for modeling in research organizations, including the IMF and central banks, can be systematized into five stages based on model types, such as large-scale econometric models, SVAR models, hybrid models, semi-structural models, and DSGE models [57]. DSGE models are the most theoretically

grounded and assume supply and demand are equal in all markets during the research period [58].

Macro models based on simulation systems belong to classical econometric macro models. Their peak of popularity fell in the 1960s-1990s. They became widespread in the United States, and one of the first macroeconomic simulation models in Ukraine was only developed in 1999 by the Center for Social and Economic Research in Warsaw. Initially, the purpose of building this model was to analyze the consequences of the significant shadow sector in Ukraine, and then it was expanded for short-term forecasting and determining the main directions of the country's macroeconomic policy. It consisted of six main sectors - consumption, investment, international trade, government finances, labor market, money, and credit markets - and such blocks as households, firms, government, and the rest of the world [59]. Another interesting simulation macro model of the Ukrainian economy developed almost in the same period, consisted of five main sectors - external, monetary, real, budgetary, and labor market sectors - and allowed to reflect and evaluate interdependencies both between macroeconomic indicators within a separate sector and between sectors in general [60]. It was a logical improvement of this class of macro models for the Ukrainian economy to develop dynamic macro models [61].

Using econometric models based on simulation systems has the advantage of being easy to understand in formalizing relationships between economic indicators and sectors, as well as reflecting socioeconomic processes and phenomena. These systems remain one of the most convenient and accurate methods for modeling macroeconomic systems, accounting for historical trends and complex causal relationships between elements and allowing for the comparison of theoretical assumptions with real economic trends [56].

Essentially, the simultaneous equations model is a system of multiple regression equations that describe the relationships between variables, blocks, sectors, and economic subsystems. It allows for realistic modeling of complex macroeconomic dependencies by accounting for both direct and inverse relationships between elements of social, economic, and financial systems of varying levels of complexity. Consequently, simultaneous

equation systems use endogenous variables as explanatory variables, which are stochastic and correlated with random variables, making classical least squares methods biased. Special methods are commonly used to estimate unknown parameters, including two-step and three-step least squares methods, indirect least squares method, and maximum likelihood method, with the choice depending on system identifiability [56].

There are two main conditions for identifying a simultaneous equation system: order and rank. The order condition requires that each equation in the system must have at least (m-1) endogenous and predetermined variables (all exogenous and lagged endogenous variables included in the model) excluded for identification, where m is the total number of endogenous variables in the model. If fewer than (m-1) variables are excluded, the system is over-identified, and if more than (m-1) variables are excluded, it is under-identified. The order condition is necessary but not sufficient for identification, so the system must also meet the rank condition. The rank condition requires that at least one non-zero (m-1)(m-1) determinant can be formed from the coefficients of the excluded variables in one equation and included variables in other equations of the system [62].

If one equation in a simultaneous equation system has more identifying information than necessary, the entire system is considered over-identified. Conversely, if one equation has less identifying information than necessary, the whole system is considered under-identified and cannot be evaluated. To evaluate simultaneous equation systems, the two-stage least squares (2SLS) method is commonly used because it can evaluate both accurately identified and over-identified systems. The first stage of 2SLS involves estimating the endogenous variables as functions of all predetermined variables of the system. The second stage substitutes the estimated values of the endogenous variables for the initial values on the right-hand side of the corresponding equations of the system. This procedure leads to independence between random variables and factors in all equations of the system and allows for unbiased estimates of unknown parameters [56].

The specification of each simultaneous equation model is influenced by factors such as the research objective, economic theory, and available statistical data. However, a simultaneous equation system typically has the following structure:

$$\begin{cases} Y_{1t} = \beta_{10} + \beta_{12}Y_{2t} + \ldots + \beta_{1m}Y_{mt} + \gamma_{11}X_{1t} + \ldots + \gamma_{1k}X_{kt} + \varepsilon_{1t}; \\ Y_{2t} = \beta_{20} + \beta_{21}Y_{1t} + \ldots + \beta_{2m}Y_{mt} + \gamma_{21}X_{1t} + \ldots + \gamma_{2k}X_{kt} + \varepsilon_{2t}; \\ Y_{mt} = \beta_{m0} + \beta_{m1}Y_{1t} + \ldots + \beta_{mm-1}Y_{m-1,t} + \gamma_{m1}X_{1t} + \ldots + \gamma_{mk}X_{kt} + \varepsilon_{mt}, \end{cases}$$

where $Y_{1t}, Y_{2t}, \ldots, Y_{mt}$ – the endogenous variables in a simultaneous equation system;

$X_{1t}, X_{2t}, \ldots, X_{mt}$ – the predetermined or exogenous variables;

$\varepsilon_{1t}, \varepsilon_{2t}, \ldots, \varepsilon_{mt}$ – random variables in period t;

$t = 1, 2, \ldots, N$ – total number of observations;

$k = \overline{1, K}$ – the number of predetermined or exogenous variables;

$\beta_{10}, \beta_{12}, \ldots, \beta_{mm-1}$ – the unknown coefficients of the endogenous variables of the system;

$\gamma_{11}, \gamma_{12}, \ldots, \gamma_{mk-1}$ – the unknown coefficients of the exogenous variables of the system;

$m = \overline{1, M}$ – total number of endogenous variables [62].

The process of evaluating a system of simultaneous equations typically involves several key steps. These include identifying the endogenous and exogenous variables in the model, testing the system for identification, estimating, and testing the equations using the appropriate specifications and classical assumptions, and diagnosing the adequacy and sensitivity of the model, as well as its predictive power. Finally, the model can be used practically depending on the purpose of the research [62].

To sum it up, macro models built based on simultaneous equations are a powerful econometric tool for studying complex macroeconomic interdependencies of real socio-economic systems of varying levels of complexity, especially in the Ukrainian economy. They can be both highly detailed and compact, making them suitable for scenario analysis and preliminary diagnostics.

2.2. Equations specification and assessment of the adequacy of the generalized simulative macro model

To demonstrate the interconnection of monetary indicators and their influence on the key policy rate, the macroeconomic model is built. Although the model is straightforward, it allows for a diverse set of scenario analyses to identify in which direction the key policy rate should be led and attain macroeconomic stability, while considering potential internal and external destabilizing risks and factors.

The macro model of the Ukrainian economy includes five basic equations, determining the inflation rate (CPI), exchange rate USD/UAH, GDP gap, international reserves, and the key policy rate. The model is based on the interconnections inherent in the monetary transmission channels' work (see Figure 2.1).

Let`s get down to the specification of each equation and its check of the classical assumptions using the EViews Software Package. We will start with the inflation equation. Let`s recall that the main aim of the NBU is to maintain price stability, and it uses a semi-structural econometric model to forecast future CPI based on variables such as imported inflation, demand pressure, exchange rate, and others.

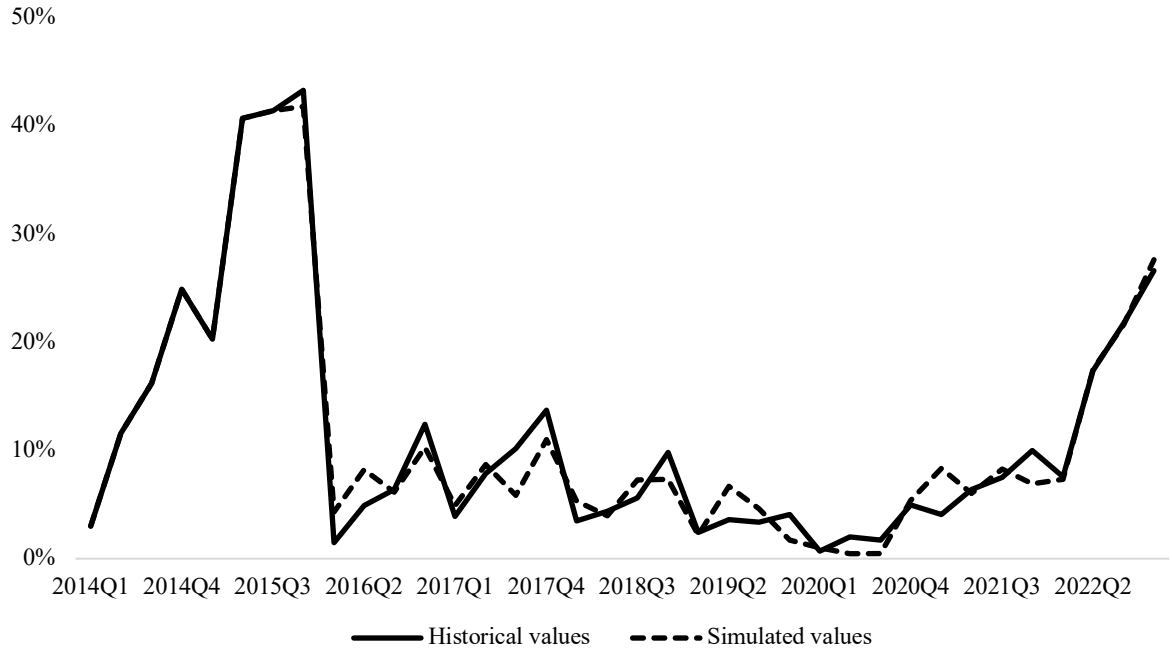
The final equation of Ukraine's macro model for inflation includes several factors such as the previous values of inflation, the key policy rate, the exchange rate, the inflation of Ukraine`s main trade partners, and the effect of the war. All these indicators explain the current level of inflation of 93,8%. Unfortunately, in Ukraine, the exchange rate volatility has the strongest effect on inflation, as for quite a long period Ukraine had a pegged exchange rate, and economic agents were building their forecasts based on the value of 1 USD. In general, a devaluation of a country's exchange rate leads to increased prices of imported goods and services, making it more expensive to import. Domestic producers who rely on imported raw materials face an increase in production costs, leading to higher prices for their products. A devaluation also worsens inflation

expectations among consumers and businesses, leading to higher demand and higher prices [13].

The key rate also has a significant impact on inflation. However, there is a one and half year lag in the specified equation due to the specifics of Ukraine's situation. It was only after 2016 that the accounting rate began affecting money value and inflation [2]. According to our regression, a 1% increase in the key policy rate 6 quarters before decreases the inflation by 0,82%.

Another indicator that influences Ukraine`s inflation is the aggregated inflation of main trade partners. An increase in the inflation rate of a country's main trade partners leads to an increase in the cost of imports, which causes domestic producers to increase their prices, leading to inflation. An increase in demand for exports from the country due to higher inflation in trade partners can also contribute to inflation [6]. According to our regression, a 1% increase in the aggregated inflation of main trade partners leads to a 0,17% increase in Ukraine`s inflation.

Figure 2.1. Historical and simulated values of the quarterly inflation, %



Source: made by the author according to the regression in EViews

The war started in Ukraine back in 2014 and moved to another level in 2022 when russia launched a full-scale invasion. The war hostilities and occupation of territories, firstly Crimea peninsula and Eastern parts of Ukraine, and then Southern and Northern parts, which were lately deliberated by Ukrainian armed forces. In 2014-2016 inflation was accelerating primarily due to the devaluation processes. At the same time, the uncertainty regarding the events in the East and high devaluation expectations determined the growth of inflationary expectations, which gave inflation a self-sustaining character [63]. Moreover, the growth of consumer prices significantly accelerated due to a considerable increase in housing and communal tariffs, for gas for the population [64].

The primary cause of the increase in inflation in 2022 was due to Russia's full-scale war of aggression, which destroyed businesses and infrastructure, disrupted production and supply chains, increased production costs for businesses, and demand surges for certain goods and services. The war's indirect consequences, such as exchange rate effects and worsening expectations of households and businesses, also contributed to the rise in prices. Furthermore, the global acceleration of inflation, which resulted in most countries posting new multi-year inflation highs last year, also exerted pressure on prices in Ukraine [65]. As a result, according to the inflation regression, in the case of the beginning of war hostilities, inflation will accelerate to 10,3%.

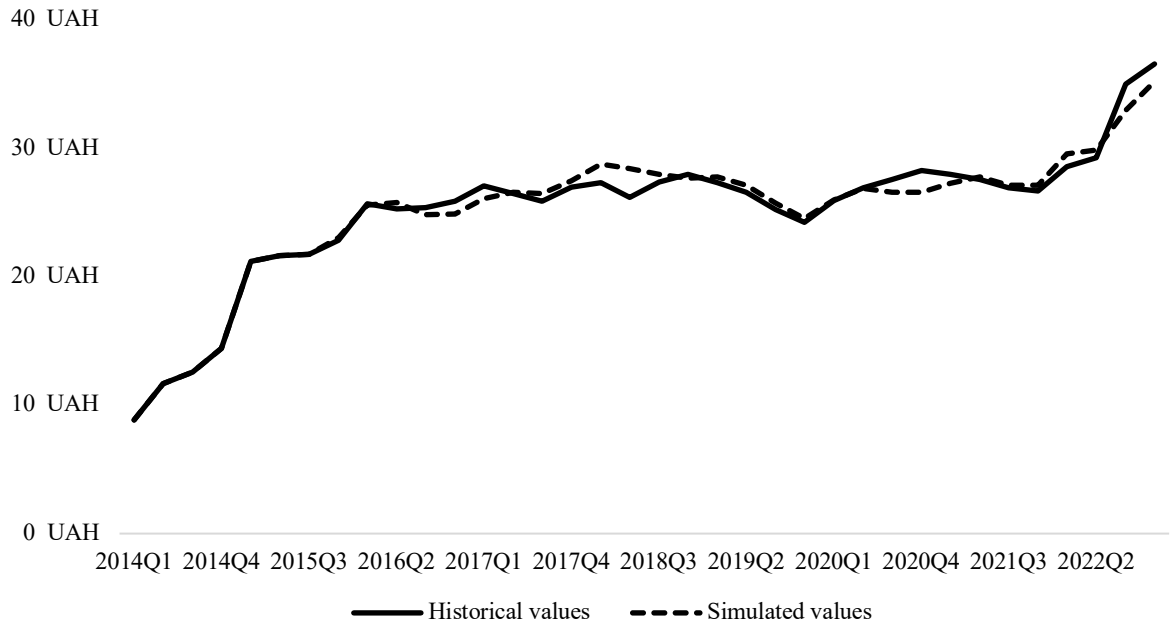
The next one is the exchange rate. It greatly impacts inflation, with devaluation having more significant effects than revaluation, so it is crucial to include this equation in the macro-model of Ukraine's economy for distinguishing the key policy rate [66]. Economic theory and practical aspects of macro-modeling support considering the exchange rate in various models. The NBU uses a model to estimate the equilibrium level of the real effective exchange rate, which includes factors like the balance of payments and interest rates. The exchange rate assessment results are used in developing a generalized forecast for economic indicators through the QPM [67].

To specify the exchange rate equation in the macro model, its dependence on the previous value, the key interest rate, international reserves, and external debt to GDP ratio

must be considered. The exchange rate dynamics can be explained by 88% through the influence of these indicators. The previous value of the exchange rate influences the current value through linkage to past values (it will increase by 0,7%). From the beginning of 2015 till the 24th of February 2022, the exchange rate has been depending on the currency supply and demand in the money market, so it is vital to look at it even now when the exchange rate is pegged. In general, an increase in international reserves signals that a country has a strong and stable economy. This typically increases confidence in the country's currency and leads to an increase in the demand for the currency, which, in turn, increases the value of the exchange rate. However, in certain situations, such as when a country accumulates international reserves through unsustainable or short-term means, it can lead to concerns among investors and a decrease in confidence in the country's economy. This can decrease the demand for the currency and lead to a decrease in the value of the exchange rate [68]. This is what we can observe right now in Ukraine, as the international reserves have been increasing since the beginning of the full-scale invasion and have even risen to an 11-year high of 35,9 billion USD [49]. However, in the cash market, the hryvnia exchange rate was still much above the official rate (with a 1 % increase in reserves, the UAH revaluates by 0.05%).

Besides, the key policy rate also plays a vital role, as its increase leads to the revaluation of the currency in normal conditions, and vice versa [69]. A 1% increase in the key rate results in a 0.01% exchange rate appreciation, driven by changes in asset yields and capital inflows. Finally, the foreign debt-to-GDP ratio reflects the impact of changes in external borrowing, as well as demand and supply for currency, on the exchange rate [70]. It has a substantial impact on exchange rate formation, with a 1% increase leading to a 0.15% devaluation. Figure 2.2 depicts the real values of the official exchange rate of 1 USD to UAH, and the ones that were simulated with the model.

Figure 2.2. Historical and simulated values of the exchange rate UAH/USD



Source: made by the author according to the regression in EViews

The third one is the GDP gap. This indicator is an important component of Taylor`s rule, as it measures the slack or excess capacity in the economy [71]. The GDP gap is important in predicting the policy rate because it reflects the state of the economy and its growth potential. When the economy is operating below its potential, there is excess capacity, and the central bank can lower interest rates to stimulate economic activity and reduce unemployment. Conversely, when the economy is operating above its potential, there is upward pressure on prices, and the central bank can raise interest rates to cool down the economy and prevent inflation from rising too much [72].

To estimate the GPD gap, the following indicators were considered: its previous level, key policy rate, employment rate, terms of trade, real effective exchange rate, and inflation. The GDP dynamics can be explained by 79% through the influence of these indicators. The previous values of the GDP gap influence the current value through linkage to past values. Also, the key policy rate affects the GDP gap. When interest rates increase, businesses and individuals are less likely to borrow money for investments or purchases, which can lead to a decrease in consumer spending and business investments.

This, in turn, can lead to a decrease in the GDP gap as the economy slows down and operates closer to its potential output [69, 71]. In the case of our regression, the 1 % increase in the key policy rate leads to the 0,01% decrease in GDP gap output.

Besides, the employment rate is an important indicator of the state of the labor market and the economy's capacity to produce goods and services. The increase in the employment rate can increase the GDP gap because it means more people are employed and earning income, which can lead to an increase in consumer spending. As consumers spend more, businesses can increase their production to meet the demand, leading to an increase in the actual GDP. When the actual GDP increases, it can move closer to the potential GDP, which widens the GDP gap. Additionally, higher employment can lead to increased productivity and innovation, which can also contribute to economic growth and a wider GDP gap [73]. Therefore, an increase in the employment rate can be an indicator of a growing economy, which can result in a wider GDP gap (a 1% increase in the employment rate increases the GDP gap by 0,02%).

In addition to it, an increase in REER can increase the GDP gap as it can make a country's exports more expensive for foreign buyers. This, in turn, can lead to a decrease in demand for exports, resulting in a decrease in production, and ultimately, a decrease in the actual GDP. When the actual GDP decreases, it can move further away from the potential GDP, leading to a narrower GDP gap [74]. In the case of our regression, the 1% increase in the REER leads to the 0,75% increase in GDP gap output.

Besides, inflation plays a vital role in distinguishing the GDP gap of Ukraine. An increase in inflation decreases the GDP gap (in our case, a 1% increase in inflation leads to a 0,01% decrease in GDP gap), as it leads to an increase in nominal GDP, not adjusted for inflation. When there is an increase in the general price level of goods and services, nominal GDP increases even if the actual production of goods and services remains the same. As a result, the gap between the actual GDP and potential GDP narrows. Additionally, inflation can lead to an increase in investments and production in the short run as businesses try to take advantage of rising prices. However, if inflation becomes too

high, it can lead to a decrease in consumer and investor confidence, resulting in a decrease in spending and a narrower GDP gap [73].

Finally, terms of trade play also a crucial role in GDP gap formation. According to our regression, a 1% increase in the terms of trade decreases the GDP gap by 0,21%, as the improvement of this indicator increases the income of the country's exporters. Terms of trade refer to the ratio of the price of a country's exports to the price of its imports. When the terms of trade improve, it means that the price of exports has increased relative to imports, resulting in higher export earnings for the country. This can lead to an increase in the country's actual GDP, which can narrow the gap between the actual GDP and potential GDP. Additionally, an improvement in the terms of trade can encourage investment and economic growth, which can further reduce the GDP gap [75].

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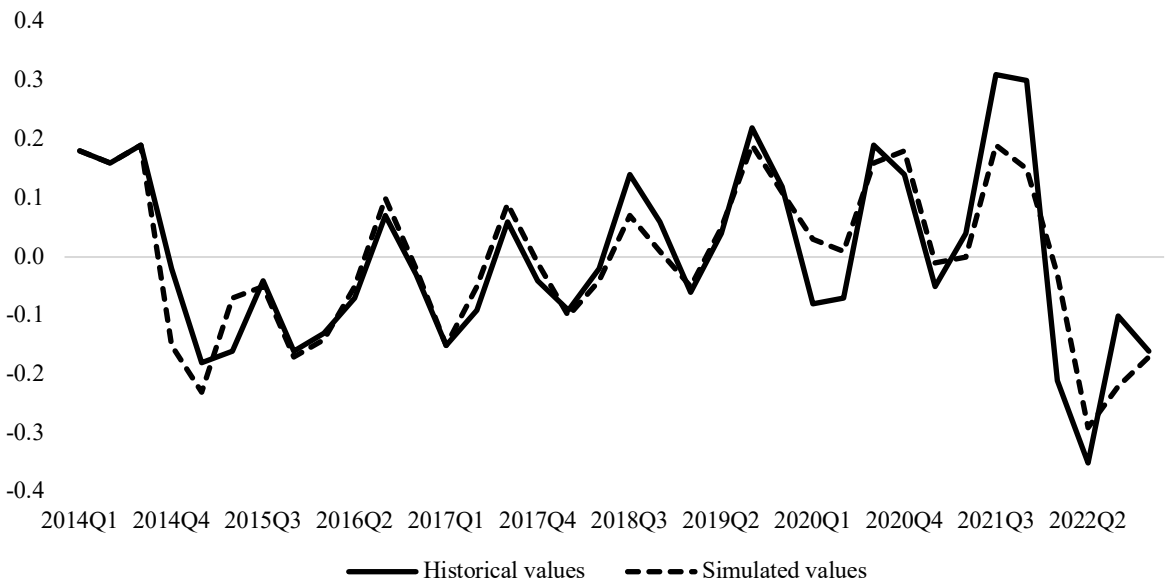
Figure 2.3. Historical and simulated values of the GDP gap to potential output



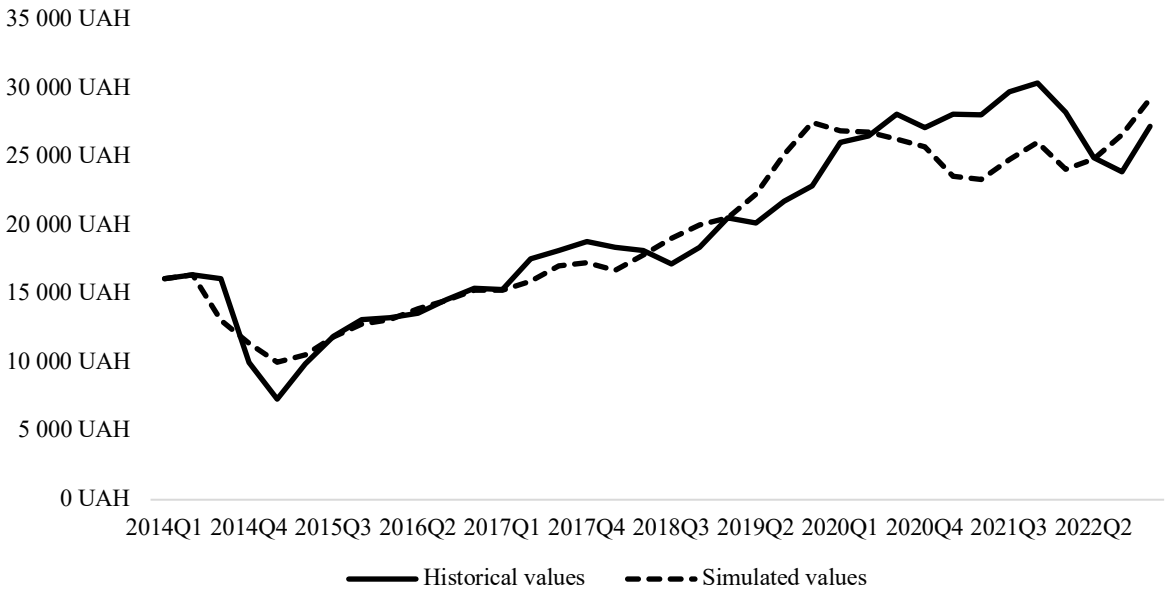
Source: made by the author according to the regression in EViews

Another one is international reserves. Even though, they are not part of the main equation – the key policy rate. In the case of 2023, international reserves play important roles in distinguishing what currency restrictions should be and how long the exchange

rate should be pegged. In our equation, the reserves are defined by the reserves in the previous quarter (the high volumes of reserves in the previous quarter increase the international reserves in the next quarter by 0,75%), the real effective exchange rate (REER), GDP gap, and foreign debt. All these indicators explain the formation of the international reserves by 91,15% (see Table 2.1).

REER affects Ukraine's international reserves through its impact on trade balances. In our equation, the increase of REER by 1% leads to the increase of reserves by 0,92%, as it makes exports more expensive and imports cheaper, which could lead to an increase in trade surplus, meaning that the country is earning more foreign currency than it is spending. and the accumulation of international reserves. As a result, this surplus can be used to build up international reserves [76]. In terms of the GDP gap and its effect on international reserves, our equation demonstrates that the increase of the GDP gap by 1% decreases the reserves by 0,25%. It happens due to weaker economic performance and potential difficulty in repaying external debt, which can lead to capital outflows and lower foreign currency inflows. This can put pressure on the country's international reserves as they may need to be used to cover external debt payments or support the currency. Additionally, a weaker economy may result in lower exports and foreign investment, further reducing foreign currency inflows and international reserves [77]. Last but not least, the increase of foreign debt of the country also negatively impacts the international reserves (in our case, a 1% increase in the volume of the foreign debt leads to a 0,67% decrease in the reserves of Ukraine). If the foreign debt increase, it means that a country is borrowing more from other countries, which results in an outflow of money from the country. As a result, the country's international reserves decrease, as it must use them to pay off its foreign debt obligations. Additionally, an increase in foreign debt can lead to a decrease in the country's creditworthiness and increase the risk of default, which can further reduce the country's international reserves [78].

Figure 2.4. Historical and simulated values of international reserves, million USD



Source: made by the author according to the regression in EViews

Last but not least is the equation, which allows us to estimate what the key policy rate is. It is based on the well-known monetary policy rule with many modifications tailored to the needs of different central banks and national economies - Taylor's rule. The rule was formulated by J. Taylor to respond to changes in economic indicators by determining a new accounting rate based on the inflation rate for the previous four quarters and the deviation of real GDP from the target value. Two approaches to evaluating the coefficients of the rule exist - implicit evaluation within the macroeconomic model or explicit evaluation in a multifactor regression model linking the key rate with macroeconomic indicators [79].

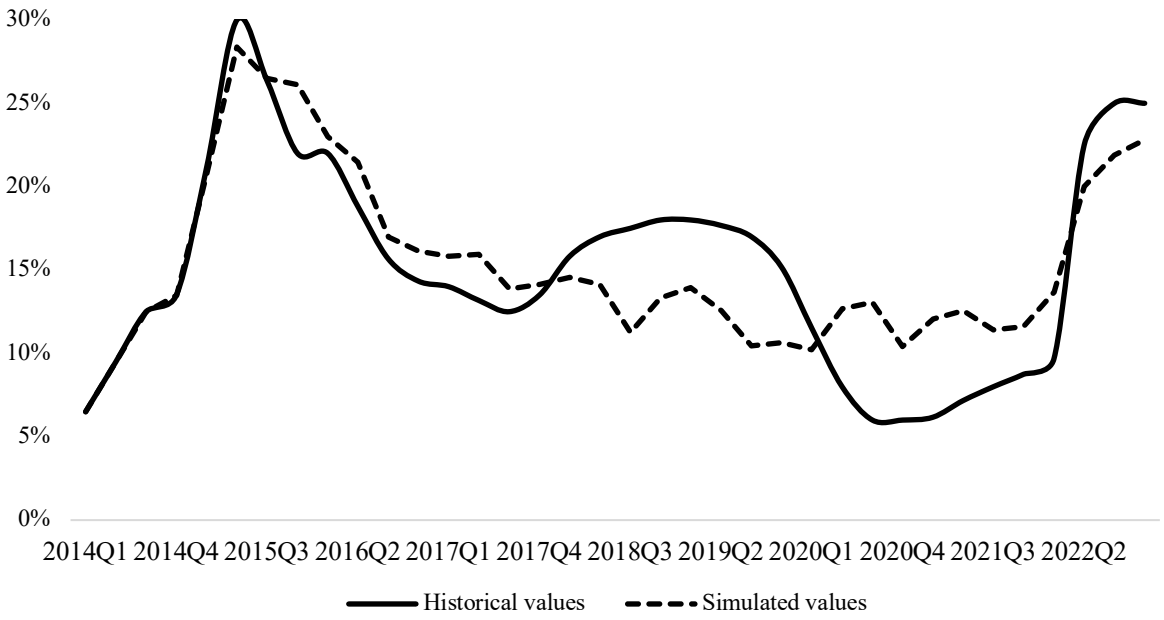
Under Ukraine's inflation-targeting regime, monetary policy decisions are made based on inflation forecasts. The NBU follows its version of Taylor's rule, determining the new key policy rate using factors such as retrospective interest rate, neutral rate, expected inflation, inflation deviation from target, and GDP gap. The goal is to bring current inflation closer to the target in the medium term [80-81].

Both implicit and explicit approaches were used to develop the macroeconomic model. A classical regression equation was estimated and incorporated into the model, where the key policy rate depends on its previous level. This is because previous periods must be considered during current decisions. The NBU's inflation targeting policy requires the inclusion of inflation in the equation to achieve a target value of 5% inflation in the medium term [56]. Economic growth, indicated by the GDP gap, is also crucial in setting the key policy rate. Raising it strengthens the hryvnia by attracting investment through higher government security and deposit rates, thus increasing capital inflow. The exchange rate's volatility affects inflation, causing the consumer price index to rise during devaluation, which significantly impacted Ukraine in 2015 [66].

According to our specification, the NBU's key interest rate is influenced by variables such as the previous key interest rate, neutral rate, exchange rate, GDP gap, and the difference between actual inflation and its targeting value, explaining 84,6% of its dynamics. The bank considers past and future impacts on the economy and prices when determining the interest rate. A 1% increase in the previous quarter's interest rate leads to an 0.8% increase in the current key interest rate. The Taylor rule equation uses past interest rates and projected inflation rates to calculate the current interest rate [71]. To achieve 5% medium-term price growth, inflation values are included in the model, with a 1% increase in the deviation of actual inflation from the targeted value, leading to a 0,2% increase in the key interest rate.

Also, as was stated before, exchange rate fluctuations affect inflation, and here we represent it with the certain rise of the exchange rate within each period (7%), and when the fluctuations that lead to devaluation are very significant, there is a necessity to raise the key policy rate by 2,9% interest rate increase [6, 69, 82]. Moreover, as the neutral rate increases, the key policy rate tends to decrease because it needs to be closer to the neutral rate to achieve its policy goals [83]. According to our regression, a 1% increase in the neutral rate leads to a 0,65% decrease in the key policy.

Figure 2.5. Historical and simulated value of the key policy rate, %



Source: made by the author according to the regression in EViews

In addition to it, when the GDP gap increases, and the economy is operating above its potential, the central bank may increase the key policy rate to reduce the inflationary pressures in the economy. By increasing the key policy rate, the central bank makes borrowing more expensive, which reduces consumer and business spending, leading to a decrease in demand for goods and services. The reduction in demand helps to reduce upward pressure on prices, which can help to keep inflation in check [6, 71]. As a result, the increase in the GDP gap by 1% increases the key policy rate by 7,22%. Figure 2.5 reproduces the macro model's key interest rate dynamics (historical and simulated values).

In Table 2.1 it`s possible to get acquainted with the system of equations that have been described before. After determining the general specification of the macro model using a system of simultaneous equations, it is necessary to re-estimate it. There are several methods available for estimating macro model systems, including indirect least squares (ILS), two- or three-stage least squares (2SLS, 3SLS), and maximum likelihood estimation with full or limited information. Classical least squares cannot be used due to the violation of regression assumptions [56].

Table 2.1. Results of evaluation of the system of simulative equations

№	Model Equation Specification	Coefficient of determination
1	**Inflation equation, %**	93.82% DW = 1.88
	CPI = 0.56 + 0.17CPI(-4) – 0.82D(KEY_R(-6)) + 73.03D(LOG(ER(-3)) + 0.67PCPI(-1) + 10.295WAR	
2	**Exchange rate equation, UAH/USD**	87.99% DW = 1.81
	LOG(ER) = 0.28 + 0.73LOG(ER(-1)) – 0.01D(KEY_R)×DUMMY1 + + 0.02D(KEY_R)×(1-DUMMY1) + 0.05LOG(RESERVES(-7)) + 0.15LOG(DEBT_TO_GDP)	
3	**GDP gap equation, %**	79.00% DW = 1.44
	GDP_GAP = -1.46 – 0.56GPD_GAP(-2) – 0.01KEY_R(-1) + 0.02EMPL_R – – 0.21D(TOT) + 0.61REER – 0.01D(CPI(-2))	
4	**International reserves equation, million USD**	91.15% DW = 1.90
	LOG(RESERVES) = 9.49 + 0.75LOG(RESERVES(-1)) + 0.92REER – – 0.25GDP_GAP(-3) – 0.67LOG(FOR_DEBT(-1))	
5	**Key policy rate equation, %**	84.56% DW = 1.65
	KEY_R = 1.97 + 0.80KEY_R(-1) + 7.22GDP_GAP(-2) + 0.19×(CPI-CPI_TARGET) – 0.65D(NR(-3)) + 2.93(D(ER(-1)))×DUMMY2 + + 1.262(D(ER(-1)))×(1-DUMMY2)	

Source: made by the author according to the regressions in EViews

The choice of estimation method for systems of simultaneous equations is generally associated with the identification problem. Based on the testing of the aggregated macro model, which includes five simultaneous equations identified through the order and rank condition, it has been determined that the model is reidentified (see Appendix G). Thus, it can be estimated accurately using two-stage or three-stage least squares. We have decided to use the two-stage least squares and the evaluation results for the developed micromodel are presented in Figure 2.6.

It`s necessary to test the adequacy testing of the developed system of simultaneous equations, including checking for the presence of autocorrelation in the residuals of the macro model using the Portmanteau test [56]. Figure 2.7 shows the results of this test for the developed macro model, and it allows us to conclude that values of the Q-statistic from

the first to the twelfth lag are greater than 0.10, which indicates the absence of autocorrelation in the system of equations residuals.

Figure 2.6. Evaluation results of the 2MNK system of simulative equations

System: SYSTEM1
Estimation Method: Two-Stage Least Squares
Date: 04/07/23 Time: 20:38
Sample: 2015Q4 2022Q4
Included observations: 29
Total system (balanced) observations 145

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	0.392937	1.350081	0.291047	0.7715
C(2)	-0.815886	0.254440	-3.206599	0.0017
C(3)	75.28297	9.227604	8.158452	0.0000
C(4)	0.710150	0.257063	2.762556	0.0067
C(5)	0.166126	0.061432	2.704212	0.0079
C(6)	9.755355	2.901710	3.361933	0.0011
C(7)	0.259364	0.321859	0.805831	0.4220
C(8)	-0.006828	0.002742	-2.489902	0.0142
C(9)	0.014307	0.005186	2.758550	0.0068
C(10)	0.726225	0.093401	7.775303	0.0000
C(11)	0.051079	0.022190	2.301902	0.0232
C(12)	0.149553	0.025543	5.855028	0.0000
C(13)	-1.926664	0.297875	-6.468023	0.0000
C(14)	-0.799387	0.137429	-5.816739	0.0000
C(15)	0.026416	0.003836	6.886966	0.0000
C(16)	-0.012093	0.002640	-4.580493	0.0000
C(17)	0.908229	0.161222	5.633394	0.0000
C(18)	-0.004398	0.001408	-3.123731	0.0023
C(19)	0.014670	0.133576	0.109822	0.9127
C(20)	1.758120	1.653978	1.062965	0.2900
C(21)	0.823071	0.113976	7.221441	0.0000
C(22)	6.679376	4.274557	1.562589	0.1209
C(23)	0.214666	0.073818	2.908059	0.0044
C(24)	-0.688942	0.412449	-1.670370	0.0976
C(25)	2.324047	1.978965	1.174375	0.2427
C(26)	1.084074	0.551475	1.965771	0.0518
C(27)	3.669788	4.126881	0.889240	0.3757
C(28)	0.888806	0.083633	10.62741	0.0000
C(29)	0.292865	0.225214	1.300384	0.1961
C(30)	-0.117634	0.083645	-1.406345	0.1623
C(31)	-0.239527	0.376438	-0.636297	0.5259
Determinant residual covariance		6.58E-08		

Source: performed in EViews by the author

Figure 2.7. Evaluation results of the 2MNK system of simulative equations

System Residual Portmanteau Tests for Autocorrelations
Null Hypothesis: no residual autocorrelations up to lag h
Date: 04/07/23 Time: 20:39
Sample: 2015Q4 2022Q4
Included observations: 29

Lags	Q-Stat	Prob.	Adj Q-Stat	Prob.	df
1	24.54399	0.4881	25.42056	0.4390	25
2	47.61367	0.5697	50.19911	0.4655	50
3	69.03962	0.6720	74.09729	0.5078	75
4	85.07696	0.8566	92.70060	0.6850	100
5	101.0010	0.9435	111.9421	0.7922	125
6	121.0194	0.9604	137.1827	0.7653	150
7	141.3756	0.9707	164.0160	0.7136	175
8	168.6837	0.9476	201.7271	0.4525	200
9	186.4355	0.9714	227.4672	0.4415	225
10	201.4323	0.9893	250.3571	0.4817	250
11	212.4902	0.9979	268.1726	0.6045	275
12	226.9652	0.9994	292.8651	0.6050	300

*The test is valid only for lags larger than the System lag order.
df is degrees of freedom for (approximate) chi-square distribution
*df and Prob. may not be valid for models with lagged endogenous variables

Source: performed in EViews by the author

Another test that should be performed is the normality of random variables in a system of simultaneous equations. It is performed by executing the Jarque-Bera test, using the sequence of commands provided in the EViews software package [56]. The results of this test for the developed system of simultaneous equations are presented in Figure 2.8. As can be seen from the analysis of the test results, the p-value of the Jarque-Bera statistic is 0.49 for the residuals of the developed model, which is greater than 0.10 (10%), thus concluding that the distribution law of the random variables is normal.

Figure 2.8. Evaluation results of the 2MNK system of simulative equations

System Residual Normality Tests
Orthogonalization: Cholesky (Lutkepohl)
Null Hypothesis: residuals are multivariate normal
Date: 04/07/23 Time: 20:41
Sample: 2015Q4 2022Q4
Included observations: 29

Component	Skewness	Chi-sq	df	Prob.
1	-0.170011	0.139701	1	0.7086
2	0.521006	1.311994	1	0.2520
3	0.523670	1.325448	1	0.2496
4	0.109868	0.058343	1	0.8091
5	0.158968	0.122143	1	0.7267
Joint		2.957629	5	0.7065

Component	Kurtosis	Chi-sq	df	Prob.
1	2.555536	0.238704	1	0.6251
2	2.924353	0.006915	1	0.9337
3	4.945472	4.573375	1	0.0325
4	3.250500	0.075823	1	0.7830
5	1.861955	1.564969	1	0.2109
Joint		6.459786	5	0.2640

Component	Jarque-Bera	df	Prob.
1	0.378405	2	0.8276
2	1.318909	2	0.5171
3	5.898823	2	0.0524
4	0.134167	2	0.9351
5	1.687112	2	0.4302
Joint	9.417415	10	0.4930

Source: performed in EViews by the author

The results of the tests confirm that the estimated parameters of the developed macro model based on the simulation equations are the best linear unbiased estimators (BLUE), the random variables in the model are uncorrelated and follow a normal distribution. Therefore, the developed macro model can be used for further research, including forecasting endogenous variables, hypothesis testing, and scenario analysis.

2.3. Forecast of the key macroeconomic indicators and scenario analysis

A significant stage in developing macroeconomic models is to conduct various scenarios of economic development under different initial conditions, assumptions, and risks, especially in terms Ukrainian economy undergoing the stormiest times.

To achieve accuracy in forecasting future trends, it's important for the model to accurately reproduce historical data. Thus, a critical step in assessing the accuracy of forecasts is verifying the simulation model's ability to replicate past trends, including the model's ability to reproduce turning points.

In Appendix H it`s possible to get acquainted with the actual and model-simulated values of endogenous variables: inflation, exchange rate, GDP gap, international reserves, and key policy rate. According to the figures displayed in this appendix, the simulated values by our model represent the historical values quite well, especially in 2022.

Furtherly, the developed macro simulation model will be used to test various scenarios of economic development, and forecasting based on the system of simulation equations involves predicting both endogenous and exogenous variables. Forecasting exogenous variables can be done through various methods such as building separate ARIMA models, using trend econometric models, or obtaining data from government sources and research institutions. However, it is important to forecast exogenous variables before predicting endogenous variables.

In our case, all forecasts for the exogenous variables – PCPI, DEB_TO_GDP, REER, FOR_DEBT, EMPL_R, TOT – except WAR and CPI_TARGET, will be built using the ARIMA models. In the case of WAR, in base case scenarios, we make the assumptions based on the macro forecast of the NBU that the security risks will decline only in 2024 [52]. The targeted value of inflation remains unchanged as the NBU has not renounced its shift from 5% inflation in the long-term period [51].

Table 2.2. Assumptions for different scenarios for a system of simulation equations

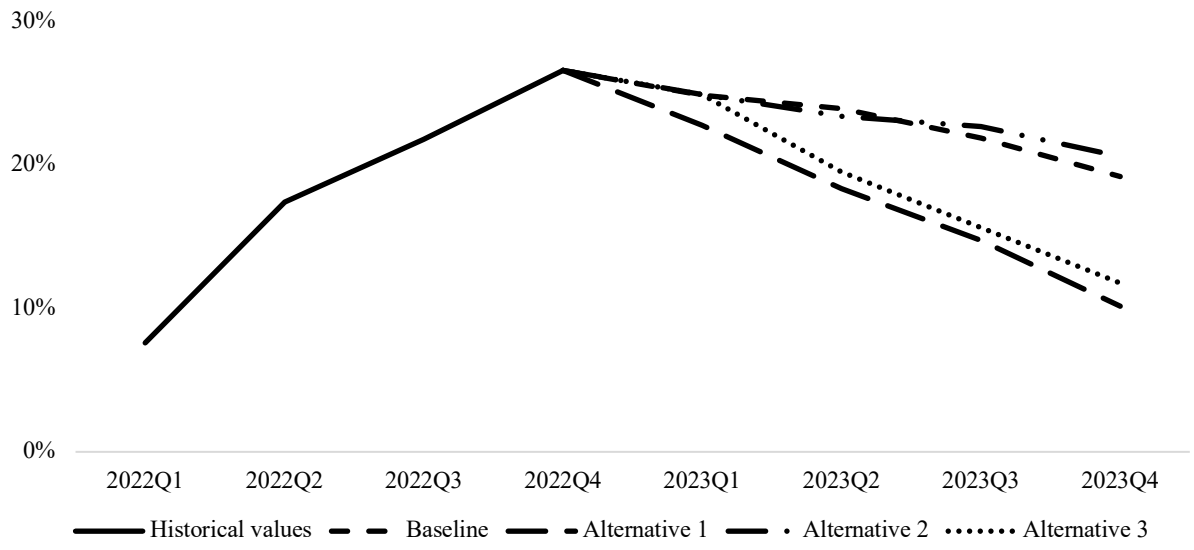
Scenarios	Assumptions
Base case	The security risks will last till the end of 2023, and the inflation of main export partners will be declining gradually, the level of foreign debt will be growing slowly according to current agreements with partners to finance the budget deficit. Moreover, the level of employment will begin to gradually increase due to business exposure to security risks and improved expectations regarding the activities of enterprises and the recovery of economic activity.
Alternative 1	The duration of security risks will persist until the end of the third quarter of 2023, while inflation among primary export partners is anticipated to decrease at a faster pace. The level of foreign debt is also predicted to grow slowly according to current agreements with partners to finance the budget deficit, even though the active hostilities might stop. There will be still a necessity to finance the military and social sectors. Additionally, due to the decline in security risks, business activity is expected to recover more swiftly and extensively, resulting in a faster increase in employment levels.
Alternative 2	The security risks will last till the end of 2023, and the inflation of main export partners will be at the same level it was as of end 2022. The foreign debt will be growing at little higher speed due to necessity in more funds to support military sector and social. Besides, economic activity will suffer again due to war hostilities and the high possibility of massive rocket and drone attacks on critical infrastructure, and as a result, the employment rate will be on the same level it has been since the beginning of the full-scale invasion.
Alternative 3	The security risks will last till the beginning of the 4th quarter of 2023, and the inflation of main export partners will be growing due to the consequences of the russian-Ukrainian war and other factors, the level of foreign debt will be growing at a higher pace, as the government will need additional foreign sources to finance the economic recovery and invest more funds in the country`s reconstruction if the grants and investing funds from the international donors are very low. Additionally, the level of employment will drop a little bit due to more people leaving the country and more companies will close their facilities or stop working due to the decreasing demand or possible assets destructions.

Source: scenarios are built on the Inflation Reports [43, 51] and the author`s assumptions

The assumptions of scenarios presented in Table 2.2 were used to build the forecasts for key (exogenous) variables – inflation, exchange rate UAH/USD, GDP gap, international reserves, and the key policy rate – and provide the recommendations of the main monetary policy tools that the NBU could use as a response for the prevailing circumstances.

According to Figure 2.9, in the baseline scenario, the peak of inflation has already been achieved in the 4th quarter of 2022, and it will continue decreasing steadily, achieving 19,2% as of the 4th quarter of 2023 due to longer active war hostilities and high level of uncertainty what will be with the critical infrastructure in autumn 2023. Moreover, this fall in price growth will be facilitated by maintaining tight monetary conditions, reducing global inflation, and weaker consumer demand in the conditions of an energy deficit.

Figure 2.9. Historical and simulated values of the quarterly inflation, %



Source: made by the author according to the regression in EViews

The alternative scenario, № 1, which can be considered the most positive one, implies the quicker declination of security risks and gradual improvement of logistics and production, a reduction in global inflation, and moderately tight monetary conditions. As a result, inflation is expected to slow down to 10,16% in the 4th quarter of 2023. Other

factors, which will lead to the decline of price growth under this scenario, are the effects of a high comparison base that together with the relaxation of security risks will lead to lower production costs, improved logistics, and the restoration of production capacity, resulting in further supply growth and stable consumer prices.

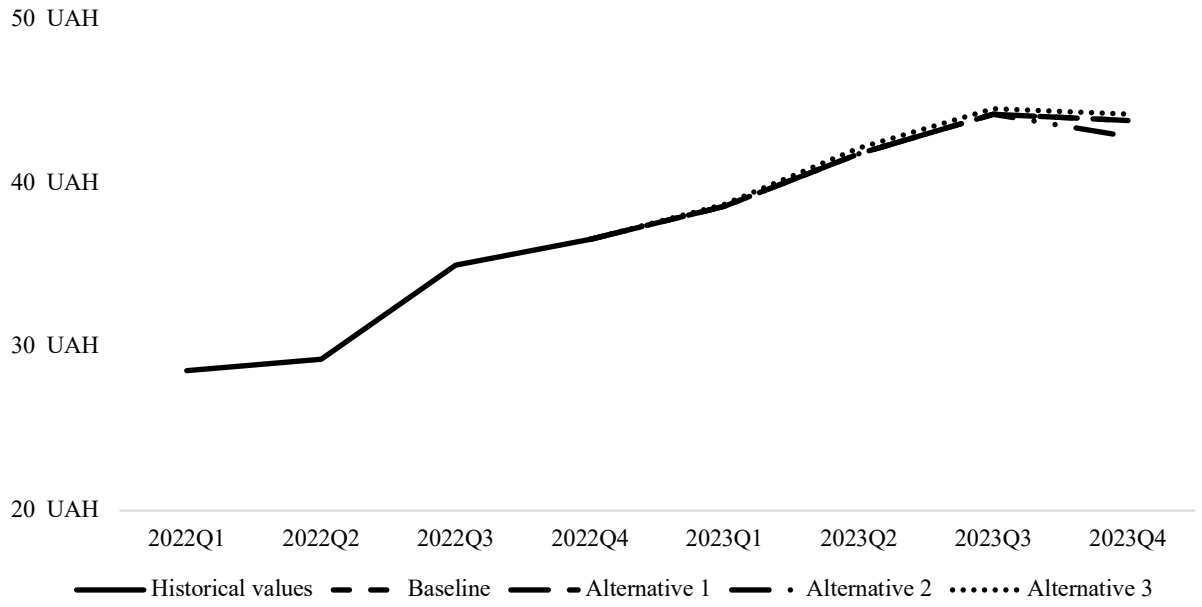
According to the alternative scenario, № 2, price pressure will remain significant due to the long-lasting consequences of the war, including the high possibility of enterprise and infrastructure destruction, and continuation of disruptions in production and supply chains. Additionally, business costs might continue rising due to russia's energy terror. As a result, inflation expectations will remain elevated and increase inflation to 20,6%.

The alternative scenario, № 3, considers earlier war hostilities ending but a worse situation with the economic recovery due to a significant negative impact of war on the assets` destruction, maintaining of tight monetary conditions, and weaker consumer demand, as more people might flee abroad and there are chances of an energy deficit. Moreover, there is a chance of higher values of global inflation, and it will accelerate the inflation to 11,8% in comparison to the baseline scenario.

According to Figure 2.10, in the baseline scenario, the alternative scenarios, № 2, № 3, hryvnia will continue devaluating, reaching an average of 44 UAH per 1 USD till the end of 2023. The main reasons for the decreasing cost of hryvnia according to these scenarios are the reduction of foreign currency income from major exporters due to the limitations in the logistics, as most of all seaports still will be closed, a decline in the trade balance, and a possible increase in emigration of the population to other countries. The country will also be facing a high level of unemployment and possible deficit in the state budget due to significant expenditures on the war (especially in the alternative scenarios, № 1, № 3). Besides, in the alternative scenarios, № 1, № 3, the war will last at least till the end of 2023, so there are still chances of massive missile shelling, which could significantly impact Ukraine's energy system, and it will put further pressure on the hryvnia, leading to a decrease in production by the real sector of the economy and creating

uncertainty about future losses from the destruction of crucial infrastructure. Moreover, these attacks could negatively impact Ukraine's industrial sector, and the hryvnia will continue to devalue.

Figure 2.10. Historical and simulated values of the exchange rate UAH/USD



Source: made by the author according to the regression in EViews

In the alternative scenario, № 1, on the cash market, USD will cost 42 UAH as of the 4th quarter of 2023. As this scenario is the most optimistic one due to the earlier ending of war hostilities, higher chances of improved logistics and possible chances of opening the seaports, decreasing level of unemployment, and a reduction in customers' inclination to purchase foreign currency as a deposit and shift to hryvnia deposits as the interest rates on them will be very close to the forecasted inflation. Besides, the provision of international financial to Ukraine will have a positive impact on the reserves and strengthening of the country's domestic currency.

According to Figure 2.11, in the baseline and alternative №1 scenarios, the GDP gap will be reduced to -0,06 and -0,07 in the 3rd quarter of 2023 due to a moderate increase of the potential GDP over the forecast horizon due to the adaptation of the economy to

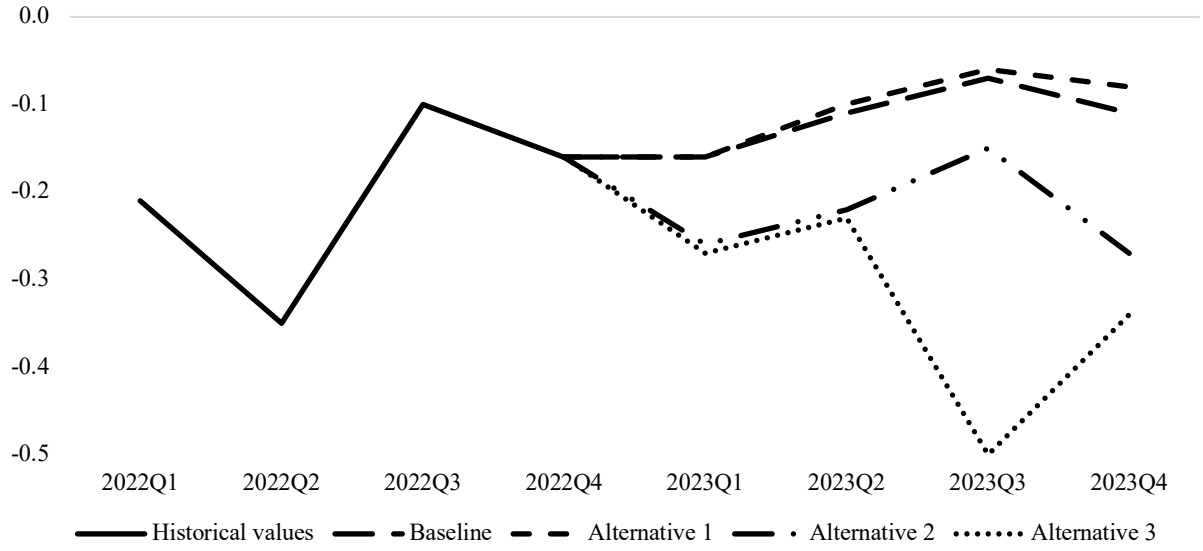
new realities and the acceleration of Euro-integration processes. At the same time, it might decrease a little bit to -0,11 and -0,08 consequently in the 4th quarter of 2023, as the potential GDP will not recover the significant losses incurred due to the destruction and damage of production capacities, disruption of technological chains, and emigration of the workforce abroad. The real GDP will be lower than its potential level due to weak domestic demand recovery, a weak labor market, and temporary logistic difficulties, while risks will remain high for a long time, negatively affecting the state's investment attractiveness.

According to the alternative scenario, № 2, the GDP gap will be higher than in the baseline, and in the alternative №1 scenarios, as there are high chances of artillery attacks on energy infrastructure, extensive destruction, and lack of equipment for repairs. As a result, it will have an impact on economic activity even in 2023 even after the government efforts to attract international assistance for the energy sector, as well as intensive restoration or replacement of damaged infrastructure. These threats will impact business expectations leading to lower levels of production and weaker demand due to the electricity deficit and higher chances of labor force emigration as the war according to this scenario will last at least till the end of 2023.

According to the alternative scenario, № 3, the GDP gap will be following the same pattern as in 2022 but have even more decline due to even more significant capital destructions, decreased investment because of uncertainty, loss of workforce through emigration, and reduced productivity due to the disruption of customary logistics and technological chains. As a result, the potential GDP may suffer a notable drop and won't rebound to previous levels within the forecast horizon due to the magnitude of the losses.

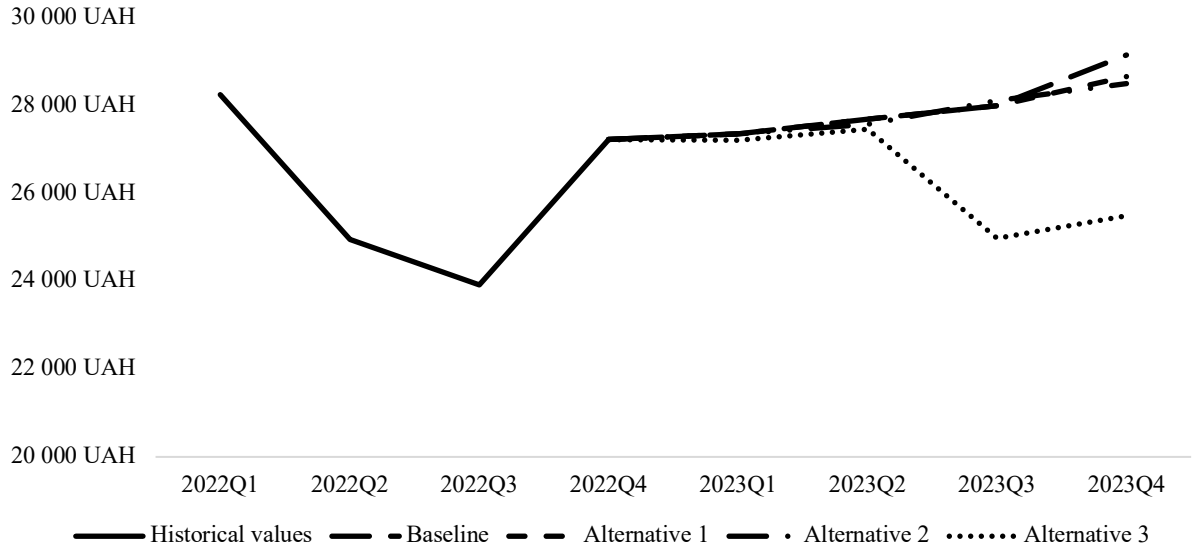
According to Figure 2.12, in the baseline scenario, the international reserves will continue growing due to inflows from international partners, coupled with reduced net foreign exchange sales by the NBU and moderate foreign exchange debt repayments by the state. Till the end of 2023, according to this scenario, international reserves will reach 29,2 billion USD.

Figure 2.11. Historical and simulated values of the GDP gap to potential output



Source: made by the author according to the regression in EViews

Figure 2.12. Historical and simulated values of international reserves, million USD

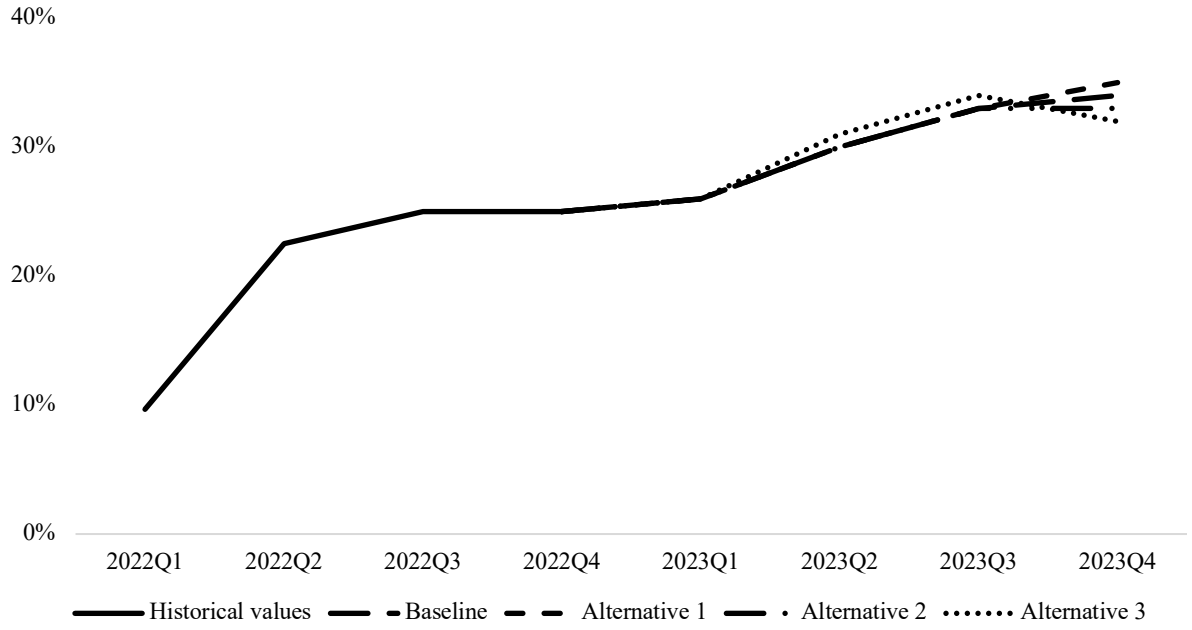


Source: made by the author according to the regression in EViews

In the alternative scenarios, № 1, № 2, the international reserves will be growing very steadily reaching 28,5-28,7 billion USD at the end of 2023. Such moderate growth will be caused by financial aid from international donors, but the exchange rate will be a

little bit higher than in the baseline scenario due to coverage of the gap between supply and demand in the FX market in Ukraine.

Figure 2.13. Historical and simulated value of the key policy rate, %



Source: made by the author according to the regression in EViews

The alternative scenario, № 3, could be considered as one of the negative ones due to a worse exit from the war hostilities ending, and the economic recovery is expected to face greater challenges, primarily due to the significant negative impact of war resulting in asset destruction, tight monetary conditions, weaker consumer demand, increased emigration, and a possible energy deficit. As a result, international reserves will decline up to 25,5 billion in the 4th quarter of 2023 due to more significant sales of foreign currency in the interbank FX market and transactions to manage public debt, primarily spending money on the servicing and repayment of public debt.

According to Figure 2.13, in the baseline scenario, alternative scenarios, № 1, 2, the key policy rate should be left at the high ratio, close to 25% to ensure stability in the exchange rate and macro-financial conditions, as well as to bring inflation back to a

sustainable downward trajectory, amid high levels of uncertainty. In the case of the alternative scenario, № 3, there might be a necessity to decreasing the key policy rate to help the business recovery in terms of a worse exit of enterprises from the active phase of the war.

Summary of Part 2:

In this part, we have discussed that macroeconomic models have proven to be effective tools for addressing socioeconomic issues. By utilizing simulation systems, economists can gain a comprehensive understanding of dynamic relationships and their impact on a country's development. These models are particularly useful because they are easy to understand and reflect socioeconomic processes and phenomena. To evaluate a system of simultaneous equations, it is important to identify the endogenous and exogenous variables, test the system for identification, estimate and test the equations using the appropriate specifications and classical assumptions, and diagnose the adequacy and sensitivity of the model, as well as its predictive power.

In the case of our macroeconomic model for the Ukrainian economy, we were able to use it to show how monetary indicators affect the key policy rate. This model, although simple, allows for scenario analyses to achieve macroeconomic stability and identify risks. The model consists of five equations for CPI, USD/UAH exchange rate, GDP gap, international reserves, and the key policy rate, and is based on the interconnections inherent in the monetary transmission channels' work.

After testing the model for accuracy with special tests and comparing the simulated values with the actual historical values, we were able to use it to make forecasts for key variables according to the baseline and three alternative scenarios. The results obtained from the model allowed us to make recommendations on how to address issues with inflation, exchange rate, and the GDP gap under different trajectories of events. By utilizing these results, policymakers can make informed decisions to achieve macroeconomic stability and ensure sustainable economic growth.

PART 3
RECOMMENDATIONS FOR MONETARY POLICY FRAMEWORK DURING THE WAR AND POST-WAR PERIODS

3.1. Monetary policy framework during the wartime

As the NBU has kept its key interest rate at a steady 25% since June 2022, and according to almost all our scenarios this rate should stay at this level at least until the end of 2023 to tackle inflation and stimulate the banks to continue banks` encouragement to compete more actively for term deposits from customers, leading to higher interest rates for hryvnia assets and a greater proportion of term deposits. Besides, the risks to both inflation and economic development in Ukraine are still significant, particularly due to the ongoing war. The uncertainty surrounding the future course of hostilities is hindering economic recovery and contributing to the formation of high inflationary and devaluation expectations. Consequently, the demand for the currency remains high, and the foreign exchange market is heavily reliant on interventions from the NBU. Additionally, there are risks associated with the potential cessation of the "grain corridor," which russia constantly threatens, as well as pressure from the excessive balance of funds in current accounts within the banking system, amidst the insufficient attractiveness of hryvnia assets. Furthermore, there is significant inflationary pressure from Ukraine's trading partners, and the bankruptcy of banks in the United States and Europe has made it challenging for leading central banks to control inflation [84].

Only in the case of the alternative scenario, №1, there is a possibility to decrease the key policy rate, as the inflation will decrease to almost 10%, and there will be a decrease in pressure on the foreign exchange market and improving prospects of international reserves. Even though, this scenario assumes that in the 4th quarter of 2023, the active phase of the war will be over, the consequences of a possible new global

financial crisis after the bankruptcy of several large Western banks could hinder the situation with the inflation development and the financial system in general [84].

Moreover, keeping the high key rate since July 2022 helped stabilize the foreign exchange market, despite the war. As a result, the market anticipates a balanced policy from NBU in the future. Based on the current situation, the best option is to align the key rate trajectory with the plan to ease administrative restrictions in the foreign exchange market. Moreover, uncertainty remains high, and the effectiveness of tight FX restrictions decreases over time, hindering business activity. To maintain exchange rate sustainability, hryvnia savings must remain attractive, and easing the most burdensome FX restrictions is increasingly relevant. However, completing this task without shocking the economy and FX market requires ensuring hryvnia savings' continued attractiveness [53].

Touching on the topic of currency restrictions, it`s vital to distinguish how they should be eased and under which conditions. The alternative scenarios, № 2, 3, demonstrate to us that the current restrictions (see Table 1.3) should stay at least till the end of the 4th quarter of 2023 due to the continuation of war hostilities and the likelihood of significant rocket and drone attacks on critical infrastructure that will cause economic activity to suffer, resulting in employment rates remaining stagnant since the beginning of the full-scale invasion. Furthermore, the government will need to seek additional foreign funding to support economic recovery and invest in the country's reconstruction if international donor grants and investment funds are insufficient. As more people leave the country and companies shut down or reduce their operations due to declining demand or asset destruction, employment levels may decline slightly.

In the case of the baseline and alternative scenarios, № 1, and considering the projected situation with the level of international reserves, the most optimal solution for the 1st and 2nd quarters of 2023 is to leave the current currency restrictions in place to reduce the demand for currency in the cash segment. But starting from the 3rd quarter of 2023, there are high possibilities to ease the limitations (see Table 1.3), namely:

- increase both cash withdrawals from currency and Ukrainian cards;

- allow the SWIFT payments from the 4th quarter of 2023, but starting from a small amount;
- increase a monthly limit firstly to UAH 150 000 and then to UAH 200 000 for the purchase by citizens of Ukraine of non-cash foreign currency with subsequent placement on an immediate deposit of three months or more;
- remove restrictions on P2P transfers from hryvnia payment cards of Ukrainian banks to cards of foreign banks, which was returned on October 5 of 2023, as the risks of using this method of withdrawing funds from the country to bypass restrictions on the purchase of foreign currency might decrease;
- increase the percentage of import payments on services and bring it to 90% from the current 50%;
- return the deadline for settlement of export-import transactions (365 days) as it was in the first month of the full-scale invasion;
- increase the foreign exchange open position step-by-step and bring it back to 15%;
- allow early repayments of loans from banks to non-residents.

Notwithstanding, in case of necessity, the NBU could continue to increase the required reserve ratio to absorb banks' excess liquidity, as it is one of the key factors in the banks' inactive reaction to the increase in the discount rate as early as early June. The advantages of such a tool are speed, ease of implementation, and effectiveness.

The regulator has also increased the required reserves for banks, as previously announced in December 2022. Effective February 11, the norms for forming mandatory reserves by banks have increased by 5 percentage points for funds on demand, funds on current accounts of legal and physical persons, funds on deposits, funds on current accounts of other non-resident banks, and credits received from international (non-financial) and other organizations. Additionally, effective March 11, the norms for forming mandatory reserves for funds on demand and funds on current accounts of physical persons have increased by 10 percentage points, both in national and foreign currencies [55].

Table 3.1. Restrictions imposed on FX transactions and capital movements under baseline and alternative 1 scenario

	Operations	I quarter 2023	II quarter 2023	III quarter 2023	IV quarter 2023
Individuals	FX cash withdrawals from FX accounts	UAH 100K/day		UAH 150K/day	UAH 200K/day
	Cash withdrawals abroad from UAH accounts	UAH 12,5K/month		UAH 50K/month	UAH 100K/month
	Settlements abroad with hryvnia cards	UAH 100K/day		UAH 200K/day	**V** No limit
	P2P card transfers	**X** Full ban		UAH 30K/month	UAH 100K/month
	FX cash purchases from banks	**cap** → cash currency purchased by banks **+ 100%** of noncash FX purchased from individuals			
	Online FX purchases	**cap** → UAH **100K/month** + deposit for 3 months		**cap** → UAH **150K/month** + deposit for 3 months	**cap** → UAH **200K/month** + deposit for 3 months
	ER for card payments	**cap → no restrictions**			
	Swift payments abroad	**X** Full ban			**cap** → UAH **50K/month**
Corporates	Import payments	Goods → **100%** (no restrictions) Services → **~ 50%**		Goods → **100%** (no restrictions) Services → **~ 70%**	Goods → **100%** (no restrictions) Services → **~ 90%**
	Deadline for settlement of export-import transactions	**→ 180 days**		**→ 270 days**	**→ 365 days**
	Repayments of debts	Interest payments are **allowed**			
Banks	FX open position	**5%**		**→ 10%**	**→ 15%**
	Repayments of loans to non-residents	Early payments are **prohibited**			Early payments are **allowed**

Source: the recommendations are generated by the author according to the baseline and alternative №1 scenarios forecasts

The NBU has already equalized the Required Reserve (RR) for retail deposits that have a maximum maturity of three months with the RR for households' funds in current

accounts. At the same time, it might be beneficial to extend this approach to the RR for corporate deposits to prevent the foreign currency from leaving Ukraine and tie up the banking system's liquidity. Another option is to apply a preferential RR rate to deposits with at least one month's maturity, as short-term profitable deposits are the most attractive to depositors. Following this suggestion, it will be possible to tie up free funds for even a month, and it might be sufficient to reduce risks [83].

Additionally, the new operational design of monetary policy involves reducing the rate on overnight certificates of deposit (CDs) to 20% and introducing three-month CDs with a fixed rate at the level of the key policy rate. The main idea of this adjustment is to provide banks with more incentives than the previous design to compete for term deposits by expanding the space for increasing deposit rates, differentiating rates on CDs with various maturities, and allowing banks that actively participate in the competition to build up their volumes of CDs at a rate of 25% in the short term. Consequently, some banks should have increased their marketing efforts and interest rates on hryvnia term deposits, while others had to be compelled to follow the market to maintain liquidity and retain customers. Although banks may still place their free funds into overnight CDs, such transactions would result in lower revenues due to changes in the operational design and the update to the RR calculation protocol [85].

At the same time, relying solely on market-based methods to address the non-market problem at hand would be futile. The leading banks, which are the least active in raising interest rates, enjoy non-competitive advantages when it comes to attracting funds to current accounts. This has reduced their responsiveness to the NBU's market-driven tools. That is why these banks must respond appropriately to the NBU's policy to redirect funds from current accounts to term deposits. To achieve this goal more efficiently and promptly, market-based incentives should be supplemented by administrative controls that the NBU has at its disposal, even during periods of martial law.

Nevertheless, the new operational design will provide the prerequisites for revitalizing bank activity in the interbank market. Banks that have advantages in raising

term deposits but insufficient liquidity to invest in three-month CDs will be motivated to receive liquidity from other banks in the interbank credit market, incentivizing the development of this market [84].

Maintaining a high key policy rate for a long time, increased reserve requirements, updated monetary policy design, and revised calculation mechanisms to make hryvnia term deposits more attractive. This decreased the spread between cash and official exchange rates, improved exchange rate and inflation expectations, reduced FX interventions, and increased international reserves. These actions strengthened and would continue fortifying the NBU's ability to maintain exchange rate sustainability and ease inflation.

The NBU recently made changes by allowing banks to adjust the calculation of permissible foreign currency sales. It is now based on 120% of non-cash currency purchases by the public instead of 100%. Additionally, e-residents can now transfer foreign currency funds received from non-residents to their accounts abroad after paying taxes in Ukraine. These administrative restrictions' easing will aid the launch of the electronic residency project and support positive developments in the foreign exchange market's cash segment [86].

Moreover, the NBU could introduce operations for the sale of government bonds from the NBU's portfolio, which would further increase the yield of hryvnia instruments. Such operations will provide an alternative opportunity for market participants (primarily the population and businesses) to buy risk-free hryvnia financial instruments with an attractive yield and flexible maturity to protect hryvnia savings from inflation. The yield level of these bonds may fluctuate within the current level of the discount rate so that hryvnia assets become more attractive for compensation [87].

3.2. Guidelines for the monetary policy framework in the aftermath of war

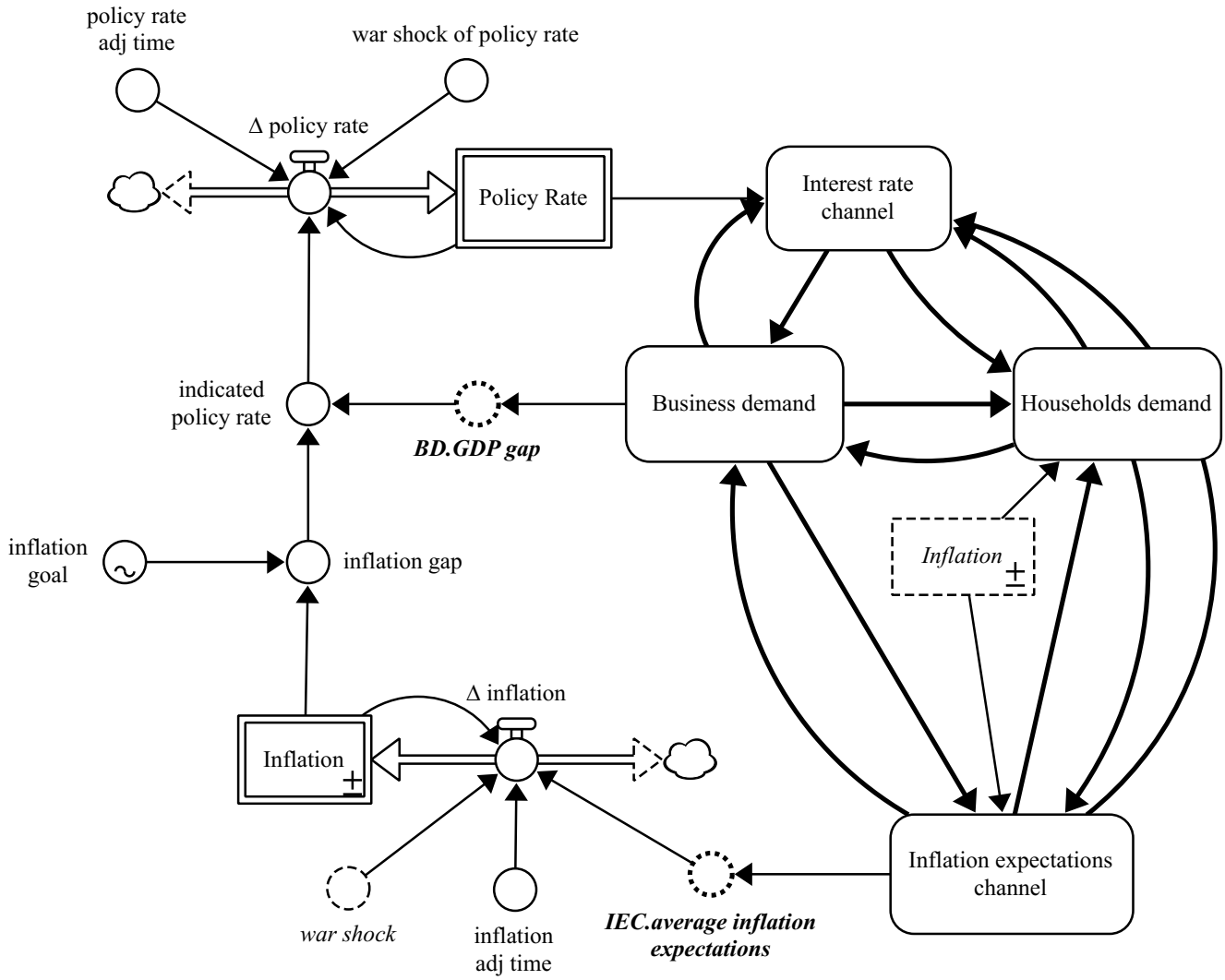
Making any forecasts for 2024-2025 is extremely complicated due to the high level of uncertainty associated with the war. The policy rate's expected path should be aimed at ensuring monetary conditions that will sustain exchange rate stability, improve expectations, and achieve a lasting reduction in inflation. The NBU must be ready to modify the timing and pace of policy rate changes depending on developments in the foreign exchange market, inflation dynamics, the stability of international support, and the effectiveness of measures to enhance the appeal of hryvnia instruments.

Nevertheless, using the tools of System Dynamics modeling we can make projections for the trajectory of the inflation and policy rate for the next two years (see Figure 3.1 and Appendix L for more details). We may assume that, according to the first scenario, the active phase part of the russian-Ukrainian war will last till the end of 2023, and we will face improvements already in 2024. It will relate to further restoration of logistics and production capacity, meaning economic growth. All things mentioned before and the consistent monetary policy of the NBU (the gradual decrease of the key policy rate to 19,5% as of the end of 2023; 13,4% as of the end of 2024; and 10,3% as of the end of 2025; the current reserves requirements will stay preserved) will alleviate inflationary pressure, despite the economic recovery and the maintenance of a soft fiscal policy. The model shows that inflation will decrease to 13,2% in 2023, 12,8% in 2024, and 8,9% in 2025, and it reflects the recent macro forecast published by the NBU.

The second scenario assumes that the active stage of full-scale war will persist for a longer duration – till the end of 2024, it would force the NBU to keep the monetary conditions more stringent and prolonged – the key policy rate will stay quite high despite its decrease in 2023-2024. According to the model`s simulations, it will be equal to 21,4% as of the end of 2023, 17,3% as of the end of 2024, and 15,3% as of the end of 2025. The NBU could also resort to the increase of the required reserves and the following modification of the operational design of monetary policy to cope with the surplus of

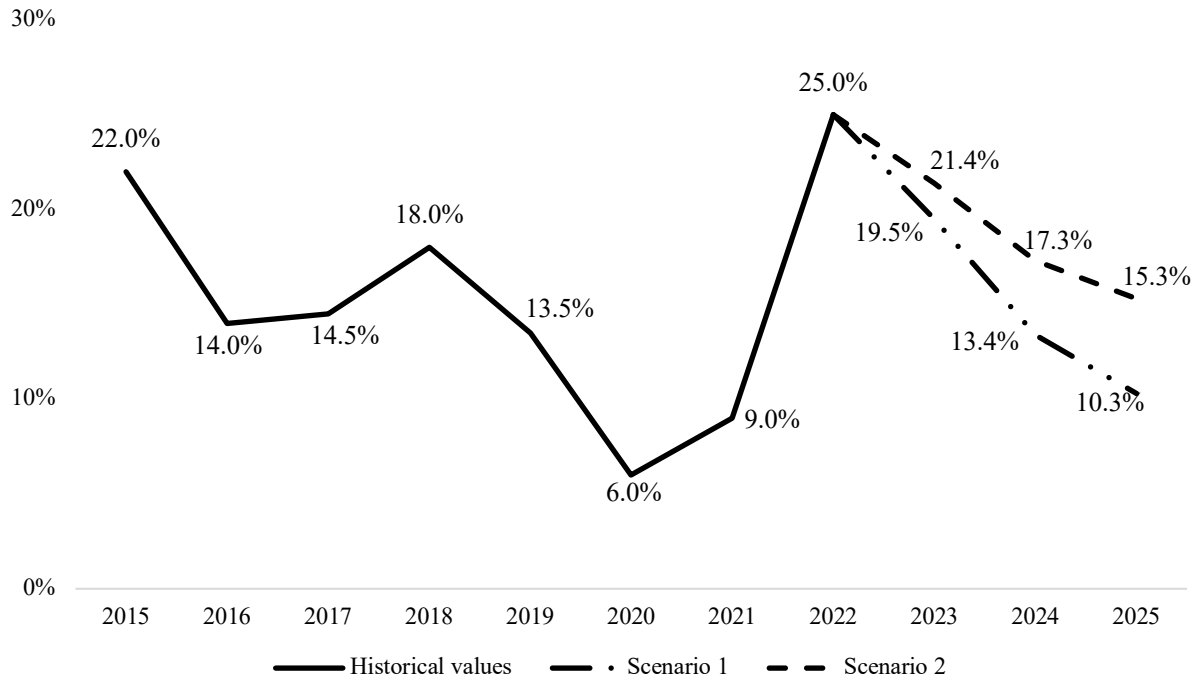
liquidity. Under this scenario, despite businesses adapting to high-security risks, economic growth in 2024 will be limited to 2%, thereby slowing down labor market recovery. Anyway, inflation will continue its downward trend due to a moratorium on raising tariffs for select utility services and tight monetary conditions. According to the model, inflation is expected to be 16,3% as of the end of 2023, 13,7% as of the end of 2024, and then drop to 9,1% as of the end of 2025.

Figure 3.1. Representation of the monetary policy in Ukraine using the System Dynamics modeling



Source: made by the author using tools of the System Dynamics in Stella Architect

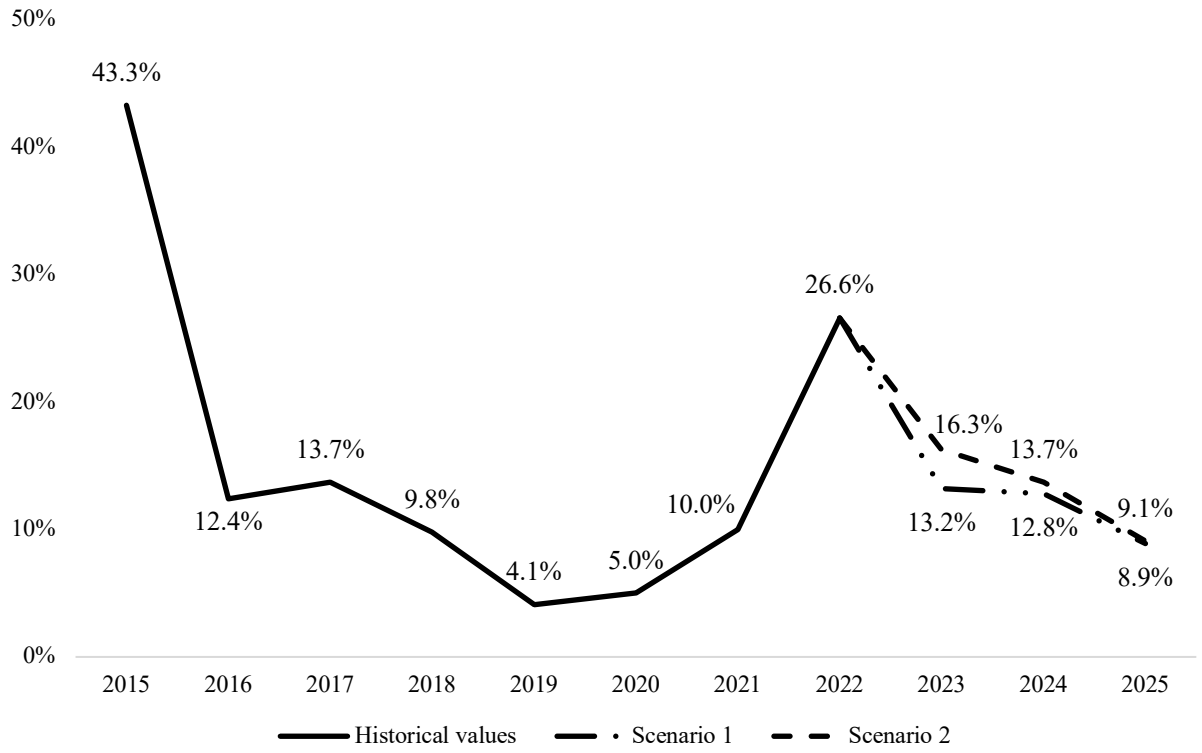
Figure 3.2. Historical and simulated values of the key policy rate, %



Source: made by the author according to the System Dynamics model in Stella Architect

According to the current macro forecast, inflation is going down, and the Monetary Policy Committee plans to decrease the key policy rate in the 4th quarter of 2023. It represents the alternative scenario № 1 of the system of the simulation equations. Considering these facts and the results of the simulations via System Dynamics modeling, we recommend the NBU lower the key policy rate to almost 20% by end-2023, with Q4 as the best time to start a reduction cycle due to the need to ease some FX restrictions. At the same time, it`s still necessary to keep the fixed exchange rate to manage the risks that might happen during the initial stage of currency liberalization.

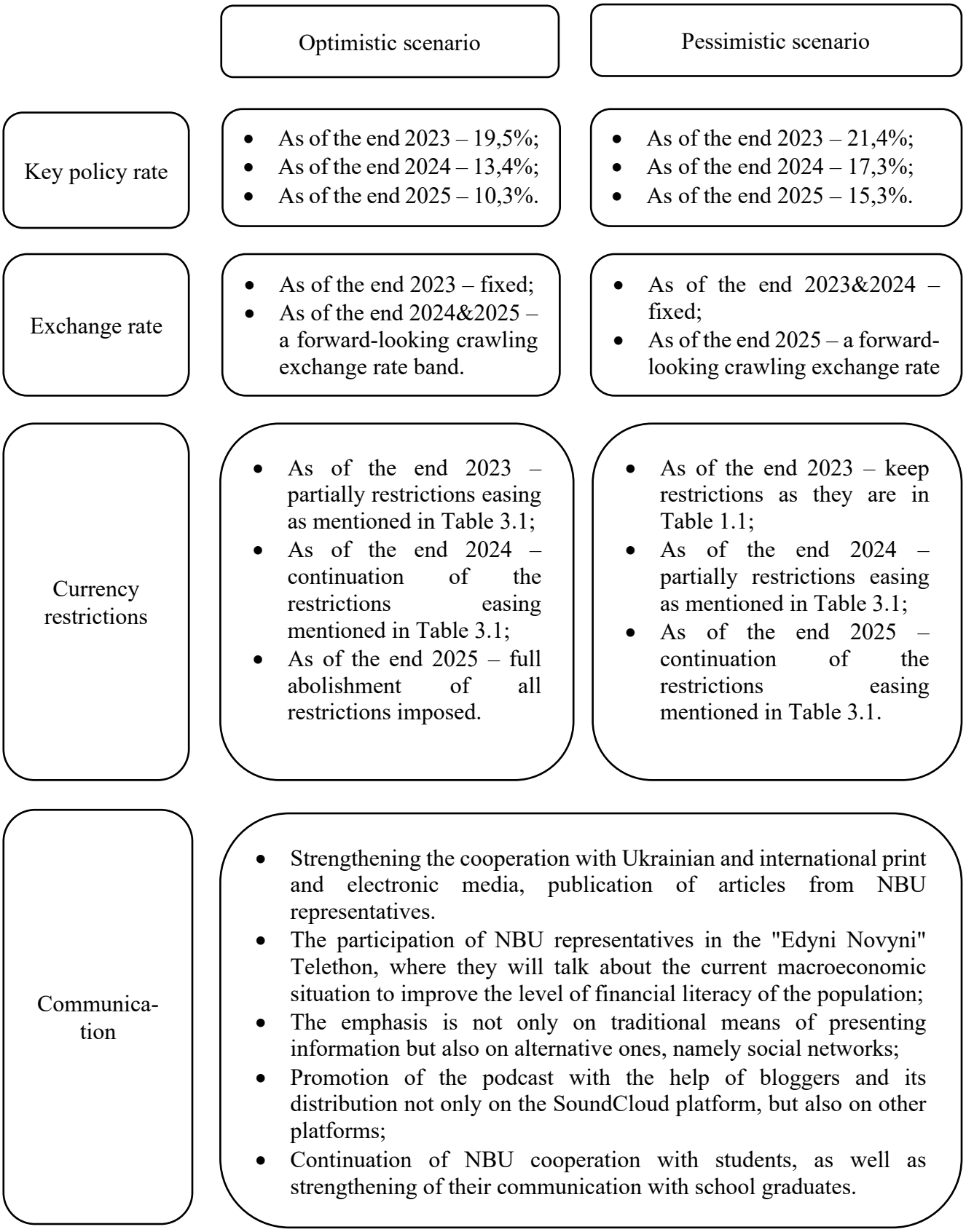
Figure 3.3. Historical and simulated values of the inflation, %



Source: made by the author according to the System Dynamics model in Stella Architect

One of the most important things that the NBU should not do in the following years is the restoration of monetary financing of the budget deficit. First of all, it is a pledge made by both the government and the central bank to the IMF as part of the new credit program – EEF [88]. Secondly, it will only resume the inflation pressure and undermine the independence of the NBU. Consequently, it is very vital to attract as many as possible international financial aid and increase the appeal of government securities among individuals and businesses. In addition to the sale of the NBU`s bonds at a rate equal to the policy rate, it is necessary to ease the process of bond purchase for citizens through online banking and popularize it as a patriotic way to support the country during the recovery period. This action could make the better attractiveness of funds in the domestic market.

Figure 3.4. Recommendations for the NBU according to different scenarios



Source: made by the author based on the forecasts using modeling

Notwithstanding, Ukraine should come back to the floating exchange rate – it is not just the statement of the NBU, but also the requirement of the IMF to revert to a pre-war monetary policy framework, which includes also classical principles of inflation targeting [88]. Israel's successful experience provides a valuable lesson for Ukraine to transition to a floating exchange rate efficiently and avoid significant devaluation of the hryvnia. In 1986, Israel pegged the New Israel Shekel (NIS) to a basket of currencies from trading partners, which eroded competitiveness and profitability. Two years later, the peg was replaced by a horizontal band of +/- 3% that was adjusted in response to speculative flows linked to inflation premiums until 1991. Due to a major economic boom resulting from immigration, the adjustable peg system was deemed unsustainable, and a forward-looking crawling exchange rate band was introduced in December 1991. This led to a decline in inflation and the adoption of inflation targeting as the primary objective for monetary policy. Over time, the width of the band increased, and interest rate policy shifted towards directly achieving the inflation target. In 1997, inflation targeting became the sole target of monetary policy, and the IMF classified Israel's monetary regime as full-fledged inflation targeting. Capital flows were liberalized, and a floating exchange rate regime was instituted in practice. Finally, in 2005, the exchange rate was officially declared as floated, and the exchange rate band was abolished [89-90]. Based on this example and various exchange rate regime tests, Ukraine should transition to a floating exchange rate through a forward-looking crawling exchange rate band with certain deviations, such as ± 5% and then ± 7% in Israel, during the post-war period.

An equally important factor is the communication carried out by the NBU with the economic agents at different levels. The regulator needs to pay significant attention to communication, since it is through effective communication with various target audiences, including the public, consumers of financial services, the academic community, state policy entities (which is specific to Ukraine), media, economic and financial entities, and experts (both domestically and internationally), as well as international organizations and other external partners, that the NBU can succeed.

Considering that the NBU uses its official website as the primary channel, most of the information presented on it is mainly of interest to the academic community in working with statistical data and reviewing reports for scientific research, as well as for stakeholders of state policy. However, ordinary citizens and users of financial services, who are not directly linked to monetary policy, mainly get news related to NBU's current actions from external sources, including media outlets (mostly “Ukrainian Pravda,” Forbes, NV, and mind.ua). Therefore, NBU needs to focus on alternative communication channels that are most used by citizens of Ukraine, namely: Telegram, Viber, TikTok, and Instagram, where the current macroeconomic situation in the country can be explained in a simplified and interactive format. Additionally, NBU should popularize its podcast, as this form of information delivery is gaining momentum and within two to three years in Ukraine, it will be possible to talk about the formation of a real podcast market. The podcast should be published not only on SoundCloud but also on the Podcast app for iOS users, as well as on YouTube (Music) and Spotify. Moreover, for more effective communication, representatives of NBU should join the Unified Telethon, as well as channels that belong to other media groups and are not involved in the common dissemination of information. Together with presenters, they can discuss NBU's decisions and its current strict monetary policy to increase trust in the central bank and anchor inflation expectations at the target level.

Additionally, the NBU should strengthen cooperation with print and electronic media so that representatives of the regulator can publish their articles on them. Unfortunately, there are very few professional journalists in the field of economics and finance. Moreover, it is appropriate for employees of various departments of the NBU to continue to conduct interactive lectures in higher education institutions, as well as in schools for 10^{th} and 11^{th} graders, using, for example, such modeling methodology as system dynamics. Students, using an interactive interface, could feel themselves in the role of "policymakers" and better master the operation of the transmission mechanism. Also, in conditions of war and remote living, online courses with certificates at the end of

their completion would positively contribute not only to students but also to young and older people who want to improve their financial literacy. Besides, the development and release of their application would allow representatives of the NBU to provide information not only to average citizens but also to business representatives, investors, and analysts to receive information about the current macroeconomic situation and non-bank financial institutions.

Moreover, the NBU can cooperate with banks in Ukraine that have online applications and agree to duplicate the information published on the NBU website in the news section, but in a simpler format that would be understandable to the average citizen. The dissemination of current actions in macro policy should also be highlighted not only in Ukrainian media but also in foreign media for better information on foreign investors, analysts, businessmen, banks, and non-banking financial institutions. Accordingly, publications in foreign media, including The Times, Financial Times, New York Times, Reuters, and others by NBU representatives will increase the awareness of foreigners, especially investors, and analysts, regarding the current and forecasted monetary policy in Ukraine.

Equally important now is the communication of the NBU Governor and all channels mentioned earlier should be involved: social networks (it would be appropriate for the new Governor to have his own Telegram channel, Instagram, Twitter, and Facebook, where he would publish relatively frequent updates on the activities of the central bank and once a month carry out a video report on the work of the NBU), media (TV and electronic and print newspapers), and conducting online press conferences on YouTube.

Summary of Part 3:

The NBU has been consistently working to combat inflation and encourage banks to compete for term deposits by maintaining a key interest rate of 25% since June 2022. We have looked at four different scenarios, and according to the current situation and NBU`s macro forecast, we are moving somewhere close to the alternative scenario № 1.

Considering these developments, our recommendation is for the NBU to reduce the key policy rate to almost 20% by the end of 2023, with Q4 being the optimal time to initiate a cycle of rate cuts to ease some FX restrictions. However, it is important to maintain the fixed exchange rate to manage potential risks that may arise during the initial phase of currency liberalization. At the same time, the gradual relaxation of currency restrictions would improve access to foreign currency for businesses and individuals and help to reduce the black market for foreign exchange. The NBU can also boost hryvnia instrument yields (e.g., treasury bonds), expand investment options, and introduce government bond sales to enhance market access, and encourage domestic financial market growth.

Furthermore, we analyzed the potential values of the main interest rate and the inflation rate for the years 2024-2025 using the approach of System Dynamics modeling. We considered two distinct situations, one characterized by optimism. According to the optimistic scenario, the active phase of the war will end by the conclusion of 2023. However, the negative scenario assumes that the war will persist until the end of 2024, resulting in a prolonged period of strict monetary measures. In both situations, the projected outcome is a decrease in inflation to 9% by the end of 2025. Nevertheless, the negative scenario foresees higher inflation in the preceding years in comparison to the positive scenario.

To improve exchange rate stability, the NBU may also consider transitioning from a pegged exchange rate to a floating exchange rate with a forward-looking crawling exchange rate band, such as Israel's successful experience. This would allow the exchange rate to adjust more flexibly to market conditions and reduce the need for currency interventions.

Finally, effective communication is crucial, and the NBU should utilize social media platforms, podcasts, and online courses to improve financial literacy and increase public understanding of monetary policy decisions. This would help to promote transparency and accountability and increase public confidence in the NBU's ability to manage the economy effectively.

CONCLUSIONS

In 2015, Ukraine adopted an inflation-targeting framework for its monetary policy, which aimed to decrease inflation to 5% annually in the medium term. However, the country faced various challenges such as economic crises, military conflict, and currency devaluation, leading to the intervention of the International Monetary Fund (IMF). To establish inflation targets for the consumer price index, the National Bank of Ukraine (NBU) released a roadmap with Monetary Policy Guidelines in March 2016. The NBU focused on building macroeconomic models, designing quarterly forecasts, and modifying monetary policy decision-making mechanisms, emphasizing the unchanging nature of the inflation target, and began implementing inflation targeting in the second half of 2015. The primary goal of the NBU was to attain price stability and avoid fiscal dominance.

To control inflation, the regulator uses the key policy rate and may adjust it to align with inflation targets. Additionally, foreign exchange (FX) interventions are used to maintain reserves and reduce exchange rate volatility, although they cannot guarantee a specific exchange rate. The central bank primarily employs the interest rate channel to execute monetary policy, managing short-term money market rates by regulating bank liquidity. The exchange rate channel is the second monetary transmission channel, enabling borrowing at lower interest rates in one country and investing in another country with higher yields. In Ukraine, the expectations channel is also crucial, with inflation expectations rapidly influencing price-setting behavior.

Before examining the changes in the monetary policy framework in Ukraine, we studied the examples of foreign countries that had faced armed conflicts in the past. During wartime, monetary policy objectives shift to address the unique challenges of a military economy, where government spending increases, and the state plays a larger role. Historical examples from World War II demonstrate how central banks employed monetary policy tools, such as purchasing government securities and imposing credit controls, to manage war-related economic challenges. After the war, many countries

implemented different approaches to monetary policy, as pegging exchange rates can be effective but risky, and financing wars through central bank funding can result in hyperinflation. Examples from Israel and Croatia illustrate that many countries have successfully recovered from wartime crises through independent monetary policy, fiscal consolidation, and market financing.

During the invasion, Ukraine fixed the exchange rate of hryvnia to the US dollar and utilized foreign exchange interventions to cover the FX deficit and stabilize the exchange rate. However, inflation rose due to production disruptions and high global energy prices. To combat inflation and protect hryvnia assets, the NBU implemented an active interest rate policy, raised required reserve ratios for banks, and kept a high key policy rate of 25%. The NBU also adjusted the exchange rate to USD/UAH 36,56 to decrease imports and increase international reserves. Although inflation has been stabilizing, there are still potential risks. To mitigate these risks, the NBU has increased reserve requirements, expanded the use of domestic government debt securities, and aimed to encourage term deposits to stabilize the FX market.

We conducted a thorough review of literature and historical context and then employed a simulative equation system to comprehensively understand dynamic relationships and phenomena. Our macroeconomic model includes five equations for inflation, exchange rate, GDP gap, international reserves, and key policy rate, allowing for scenario analyses and identification of risks. We tested the model's accuracy and utilized it to recommend strategies for achieving macroeconomic stability under different scenarios.

Based on the current macro forecast, inflation is expected to decrease, and the Monetary Policy Committee has outlined an alternative scenario where the key policy rate will be reduced in Q4 of 2023. We suggest that the NBU consider lowering the key policy rate to almost 20% by the end of 2023, with Q4 being the most suitable time to commence a rate reduction cycle. This is due to the need to ease certain FX restrictions. It is essential to maintain the fixed exchange rate during the initial phase of currency liberalization to

manage potential risks. However, eventually, the NBU will need to transition to a floating exchange rate in the post-war period, and it could consider Israel's successful experience in this regard.

At the same, risks to inflation and economic development persist due to ongoing war, uncertainty in the future course of hostilities, and other factors such as potential threats from russia, pressure from excessive funds in current accounts within the banking system, and the insufficient attractiveness of hryvnia assets. In such cases, the NBU should be ready to increase required reserves for banks to absorb excess liquidity, and the introduction of preferential rates or equalizing required reserves for different types of deposits could help reduce risks.

We also discussed the new monetary policy design that incentivizes banks to compete for term deposits by reducing rates on overnight CDs and introducing three-month CDs. Additionally, the NBU made changes in April 2023 that allow banks to adjust the permissible foreign currency volume, and e-residents can transfer funds abroad after paying taxes. These measures are expected to improve the resilience of the currency market.

Also, we examined the potential values of the primary interest rate and the inflation rate for 2024-2025 using the methodology of System Dynamics modeling. Two different scenarios were considered, with one being optimistic. In the optimistic scenario, the active phase of the war concludes by the end of 2023. However, the negative scenario assumes that the war will persist until the end of 2024, leading to an extended period of tight monetary policy. In both scenarios, inflation is projected to decline to 9% by the conclusion of 2025, but the negative scenario anticipates higher inflation in the preceding years compared to the positive scenario.

Lastly, we emphasize that effective communication is vital for the regulator to reach various audiences, and alternative channels should be used. Collaboration with media, educational institutions, and banks, as well as developing their application, can further enhance communication and financial literacy efforts.

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Appendix A

Table A.1. The monetary policy tools of the countries in the post-war period

Country	Years	Monetary policy of Central Bank
The Unites States of America	1946-1953	The monetary policy of the United States following World War II was mainly influenced by the significant expansion of the federal debt and money supply during the war. In 1946-1953, both adjustments to the discount rate and modifications to reserve requirements were employed prudently: • The preferential discount rate was abolished, marking the first move towards flexible interest rates. • The discontinuation of the buying offer on Treasury bills in July 1947 led to an increase in the rates on new issues of Treasury bills and certificates, which narrowed the spread between short-term and long-term interest rates and affected the money market rates. • The legal maximum requirements for central reserve city banks were increased to avoid a situation of bank credit`s excessive expansion. This step reduced potential bank credit expansion by about 12 bln USD. • Temporary controls were imposed on consumer credits to curb speculative purchases of securities made with borrowed money.
The United Kingdom	1945-1953	• At the end of 1945 and in 1946, the interest rates on short- and long-term government security rates were decreased to sell Treasury Bills held by government agencies to banks and purchase long-term securities from the public with the proceeds of the Treasury Bill sales (Ultra-cheap-money policy). • The postwar technique of monetary control in the UK is based on qualitative control over bank credit, consisting mainly of instructions sent out to banks by the Bank of England regarding the priorities to be given to different uses in granting bank advances. • A substantial outflow of reserves, primarily due to the UK's balance of payments situation, occurred in 1951 amounting to $1.5 billion over six months. To stop this drain, the key policy rate was raised several times step-by-step, the peg on the Treasury Bill rate was removed, and the direct or qualitative controls were further intensified.

Continuation of Table A.1

Country	Years	Monetary policy of Central Bank
Germany	1948-1953	• Currency reform was based on the change from the old Reichs mark to a new Deutsche Mark. The conversion rate of RM 10 to DM 1 was used to convert most monetary claims under the currency reform, which also declared the entire internal debt of the old Reich worthless, resulting in a reduction in the money supply and liquid assets in the economy. • The minimum reserve requirements and the key policy rate were raised to restrict bank credit in 1948 and 1950 (between this period, in 1949, some liberalization processes took place). • Imports were made harder to finance by requiring a 50% cash deposit at the central bank for import permit grants or extensions. As a result, the balance of payments position improved.
France	1945-1953	• The discount rate was raised significantly (from 1,625% to 3,5%) together with the rate on advances against securities (from 2,75% to 4,5%). These moving-ups resulted in the cost of borrowing from banks and made government bonds more appealing. In early 1950s, the discount rate was lowered to 2,5% to ease the restrictions on loans. • The direct credit controls were initiated to give the power for the National Credit Council to grant authority to provide banks with instructions or recommendations on the types of loan they should promote or discourage. • The regulations on mandatory reserves were also updated (during 1945-1950 every month, in 1951 – on daily basis) and increased.
Belgium	1944-1953	• In 1944, the country implemented a currency reform to decrease the excess purchasing power accumulated during the occupation, significantly reducing the money supply from Bfr 164 billion to Bfr 57 billion. • In the postwar years, the banking system's liquidity was also targeted to reinforce the monetary purge of 1944. Firstly, banks were required to notify the National Bank and Banking Commission of credit requests exceeding one million francs. Then, compulsory reserve requirements were implemented instead of these provisions. • After the excess money supply was removed and the credit supply was limited by reserve requirements, the discount rate technique became viable. It was increased from 1,5% (as of January 1945) to 3,75% (as of September 1950).

Continuation of Table A.1

Country	Years	Monetary policy of Central Bank
The Netherlands	1945-1953	• In September 1945, the main effort to reduce the excess money supply was made by withdrawing and freezing all currency and deposit money. • One of the provisions of the monetary purge exerted significant control over bank credit, stipulating that credit should not be granted to individuals with blocked accounts. • In the early postwar years, low-interest rates were preferred, and the interest rate weapon was not heavily utilized. • Loans over 50,000 guilders required approval from the Netherlands Bank, while informal control over nonessential credit was maintained through "gentlemen's agreements" between the central bank and credit institutions.
Israel	1985	• The Bank of Israel (BoI) increased the reserve requirements and the real discount rate to restrict the growth of deregulated banking lending. • The minimum term for dollar-indexed (PATAM) deposits was raised to one year. • The new central bank law was introduced, prohibiting borrowing from the BoI to finance the budget deficit. • The tradability of government bonds was improved. • The exchange rate was devaluated, partially unified for importers and exporters, and the rate was fixed to the USD at NIS 1,5 per dollar.
Croatia	1995-2000	• The Stabilisation Programme included the establishment of nominal exchange rate targeting framework as a crucial component. • The emergence of numerous new banks due to financial liberalization and low requirements has led to intense competition for deposits, resulting in the establishment of attractive deposit rates. • To prevent appreciation, the monetary policy facilitated capital inflows by buying foreign currency. • The excess liquidity was sterilized mainly through reserve requirement, but the CNB also issued voluntary and obligatory bills in kuna with high interest rates, which succeeded in lowering money market interest rates.

Source: based on IMF and CNB reports [30, 89-91]

Appendix B

Table B.1. List of variables in a macroeconomic model

Variable code	Name	Units	Source
Endogenous variables			
CPI	Consumer price index, to December of previous year	%	NBU
ER	Exchange rate of Ukrainian hryvnia to 1 USD	UAH/USD	NBU
RESERVES	International reserves	billion USD	NBU
GDP_GAP	The difference between the actual and potential GDP, expressed as percentage to potential GDP	%	HP filter based on NBU
KEY_R	Policy rate of the NBU	%	NBU
Exogenous variables			
PCPI	Weighted CPI of countries main trade partners: China, Poland, Turkey, Italy, the Netherlands, Egypt, India, Germany, Romania, the USA, Slovakia, Hungary, Austria, Czech Republic	%	Worldwide Inflation Data
WAR	Generated binary variable, where 1 - shocks of war, and 0 - no war shocks on the macroeconomic situation in Ukraine	-	Author`s estimation
DEBT_TO_GDP	Government debt to real GDP	-	NBU, Ministry of Finance
REER	Real effective exchange rate is the weighted average of a country's currency in relation to an index or basket of other major currencies	-	NBU
FOR_DEBT	Gross foreign debt	mln USD	NBU
EMPL_R	Employment rate, in % to population of age 15-70	%	NBU
TOT	Terms of trade (index of export prices to index of import prices	-	MFI
CPI_TARGET	Inflation target of the NBU	%	NBU
NR	Neutral interest rate is the rate at which monetary policy is neither stimulating nor restricting economic growth	%	NBU

Continuation of Table B.1

Variable code	Name	Units	Source
Exogenous variables			
DUMMY1	Generated binary variable, where 1 - relative change of key policy rate ≥ 0,18, and 0 - relative change of key policy rate < 0,18	-	Author`s estimation
DUMMY2	Generated binary variable, where 1 - relative change of exchange rate ≥ 0,07, and 0 - relative change of exchange rate < 0,07	-	Author`s estimation

Appendix C

Testing for adherence to the classical assumptions of the Inflation equation

Figure C.1. Estimation results of the Inflation equation in the EViews software package

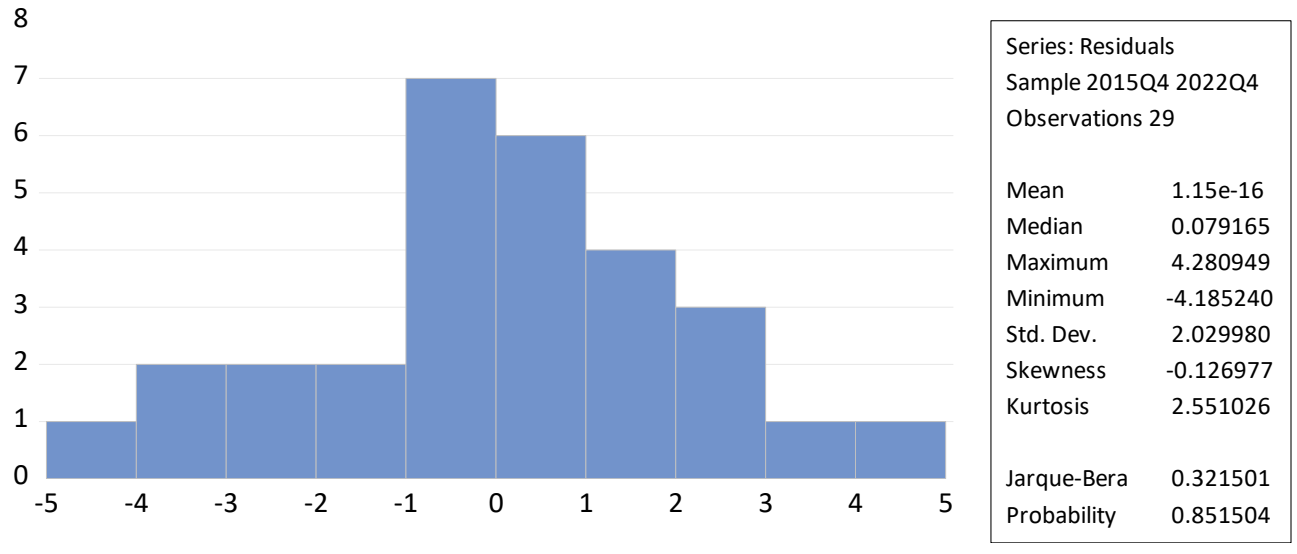
Dependent Variable: CPI
Method: Least Squares
Date: 03/12/23 Time: 11:08
Sample (adjusted): 2015Q4 2022Q4
Included observations: 29 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.558922	1.324064	0.422127	0.6769
D(KEY_R(-6))	-0.817348	0.216718	-3.771487	0.0010
D(LOG(ER(-3)))	73.02772	8.930147	8.177661	0.0000
PCPI(-1)	0.666550	0.252738	2.637314	0.0147
CPI(-4)	0.168392	0.055896	3.012600	0.0062
WAR	10.29482	2.834528	3.631934	0.0014

R-squared	0.949276	Mean dependent var	8.682759
Adjusted R-squared	0.938249	S.D. dependent var	9.013326
S.E. of regression	2.239787	Akaike info criterion	4.632630
Sum squared resid	115.3829	Schwarz criterion	4.915519
Log likelihood	-61.17314	Hannan-Quinn criter.	4.721228
F-statistic	86.08692	Durbin-Watson stat	1.879258
Prob(F-statistic)	0.000000		

Source: made by the author using EViews

Figure C.2. The results of the Jarque-Bera test on the normality of the distribution of the residuals of the Inflation rate equation



Source: made by the author using EViews

Figure C.3. The results of the Breusch-Godfrey LM test for the absence of autocorrelation

Breusch-Godfrey Serial Correlation LM Test:
Null hypothesis: No serial correlation at up to 4 lags

F-statistic	0.737399	Prob. F(4,19)	0.5780
Obs*R-squared	3.897034	Prob. Chi-Square(4)	0.4201

Test Equation:
Dependent Variable: RESID
Method: Least Squares
Date: 03/12/23 Time: 11:17
Sample: 2015Q4 2022Q4
Included observations: 29
Presample missing value lagged residuals set to zero.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.174905	1.410832	0.123973	0.9026
D(KEY_R(-6))	-0.064326	0.230702	-0.278826	0.7834
D(LOG(ER(-3)))	-1.956591	9.676745	-0.202195	0.8419
PCPI(-1)	-0.052538	0.271832	-0.193272	0.8488
CPI(-4)	-0.002303	0.058665	-0.039260	0.9691
WAR	1.304607	3.117448	0.418486	0.6803
RESID(-1)	-0.032253	0.240171	-0.134292	0.8946
RESID(-2)	-0.386207	0.252072	-1.532130	0.1420
RESID(-3)	-0.122870	0.232131	-0.529314	0.6027
RESID(-4)	-0.187822	0.236877	-0.792908	0.4376

R-squared	0.134380	Mean dependent var	1.15E-16
Adjusted R-squared	-0.275650	S.D. dependent var	2.029980
S.E. of regression	2.292754	Akaike info criterion	4.764183
Sum squared resid	99.87768	Schwarz criterion	5.235664
Log likelihood	-59.08065	Hannan-Quinn criter.	4.911845
F-statistic	0.327733	Durbin-Watson stat	2.047355
Prob(F-statistic)	0.954923		

Source: made by the author using EViews

Figure C.4. The results of the test for checking the absence of multicollinearity in the Inflation equation

Variance Inflation Factors
Sample: 2014Q1 2022Q4

Variable	Coefficient Variance	Uncentered VIF	Centered VIF
C	1.753145	10.13450	NA
D(KEY_R(-6))	0.046967	2.378443	2.378298
D(LOG(ER(-3)))	79.74753	3.057969	2.802296
PCPI(-1)	0.063877	13.45628	4.796864
CPI(-4)	0.003124	4.559061	2.552089
WAR	8.034551	6.406311	5.522682

Source: made by the author using EViews

Figure C.5. The results of White's test for the absence of heteroskedasticity

Heteroskedasticity Test: White
Null hypothesis: Homoskedasticity

F-statistic	0.794857	Prob. F(18,10)	0.6779
Obs*R-squared	17.06949	Prob. Chi-Square(18)	0.5183
Scaled explained SS	8.326628	Prob. Chi-Square(18)	0.9734

Test Equation:
Dependent Variable: RESID^2
Method: Least Squares
Date: 03/12/23 Time: 11:18
Sample: 2015Q4 2022Q4
Included observations: 29
Collinear test regressors dropped from specification

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-9.917230	21.73499	-0.456279	0.6579
D(KEY_R(-6))^2	-0.282983	0.439723	-0.643549	0.5343
D(KEY_R(-6))*D(LOG(ER(-3)))	31.95498	26.30267	1.214895	0.2523
D(KEY_R(-6))*PCPI(-1)	-0.893269	1.134994	-0.787025	0.4495
D(KEY_R(-6))*CPI(-4)	0.015836	0.169990	0.093160	0.9276
D(KEY_R(-6))*WAR	-98.65177	229.9979	-0.428925	0.6771
D(KEY_R(-6))	2.768021	5.635321	0.491191	0.6339
D(LOG(ER(-3)))^2	2346.681	1691.158	1.387617	0.1954
D(LOG(ER(-3)))*PCPI(-1)	43.52167	71.60686	0.607786	0.5569
D(LOG(ER(-3)))*CPI(-4)	-14.21356	8.900794	-1.596886	0.1414
D(LOG(ER(-3)))*WAR	1042.583	2102.385	0.495905	0.6307
D(LOG(ER(-3)))	-30.59420	268.9547	-0.113752	0.9117
PCPI(-1)^2	-0.561228	0.837385	-0.670215	0.5179
PCPI(-1)*CPI(-4)	-0.082048	0.369464	-0.222072	0.8287
PCPI(-1)*WAR	14.58608	16.84051	0.866131	0.4067
PCPI(-1)	4.952174	8.147179	0.607839	0.5568
CPI(-4)^2	-0.005997	0.027686	-0.216594	0.8329
CPI(-4)*WAR	-16.18588	18.39034	-0.880129	0.3994
CPI(-4)	0.751310	1.941425	0.386989	0.7069

R-squared	0.588603	Mean dependent var	3.978720
Adjusted R-squared	-0.151912	S.D. dependent var	5.042813
S.E. of regression	5.412308	Akaike info criterion	6.460862
Sum squared resid	292.9308	Schwarz criterion	7.356677
Log likelihood	-74.68250	Hannan-Quinn criter.	6.741420
F-statistic	0.794857	Durbin-Watson stat	2.068120
Prob(F-statistic)	0.677870		

Source: made by the author using EViews

Figure C.6. The results of the test on the correctness of the specification of the Inflation equation

Ramsey RESET Test
Equation: TEST2
Omitted Variables: Squares of fitted values
Specification: CPI C D(KEY_R(-6)) D(LOG(ER(-3))) PCPI(-1) CPI(-4) WAR

	Value	df	Probability
t-statistic	1.494258	22	0.1493
F-statistic	2.232806	(1, 22)	0.1493
Likelihood ratio	2.803282	1	0.0941

F-test summary:

	Sum of Sq.	df	Mean Squares
Test SSR	10.63136	1	10.63136
Restricted SSR	115.3829	23	5.016647
Unrestricted SSR	104.7515	22	4.761433

LR test summary:

	Value
Restricted LogL	-61.17314
Unrestricted LogL	-59.77150

Source: made by the author using EViews

Table C.1. Results of classical assumption testing for the Inflation equation

№	Assumption	Test	Critical value	Conclusion
1	Absence of heteroskedasticity	White Test	0,68	Yes
2	Absence of autocorrelation	Serial Correlation LM Test	0,58	Yes
		Durbin Watson (DW) Test	1,88	Yes
3	Absence of multicollinearity	VIF Test	<10	Yes
4	Normal distribution of residuals	Jarque-Bera Test	0,85	Yes
5	Correctness of specification	Ramsey RESET Test	0,15	Yes

Source: made by the author based on the tests` results in EViews

Appendix D

Testing for adherence to the classical assumptions of the Exchange rate equation

Figure D.1. Estimation results of the Exchange rate equation in the EViews software package

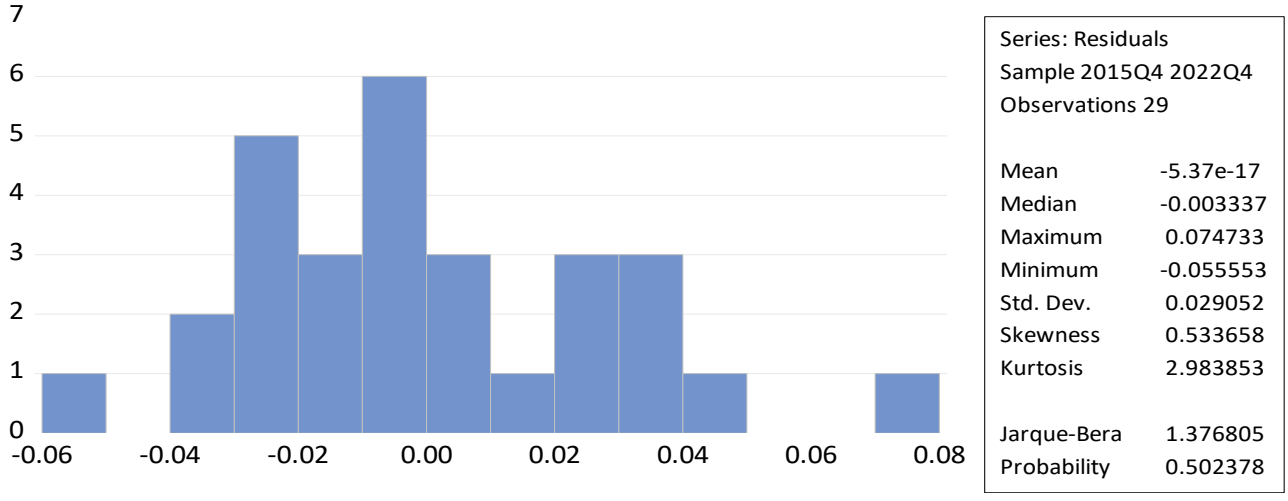
Dependent Variable: LOG(ER)
Method: Least Squares
Date: 03/12/23 Time: 14:32
Sample (adjusted): 2015Q4 2022Q4
Included observations: 29 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.279576	0.312614	0.894316	0.3804
D(KEY_R)*DUMMY1	-0.006418	0.002647	-2.424319	0.0236
D(KEY_R)*(1-DUMMY1)	0.014511	0.004817	3.012197	0.0062
LOG(ER(-1))	0.727911	0.092331	7.883683	0.0000
LOG(RESERVES(-7))	0.048758	0.021905	2.225904	0.0361
LOG(DEBT_TO_GDP)	0.146665	0.025224	5.814502	0.0000

R-squared	0.901364	Mean dependent var	3.300358
Adjusted R-squared	0.879922	S.D. dependent var	0.092505
S.E. of regression	0.032055	Akaike info criterion	-3.860728
Sum squared resid	0.023633	Schwarz criterion	-3.577839
Log likelihood	61.98055	Hannan-Quinn criter.	-3.772131
F-statistic	42.03635	Durbin-Watson stat	1.811582
Prob(F-statistic)	0.000000		

Source: made by the author using EViews

Figure D.2. The results of the Jarque-Bera test on the normality of the distribution of the residuals of the Exchange rate equation



Source: made by the author using EViews

Figure D.3. The results of the Breusch-Godfrey LM test for the absence of autocorrelation

Breusch-Godfrey Serial Correlation LM Test:
Null hypothesis: No serial correlation at up to 4 lags

F-statistic	0.776909	Prob. F(4,19)	0.5538
Obs*R-squared	4.076487	Prob. Chi-Square(4)	0.3958

Test Equation:
Dependent Variable: RESID
Method: Least Squares
Date: 03/12/23 Time: 14:41
Sample: 2015Q4 2022Q4
Included observations: 29
Presample missing value lagged residuals set to zero.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.036905	0.384129	-0.096075	0.9245
D(KEY_R)*DUMMY1	-0.000193	0.002947	-0.065498	0.9485
D(KEY_R)*(1-DUMMY1)	-0.001426	0.005495	-0.259556	0.7980
LOG(ER(-1))	0.010080	0.115068	0.087597	0.9311
LOG(RESERVES(-7))	-5.72E-05	0.022436	0.002550	0.9980
LOG(DEBT_TO_GDP)	0.001709	0.028553	0.059863	0.9529
RESID(-1)	0.104117	0.288175	0.361297	0.7219
RESID(-2)	-0.431075	0.272246	-1.583402	0.1298
RESID(-3)	-0.038226	0.276391	-0.138305	0.8915
RESID(-4)	-0.016818	0.276556	-0.060811	0.9521

R-squared	0.140569	Mean dependent var	-5.37E-17
Adjusted R-squared	-0.266531	S.D. dependent var	0.029052
S.E. of regression	0.032696	Akaike info criterion	-3.736350
Sum squared resid	0.020311	Schwarz criterion	-3.264869
Log likelihood	64.17707	Hannan-Quinn criter.	-3.588688
F-statistic	0.345293	Durbin-Watson stat	2.040228
Prob(F-statistic)	0.947312		

Source: made by the author using EViews

Figure D.4. The results of the test for checking the absence of multicollinearity in the Exchange rate equation

Variance Inflation Factors
Sample: 2014Q1 2022Q4

Variable	Coefficient Variance	Uncentered VIF	Centered VIF
C	0.097727	2758.162	NA
D(KEY_R)*DUMMY1	7.01E-06	1.325248	1.322098
D(KEY_R)*(1-DUMMY1)	2.32E-05	1.432219	1.412826
LOG(ER(-1))	0.008525	2593.866	1.578305
LOG(RESERVES(-7))	0.000480	1288.246	1.392739
LOG(DEBT_TO_GDP)	0.000636	22.46936	1.233323

Source: made by the author using EViews

Figure D.5. The results of White's test for the absence of heteroskedasticity

Heteroskedasticity Test: White
Null hypothesis: Homoskedasticity

F-statistic	2.106133	Prob. F(17,11)	0.1056
Obs*R-squared	22.18438	Prob. Chi-Square(17)	0.1777
Scaled explained SS	13.84161	Prob. Chi-Square(17)	0.6783

Test Equation:
Dependent Variable: RESID^2
Method: Least Squares
Date: 03/12/23 Time: 14:41
Sample: 2015Q4 2022Q4
Included observations: 29
Collinear test regressors dropped from specification

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.707924	0.729663	-0.970207	0.3528
D(KEY_R)*DUMMY1^2	0.019082	0.026118	0.730587	0.4803
D(KEY_R)*DUMMY1*LOG(ER(-1))	0.001286	0.006591	0.195047	0.8489
D(KEY_R)*DUMMY1*LOG(INR_RESERV(-7))	-0.002533	0.004036	-0.627462	0.5432
D(KEY_R)*DUMMY1*LOG(DEBT_TO_GDP)	0.001524	0.002049	0.743562	0.4727
D(KEY_R)*(1-DUMMY1)^2	-0.029521	0.009449	-3.124159	0.0097
D(KEY_R)*(1-DUMMY1)*LOG(ER(-1))	0.004428	0.001873	2.364173	0.0375
D(KEY_R)*(1-DUMMY1)*LOG(RESERVES(-7))	0.001605	0.000922	1.740167	0.1097
D(KEY_R)*(1-DUMMY1)*LOG(DEBT_TO_GDP)	-2.74E-05	0.001000	-0.027384	0.9786
LOG(ER(-1))^2	-0.042451	0.055733	-0.761681	0.4623
LOG(ER(-1))*LOG(RESERVES(-7))	0.000498	0.037207	0.013381	0.9896
LOG(ER(-1))*LOG(DEBT_TO_GDP)	0.013326	0.024753	0.538365	0.6010
LOG(ER(-1))	0.259577	0.227319	1.141906	0.2777
LOG(RESERVES(-7))^2	-0.004020	0.003130	-1.284563	0.2253
LOG(RESERVES(-7))*LOG(DEBT_TO_GDP)	0.004637	0.006121	0.757498	0.4647
LOG(RESERVES(-7))	0.070007	0.116390	0.601485	0.5597
LOG(DEBT_TO_GDP)^2	0.002320	0.006034	0.384508	0.7079
LOG(DEBT_TO_GDP)	-0.093444	0.075544	-1.236949	0.2419

R-squared	0.764979	Mean dependent var	0.000815
Adjusted R-squared	0.401764	S.D. dependent var	0.001168
S.E. of regression	0.000904	Akaike info criterion	-10.90858
Sum squared resid	8.98E-06	Schwarz criterion	-10.05991
Log likelihood	176.1744	Hannan-Quinn criter.	-10.64279
F-statistic	2.106133	Durbin-Watson stat	1.901700
Prob(F-statistic)	0.105643		

Source: made by the author using EViews

Figure D.6. The results of the test on the correctness of the specification of the Exchange rate equation

Ramsey RESET Test
Equation: TEST2
Omitted Variables: Squares of fitted values
Specification: LOG(ER) C D(KEY_R)*DUMMY1 D(KEY_R)*(1 -DUMMY1) LOG(ER(-1)) LOG(RESERVES(-7)) LOG(DEBT_TO_GDP)

	Value	df	Probability
t-statistic	1.267446	22	0.2182
F-statistic	1.606419	(1, 22)	0.2182
Likelihood ratio	2.043810	1	0.1528

F-test summary:

	Sum of Sq.	df	Mean Squares
Test SSR	0.001608	1	0.001608
Restricted SSR	0.023633	23	0.001028
Unrestricted SSR	0.022025	22	0.001001

LR test summary:

	Value
Restricted LogL	61.98055
Unrestricted LogL	63.00246

Source: made by the author using EViews

Table D.1. Results of classical assumption testing for the Exchange rate equation

№	Assumption	Test	Critical value	Conclusion
1	Absence of heteroskedasticity	White Test	0,11	Yes
2	Absence of autocorrelation	Serial Correlation LM Test	0,55	Yes
		Durbin Watson (DW) Test	1,81	Yes
3	Absence of multicollinearity	VIF Test	<10	Yes
4	Normal distribution of residuals	Jarque-Bera Test	0,50	Yes
5	Correctness of specification	Ramsey RESET Test	0,22	Yes

Source: made by the author based on the tests` results in EViews

Appendix E

Testing for adherence to the classical assumptions of the International reserves equation

Figure E.1. Estimation results of the International reserves equation in the EViews software package

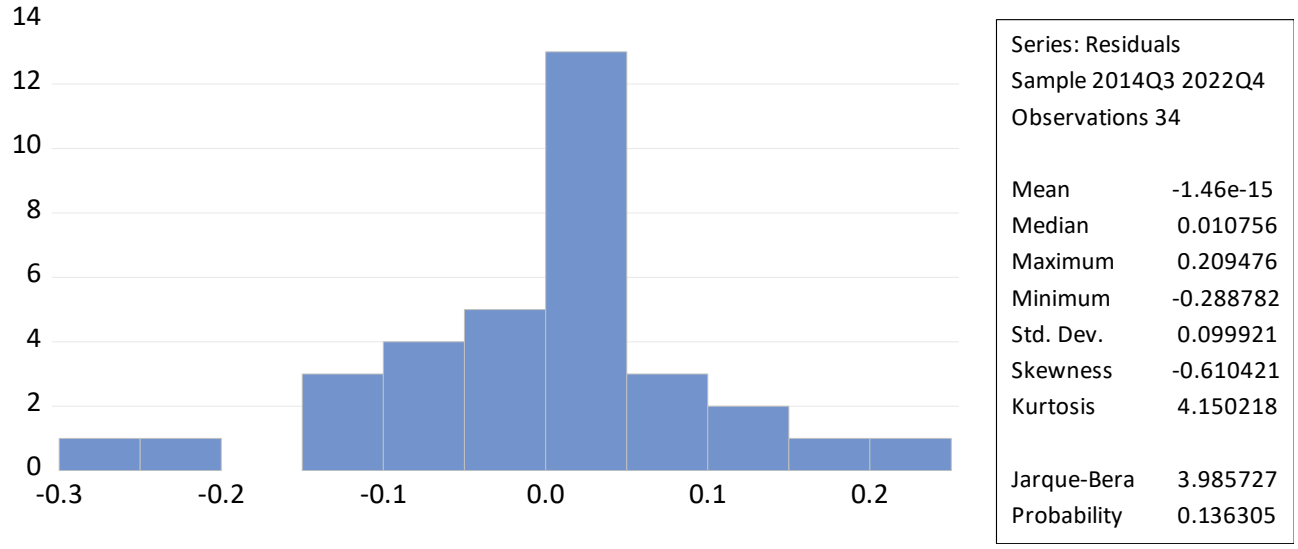
Dependent Variable: LOG(RESERVES)
Method: Least Squares
Sample (adjusted): 2014Q3 2022Q4
Included observations: 34 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	9.496456	4.578312	2.074226	0.0470
LOG(RESERVES(-1))	0.758669	0.093032	8.154924	0.0000
REER	0.918090	0.293457	3.128534	0.0040
GDP_GAP(-2)	-0.255561	0.133380	-1.916040	0.0653
LOG(FOR_DEBT(-1))	-0.675450	0.391774	-1.724079	0.0953

R-squared	0.922209	Mean dependent var	9.848135
Adjusted R-squared	0.911480	S.D. dependent var	0.358257
S.E. of regression	0.106590	Akaike info criterion	-1.504603
Sum squared resid	0.329481	Schwarz criterion	-1.280138
Log likelihood	30.57824	Hannan-Quinn criter.	-1.428054
F-statistic	85.94899	Durbin-Watson stat	1.897542
Prob(F-statistic)	0.000000		

Source: made by the author using EViews

Figure E.2. The results of the Jarque-Bera test on the normality of the distribution of the residuals of the International reserves equation



Source: made by the author using EViews

Figure E.3. The results of the Breusch-Godfrey LM test for the absence of autocorrelation

Breusch-Godfrey Serial Correlation LM Test:
Null hypothesis: No serial correlation at up to 4 lags

F-statistic	1.143437	Prob. F(4,25)	0.3591
Obs*R-squared	5.258293	Prob. Chi-Square(4)	0.2618

Test Equation:
Dependent Variable: RESID
Method: Least Squares
Date: 04/07/23 Time: 20:17
Sample: 2014Q3 2022Q4
Included observations: 34
Presample missing value lagged residuals set to zero.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-2.230983	4.722104	-0.472455	0.6407
LOG(RESERVES(-1))	0.176271	0.133391	1.321461	0.1983
REER	-0.467670	0.380759	-1.228259	0.2308
GDP_GAP(-2)	0.005753	0.132991	0.043257	0.9658
LOG(FOR_DEBT(-1))	0.077394	0.392216	0.197325	0.8452
RESID(-1)	-0.196598	0.234692	-0.837686	0.4101
RESID(-2)	-0.539221	0.258938	-2.082431	0.0477
RESID(-3)	-0.148227	0.229192	-0.646739	0.5237
RESID(-4)	-0.089441	0.213454	-0.419020	0.6788

R-squared	0.154656	Mean dependent var	-1.46E-15
Adjusted R-squared	-0.115855	S.D. dependent var	0.099921
S.E. of regression	0.105551	Akaike info criterion	-1.437320
Sum squared resid	0.278525	Schwarz criterion	-1.033283
Log likelihood	33.43444	Hannan-Quinn criter.	-1.299532
F-statistic	0.571719	Durbin-Watson stat	1.772801
Prob(F-statistic)	0.790939		

Source: made by the author using EViews

Figure E.4. The results of the test for checking the absence of multicollinearity in the International reserves equation

Variance Inflation Factors
Date: 04/07/23 Time: 20:17
Sample: 2014Q1 2022Q4
Included observations: 34

Variable	Coefficient Variance	Uncentered VIF	Centered VIF
C	20.96095	62727.43	NA
LOG(RESERVES(-1))	0.008655	2507.538	3.135466
REER	0.086117	196.1304	3.023838
GDP_GAP(-2)	0.017790	1.223191	1.221373
LOG(FOR_DEBT(-1))	0.153487	62861.32	1.179538

Source: made by the author using EViews

Figure E.5. The results of White's test for the absence of heteroskedasticity

Heteroskedasticity Test: White
Null hypothesis: Homoskedasticity

F-statistic	9.492349	Prob. F(13,20)	0.0000
Obs*R-squared	29.25804	Prob. Chi-Square(13)	0.0060
Scaled explained SS	33.52694	Prob. Chi-Square(13)	0.0014

Test Equation:
Dependent Variable: RESID^2
Method: Least Squares
Date: 04/07/23 Time: 20:16
Sample: 2014Q3 2022Q4
Included observations: 34
Collinear test regressors dropped from specification

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-27.85469	19.28144	-1.444638	0.1640
LOG(RESERVES(-1))^2	-0.037137	0.035100	-1.058034	0.3027
LOG(RESERVES(-1))*REER	0.018070	0.232283	0.077793	0.9388
LOG(RESERVES(-1))*GDP_GAP(-2)	-0.218908	0.085589	-2.557661	0.0188
LOG(RESERVES(-1))*LOG(FOR_DEBT(-1))	-0.513155	0.385848	-1.329940	0.1985
LOG(RESERVES(-1))	6.668282	4.754994	1.402375	0.1761
REER^2	-0.643368	0.488549	-1.316897	0.2028
REER*GDP_GAP(-2)	0.018992	0.282673	0.067188	0.9471
REER*LOG(FOR_DEBT(-1))	1.340238	1.000724	1.339268	0.1955
REER	-14.65321	11.72775	-1.249448	0.2259
GDP_GAP(-2)^2	-0.100319	0.075008	-1.337447	0.1961
GDP_GAP(-2)*LOG(FOR_DEBT(-1))	1.297572	0.435015	2.982825	0.0074
GDP_GAP(-2)	-12.99824	5.025397	-2.586509	0.0176
LOG(FOR_DEBT(-1))^2	0.178060	0.134079	1.328018	0.1991

R-squared	0.860531	Mean dependent var	0.009691
Adjusted R-squared	0.769875	S.D. dependent var	0.017458
S.E. of regression	0.008375	Akaike info criterion	-6.434226
Sum squared resid	0.001403	Schwarz criterion	-5.805725
Log likelihood	123.3818	Hannan-Quinn criter.	-6.219889
F-statistic	9.492349	Durbin-Watson stat	2.453410
Prob(F-statistic)	0.000007		

Source: made by the author using EViews

Figure E.6. The results of the test on the correctness of the specification of the International reserves equation

Ramsey RESET Test
Equation: TEST1
Omitted Variables: Squares of fitted values
Specification: LOG(RESERVES) C LOG(RESERVES(-1)) REER GDP_GAP(-2) LOG(FOR_DEBT(-1))

	Value	df	Probability
t-statistic	0.320412	28	0.7510
F-statistic	0.102664	(1, 28)	0.7510
Likelihood ratio	0.124435	1	0.7243

F-test summary:

	Sum of Sq.	df	Mean Squares
Test SSR	0.001204	1	0.001204
Restricted SSR	0.329481	29	0.011361
Unrestricted SSR	0.328277	28	0.011724

LR test summary:

	Value
Restricted LogL	30.57824
Unrestricted LogL	30.64046

Source: made by the author using EViews

Table E.1. Results of classical assumption testing for the International reserves equation

№	Assumption	Test	Critical value	Conclusion
1	Absence of heteroskedasticity	White Test	0,00	No
2	Absence of autocorrelation	Serial Correlation LM Test	0,36	Yes
		Durbin Watson (DW) Test	1,90	Yes
3	Absence of multicollinearity	VIF Test	<10	Yes
4	Normal distribution of residuals	Jarque-Bera Test	0,14	Yes
5	Correctness of specification	Ramsey RESET Test	0,75	Yes

Source: made by the author based on the tests` results in EViews

Appendix F

Testing for adherence to the classical assumptions of the GDP gap equation

Figure F.1. Estimation results of the GDP gap equation in the EViews software package

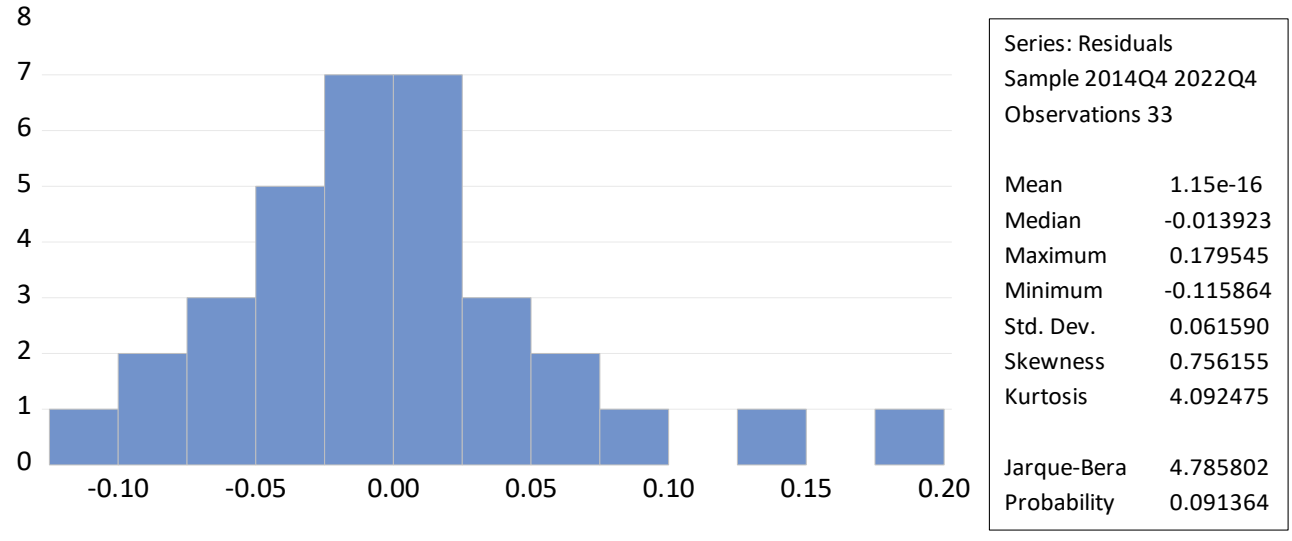
Dependent Variable: GDP_GAP
Method: Least Squares
Date: 04/07/23 Time: 19:22
Sample (adjusted): 2014Q4 2022Q4
Included observations: 33 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-1.460303	0.259274	-5.632271	0.0000
GDP_GAP(-2)	-0.565665	0.119518	-4.732888	0.0001
EMPL_R	0.022433	0.003747	5.986865	0.0000
KEY_R(-1)	-0.012089	0.002546	-4.749005	0.0001
REER	0.612044	0.129899	4.711682	0.0001
D(CPI(-2))	-0.002642	0.001329	-1.988451	0.0574
D(TOT(-2))	0.214960	0.117613	1.827680	0.0791

R-squared	0.829435	Mean dependent var	-0.018342
Adjusted R-squared	0.790073	S.D. dependent var	0.149130
S.E. of regression	0.068328	Akaike info criterion	-2.343160
Sum squared resid	0.121387	Schwarz criterion	-2.025719
Log likelihood	45.66215	Hannan-Quinn criter.	-2.236351
F-statistic	21.07237	Durbin-Watson stat	1.436768
Prob(F-statistic)	0.000000		

Source: made by the author using EViews

Figure F.2. The results of the Jarque-Bera test on the normality of the distribution of the residuals of the GDP gap equation



Source: made by the author using EViews

Figure F.3. The results of the Breusch-Godfrey LM test for the absence of autocorrelation

Breusch-Godfrey Serial Correlation LM Test:
Null hypothesis: No serial correlation at up to 4 lags

F-statistic	1.536901	Prob. F(4,22)	0.2262
Obs*R-squared	7.207396	Prob. Chi-Square(4)	0.1253

Test Equation:
Dependent Variable: RESID
Method: Least Squares
Sample: 2014Q4 2022Q4
Included observations: 33

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.208531	0.267711	0.778940	0.4443
GDP_GAP(-2)	0.018162	0.163618	0.111005	0.9126
EMPL_R	-0.006004	0.004578	-1.311563	0.2032
KEY_R(-1)	0.003209	0.004582	0.700234	0.4911
REER	0.044091	0.138019	0.319459	0.7524
D(CPI(-2))	0.000346	0.001327	0.260953	0.7966
D(TOT(-2))	0.150537	0.132702	1.134397	0.2688
RESID(-1)	0.243753	0.208971	1.166447	0.2559
RESID(-2)	0.035668	0.274503	0.129937	0.8978
RESID(-3)	-0.073598	0.260488	-0.282539	0.7802
RESID(-4)	-0.708778	0.331736	-2.136569	0.0440

R-squared	0.218406	Mean dependent var	1.15E-16
Adjusted R-squared	-0.136864	S.D. dependent var	0.061590
S.E. of regression	0.065670	Akaike info criterion	-2.347156
Sum squared resid	0.094875	Schwarz criterion	-1.848320
Log likelihood	49.72807	Hannan-Quinn criter.	-2.179313
F-statistic	0.614760	Durbin-Watson stat	1.665010
Prob(F-statistic)	0.785183		

Source: made by the author using EViews

Figure F.4. The results of the test for checking the absence of multicollinearity in the GDP gap equation

Variance Inflation Factors
Sample: 2014Q1 2022Q4
Included observations: 33

Variable	Coefficient Variance	Uncentered VIF	Centered VIF
C	0.067223	475.1540	NA
GDP_GAP(-2)	0.014285	2.287642	2.287619
EMPL_R	1.40E-05	238.3644	1.395311
KEY_R(-1)	6.48E-06	12.36979	1.664801
REER	0.016874	91.72159	1.352348
D(CPI(-2))	1.77E-06	1.071907	1.069531
D(TOT(-2))	0.013833	1.739229	1.738030

Source: made by the author using EViews

Figure F.5. The results of White's test for the absence of heteroskedasticity

Heteroskedasticity Test: White
Null hypothesis: Homoskedasticity

F-statistic	1.675388	Prob. F(27,5)	0.2974
Obs*R-squared	29.71547	Prob. Chi-Square(27)	0.3271
Scaled explained SS	28.52184	Prob. Chi-Square(27)	0.3845

Test Equation:
Dependent Variable: RESID^2
Method: Least Squares
Date: 04/07/23 Time: 19:24
Sample: 2014Q4 2022Q4
Included observations: 33

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.716636	2.415666	0.710626	0.5091
GDP_GAP(-2)^2	0.512399	0.472034	1.085514	0.3272
GDP_GAP(-2)*EMPL_R	-0.035112	0.041504	-0.845995	0.4362
GDP_GAP(-2)*KEY_R(-1)	-0.000243	0.007905	-0.030688	0.9767
GDP_GAP(-2)*REER	-0.054943	0.695141	-0.079038	0.9401
GDP_GAP(-2)*D(CPI(-2))	0.009246	0.005249	1.761268	0.1385
GDP_GAP(-2)*D(TOT(-2))	-0.091338	0.399941	-0.228380	0.8284
GDP_GAP(-2)	1.788403	1.903832	0.939370	0.3907
EMPL_R^2	0.000364	0.000679	0.535994	0.6149
EMPL_R*KEY_R(-1)	0.000268	0.000924	0.289842	0.7836
EMPL_R*REER	0.024378	0.040288	0.605102	0.5715
EMPL_R*D(CPI(-2))	-0.000767	0.000671	-1.142854	0.3049
EMPL_R*D(TOT(-2))	-0.071153	0.058910	-1.207829	0.2811
EMPL_R	-0.065080	0.075632	-0.860480	0.4288
KEY_R(-1)^2	-0.000165	0.000153	-1.078644	0.3300
KEY_R(-1)*REER	-0.013989	0.012366	-1.131222	0.3093
KEY_R(-1)*D(CPI(-2))	-2.87E-05	0.000106	-0.269879	0.7980
KEY_R(-1)*D(TOT(-2))	0.005830	0.009176	0.635415	0.5531
KEY_R(-1)	0.003674	0.036758	0.099960	0.9243
REER^2	-0.446016	0.631838	-0.705903	0.5118
REER*D(CPI(-2))	0.001913	0.007199	0.265729	0.8011
REER*D(TOT(-2))	0.498774	0.639247	0.780252	0.4705
REER	-0.148357	1.496147	-0.099159	0.9249
D(CPI(-2))^2	8.27E-06	1.90E-05	0.436176	0.6809
D(CPI(-2))*D(TOT(-2))	-0.001141	0.005949	-0.191815	0.8554
D(CPI(-2))	0.039005	0.028724	1.357937	0.2325
D(TOT(-2))^2	-0.233991	0.230323	-1.015924	0.3563
D(TOT(-2))	3.080534	2.610242	1.180172	0.2910

R-squared	0.900469	Mean dependent var	0.003678
Adjusted R-squared	0.363000	S.D. dependent var	0.006569
S.E. of regression	0.005243	Akaike info criterion	-7.854025
Sum squared resid	0.000137	Schwarz criterion	-6.584261
Log likelihood	157.5914	Hannan-Quinn criter.	-7.426788
F-statistic	1.675388	Durbin-Watson stat	2.537588
Prob(F-statistic)	0.297446		

Source: made by the author using EViews

Figure F.6. The results of the test on the correctness of the specification of the GDP gap equation

Ramsey RESET Test
Equation: TEST1
Omitted Variables: Squares of fitted values
Specification: GDP_GAP C GDP_GAP(-2) EMPL_R() KEY_R(-1) REER D(CPI(-2)) D(TOT(-2))

	Value	df	Probability
t-statistic	1.086658	25	0.2876
F-statistic	1.180826	(1, 25)	0.2876
Likelihood ratio	1.522999	1	0.2172

F-test summary:

	Sum of Sq.	df	Mean Squares
Test SSR	0.005475	1	0.005475
Restricted SSR	0.121387	26	0.004669
Unrestricted SSR	0.115912	25	0.004636

LR test summary:

	Value
Restricted LogL	45.66215
Unrestricted LogL	46.42365

Source: made by the author using EViews

Table F.1. Results of classical assumption testing for the GDP gap equation

№	Assumption	Test	Critical value	Conclusion
1	Absence of heteroskedasticity	White Test	0,29	Yes
2	Absence of autocorrelation	Serial Correlation LM Test	0,23	Yes
		Durbin Watson (DW) Test	1,44	Yes
3	Absence of multicollinearity	VIF Test	<10	Yes
4	Normal distribution of residuals	Jarque-Bera Test	0,09	Yes
5	Correctness of specification	Ramsey RESET Test	0,29	Yes

Source: made by the author based on the tests` results in EViews

Appendix G

Testing for adherence to the classical assumptions of the Key policy rate equation

Figure G.1. Estimation results of the Key policy rate equation in the EViews software package

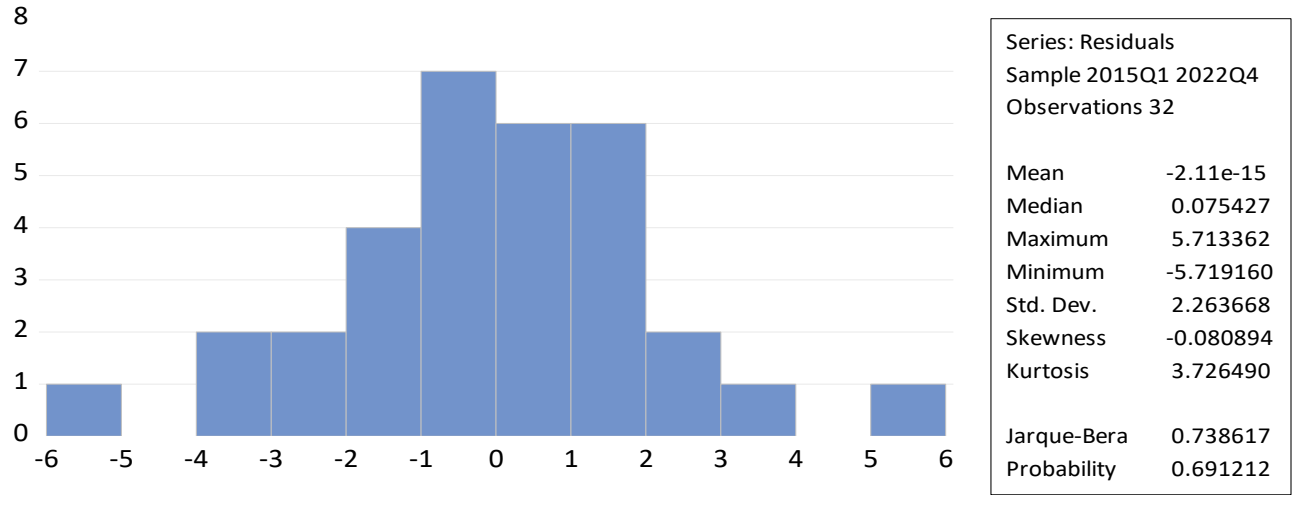
Dependent Variable: KEY_R
Method: Least Squares
Sample (adjusted): 2015Q1 2022Q4
Included observations: 32 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.971943	1.482139	1.330471	0.1954
KEY_R(-1)	0.802756	0.098551	8.145613	0.0000
GDP_GAP(-2)	7.224571	3.991109	1.810167	0.0823
CPI-CPI_TARGET	0.192111	0.064220	2.991436	0.0062
D(NR(-3))	-0.653543	0.325618	-2.007084	0.0557
(D(ER(-1)))*DUMMY1	2.931421	1.158845	2.529605	0.0181
(D(ER(-1)))*(1-DUMMY1)	1.261699	0.326933	3.859200	0.0007

R-squared	0.875544	Mean dependent var	15.73375
Adjusted R-squared	0.845675	S.D. dependent var	6.416602
S.E. of regression	2.520714	Akaike info criterion	4.877601
Sum squared resid	158.8500	Schwarz criterion	5.198231
Log likelihood	-71.04162	Hannan-Quinn criter.	4.983881
F-statistic	29.31242	Durbin-Watson stat	1.658256
Prob(F-statistic)	0.000000		

Source: made by the author using EViews

Figure G.2. The results of the Jarque-Bera test on the normality of the distribution of the residuals of the Key policy rate equation



Source: made by the author using EViews

Figure G.3. The results of the Breusch-Godfrey LM test for the absence of autocorrelation

Breusch-Godfrey Serial Correlation LM Test:
Null hypothesis: No serial correlation at up to 4 lags

F-statistic	0.292936	Prob. F(4,21)	0.8792
Obs*R-squared	1.691152	Prob. Chi-Square(4)	0.7923

Test Equation:
Dependent Variable: RESID
Method: Least Squares
Sample: 2015Q1 2022Q4
Included observations: 32
Presample missing value lagged residuals set to zero.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.006198	2.090363	0.481351	0.6352
KEY_R(-1)	-0.064482	0.139340	-0.462766	0.6483
GDP_GAP(-2)	-0.875263	4.888353	-0.179051	0.8596
CPI-CPI_TARGET	-0.025574	0.074739	-0.342172	0.7356
D(NR(-3))	0.070167	0.376962	0.186138	0.8541
(D(ER(-1)))*DUMMY1	0.176947	1.323106	0.133736	0.8949
(D(ER(-1)))*(1-DUMMY1)	0.050479	0.357285	0.141285	0.8890
RESID(-1)	0.242672	0.250028	0.970577	0.3428
RESID(-2)	0.070829	0.273331	0.259132	0.7981
RESID(-3)	0.125594	0.273459	0.459281	0.6508
RESID(-4)	0.005134	0.269513	0.019051	0.9850

R-squared	0.052849	Mean dependent var	-2.11E-15
Adjusted R-squared	-0.398176	S.D. dependent var	2.263668
S.E. of regression	2.676663	Akaike info criterion	5.073305
Sum squared resid	150.4550	Schwarz criterion	5.577152
Log likelihood	-70.17288	Hannan-Quinn criter.	5.240316
F-statistic	0.117174	Durbin-Watson stat	1.989558
Prob(F-statistic)	0.999337		

Source: made by the author using EViews

Figure G.4. The results of the test for checking the absence of multicollinearity in the Key policy equation

Variance Inflation Factors
Sample: 2014Q1 2022Q4

Variable	Coefficient Variance	Uncentered VIF	Centered VIF
C	2.196735	11.06319	NA
KEY_R(-1)	0.009712	13.38261	1.821010
GDP_GAP(-2)	15.92895	1.807967	1.806272
CPI-CPI_TARGET	0.004124	1.369709	1.315073
D(NR(-3))	0.106027	1.846884	1.845194
(D(ER(-1)))*DUMMY1	1.342922	1.235578	1.117292
(D(ER(-1)))*(1-DUMMY1)	0.106885	1.780447	1.606552

Source: made by the author using EViews

Figure G.5. The results of White's test for the absence of heteroskedasticity

Heteroskedasticity Test: White
Null hypothesis: Homoskedasticity

F-statistic	3.799524	Prob. F(24,7)	0.0376
Obs*R-squared	29.71868	Prob. Chi-Square(24)	0.1943
Scaled explained SS	24.72768	Prob. Chi-Square(24)	0.4207

Test Equation:
Dependent Variable: RESID^2
Method: Least Squares
Date: 04/07/23 Time: 19:26
Sample: 2015Q1 2022Q4
Included observations: 32
Collinear test regressors dropped from specification

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-14.52864	12.77237	-1.137506	0.2928
KEY_R(-1)^2	-0.125966	0.078338	-1.607993	0.1519
KEY_R(-1)*GDP_GAP(-2)	-1.801267	3.960566	-0.454800	0.6630
KEY_R(-1)*(CPI-CPI_TARGET)	0.169060	0.165268	1.022944	0.3404
KEY_R(-1)*D(NR(-3))	-0.054366	0.520998	-0.104350	0.9198
KEY_R(-1)*(D(ER(-1)))*DUMMY1	0.123223	6.336487	0.019447	0.9850
KEY_R(-1)*(D(ER(-1)))*(1-DUMMY1)	0.175496	0.485293	0.361630	0.7283
KEY_R(-1)	3.256815	2.082520	1.563882	0.1618
GDP_GAP(-2)^2	186.0908	131.6805	1.413199	0.2005
GDP_GAP(-2)*(CPI-CPI_TARGET)	5.631216	5.897441	0.954858	0.3715
GDP_GAP(-2)*D(NR(-3))	-44.65351	39.32232	-1.135577	0.2935
GDP_GAP(-2)*(D(ER(-1)))*DUMMY1	154.0505	256.2806	0.601101	0.5667
GDP_GAP(-2)*(D(ER(-1)))*(1-DUMMY1)	10.69080	14.57813	0.733345	0.4872
GDP_GAP(-2)	7.132352	44.50848	0.160247	0.8772
(CPI-CPI_TARGET)^2	0.007539	0.043814	0.172071	0.8683
(CPI-CPI_TARGET)*D(NR(-3))	-0.479828	0.574150	-0.835718	0.4309
(CPI-CPI_TARGET)*(D(ER(-1)))*DUMMY1	-1.254139	0.681022	-1.841555	0.1081
(CPI-CPI_TARGET)*(D(ER(-1)))*(1-DUMMY1)	-0.150280	0.287397	-0.522900	0.6172
CPI-CPI_TARGET	-2.624182	2.816562	-0.931697	0.3825
D(NR(-3))^2	-1.052338	1.122908	-0.937154	0.3799
D(NR(-3))*(D(ER(-1)))*DUMMY1	-88.67938	62.56338	-1.417433	0.1993
D(NR(-3))*(D(ER(-1)))*(1-DUMMY1)	0.927069	1.621465	0.571748	0.5854
D(NR(-3))	1.060265	6.306368	0.168126	0.8712
(D(ER(-1)))*DUMMY1^2	18.05370	101.5498	0.177782	0.8639
(D(ER(-1)))*(1-DUMMY1)^2	-3.117289	8.808141	-0.353910	0.7338

R-squared	0.928709	Mean dependent var	4.964061
Adjusted R-squared	0.684281	S.D. dependent var	8.327856
S.E. of regression	4.679329	Akaike info criterion	5.966861
Sum squared resid	153.2728	Schwarz criterion	7.111967
Log likelihood	-70.46977	Hannan-Quinn criter.	6.346431
F-statistic	3.799524	Durbin-Watson stat	2.483067
Prob(F-statistic)	0.037634		

Source: made by the author using EViews

Figure G.6. The results of the test on the correctness of the specification of the Key policy rate equation

Ramsey RESET Test
Equation: TEST1
Omitted Variables: Squares of fitted values
Specification: KEY_R C KEY_R(-1) GDP_GAP(-2) CPI-CPI_TARGET D(NR(-3)) (D(ER(-1)))*DUMMY1 (D(ER(-1)))*(1-DUMMY1)

	Value	df	Probability
t-statistic	0.974943	24	0.3393
F-statistic	0.950513	(1, 24)	0.3393
Likelihood ratio	1.242898	1	0.2649

F-test summary:

	Sum of Sq.	df	Mean Squares
Test SSR	6.051539	1	6.051539
Restricted SSR	158.8500	25	6.353998
Unrestricted SSR	152.7984	24	6.366601

LR test summary:

	Value
Restricted LogL	-71.04162
Unrestricted LogL	-70.42017

Source: made by the author using EViews

Table G.1. Results of classical assumption testing for the Key policy rate equation

№	Assumption	Test	Critical value	Conclusion
1	Absence of heteroskedasticity	White Test	0,04	No
2	Absence of autocorrelation	Serial Correlation LM Test	0,88	Yes
		Durbin Watson (DW) Test	1,66	Yes
3	Absence of multicollinearity	VIF Test	<10	Yes
4	Normal distribution of residuals	Jarque-Bera Test	0,69	Yes
5	Correctness of specification	Ramsey RESET Test	0,34	Yes

Source: made by the author based on the tests` results in EViews

Appendix H

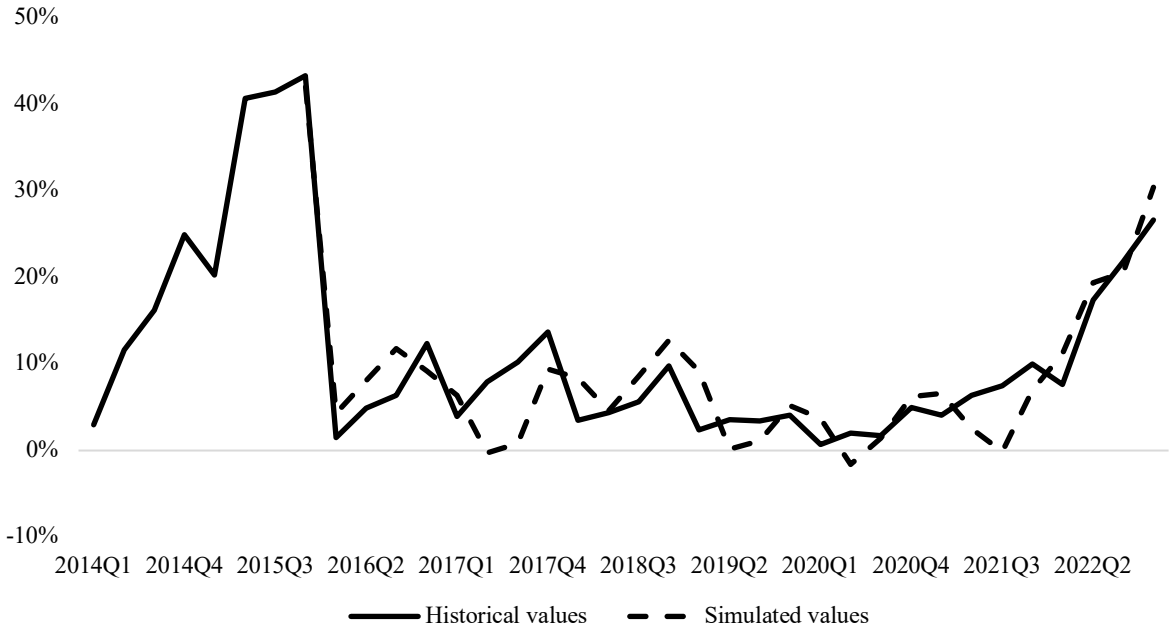
Table H.1. Results of testing the identifiability of the system of equations in an aggregated macro model under order conditions

Endogenous variables	Exogeneous variables	Predetermined variables (lag endogenous)	Order condition	Conclusion
Inflation equation				
CPI	PCPI(-1), WAR	KEY_R(-6), ER(-3), CPI(-4)	23-5>1-1	Reidentified
Exchange rate equation				
ER, KEY_R	DEBT_TO_GDP, DUMMY1	RESERVES(-7), ER(-1)	23-4>2-1	Reidentified
International reserves equation				
RESERVES	REER, FOR_DEBT(-1)	RESERVES(-1), GDP_GAP(-2)	23-4>1-1	Reidentified
GDP gap equation				
GDP_GAP	EMPL_R, TOT(-2), REER,	KEY_R(-1), GDP_GAP(-2), CPI(-2)	23-6>1-1	Reidentified
Key policy rate equation				
KEY_R, CPI	DUMMY2, CPI_TARGET, NR(-3)	GDP_GAP(-2), ER(-1)	23-5>2-1	Reidentified

Source: made by the author based on the regressions

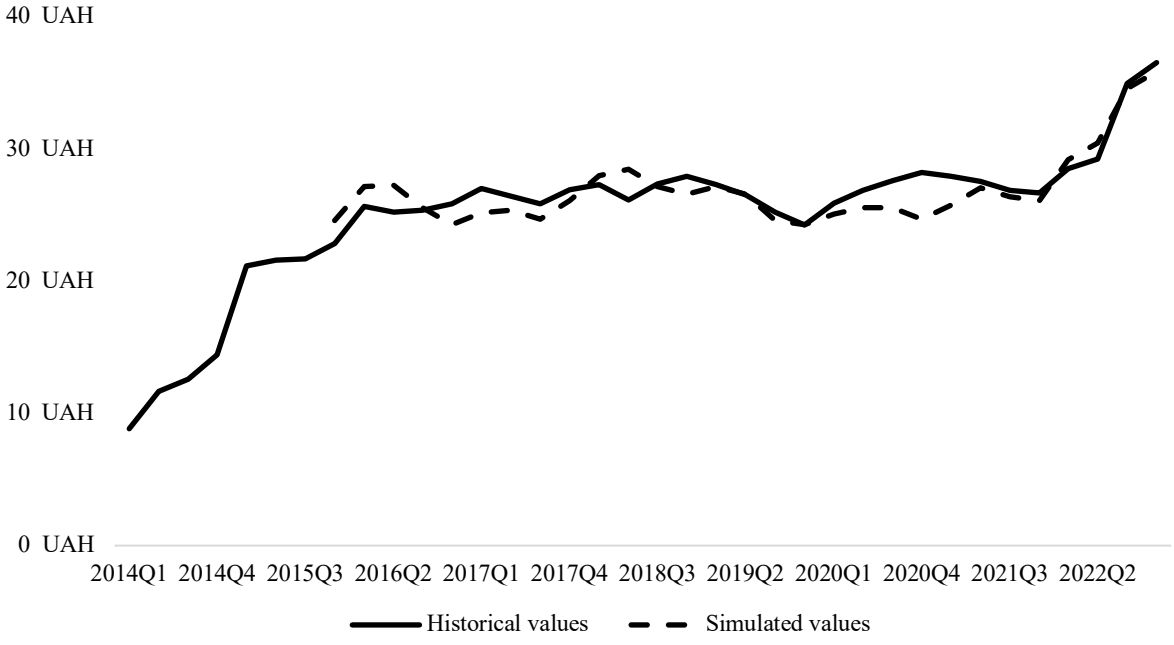
Appendix I

Figure I.1. Historical and simulated values of the quarterly inflation, %



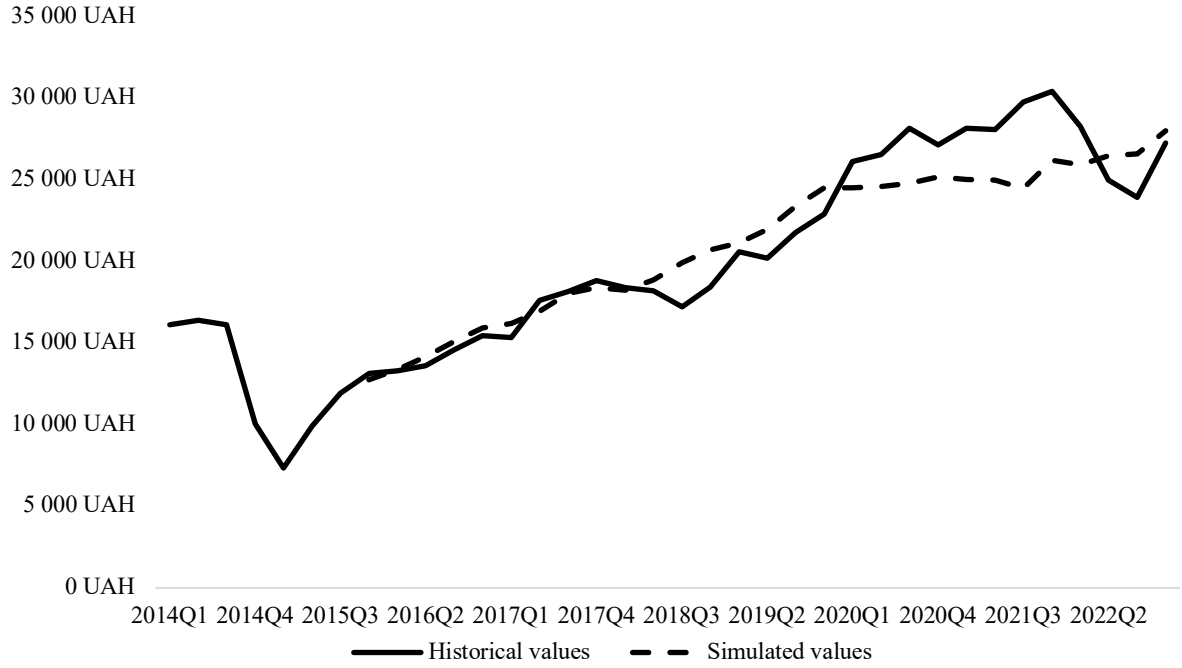
Source: made by the author using EViews

Figure I.2. Historical and simulated values of the exchange rate UAH/USD



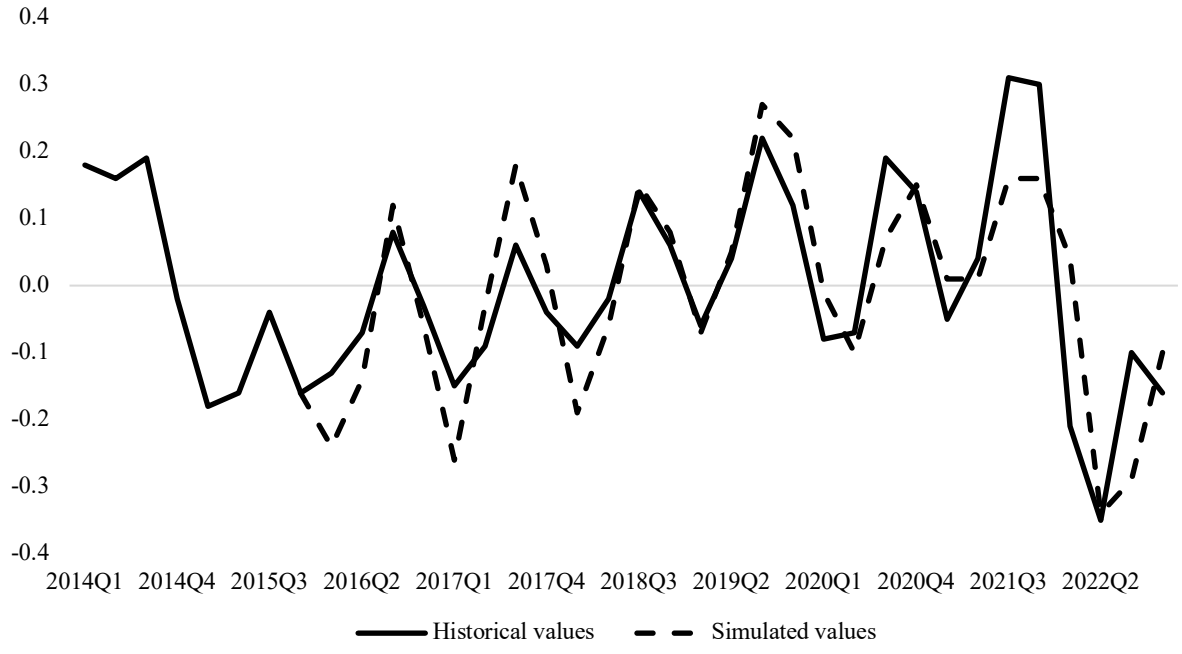
Source: made by the author using EViews

Figure I.3. Historical and simulated values of international reserves, million USD



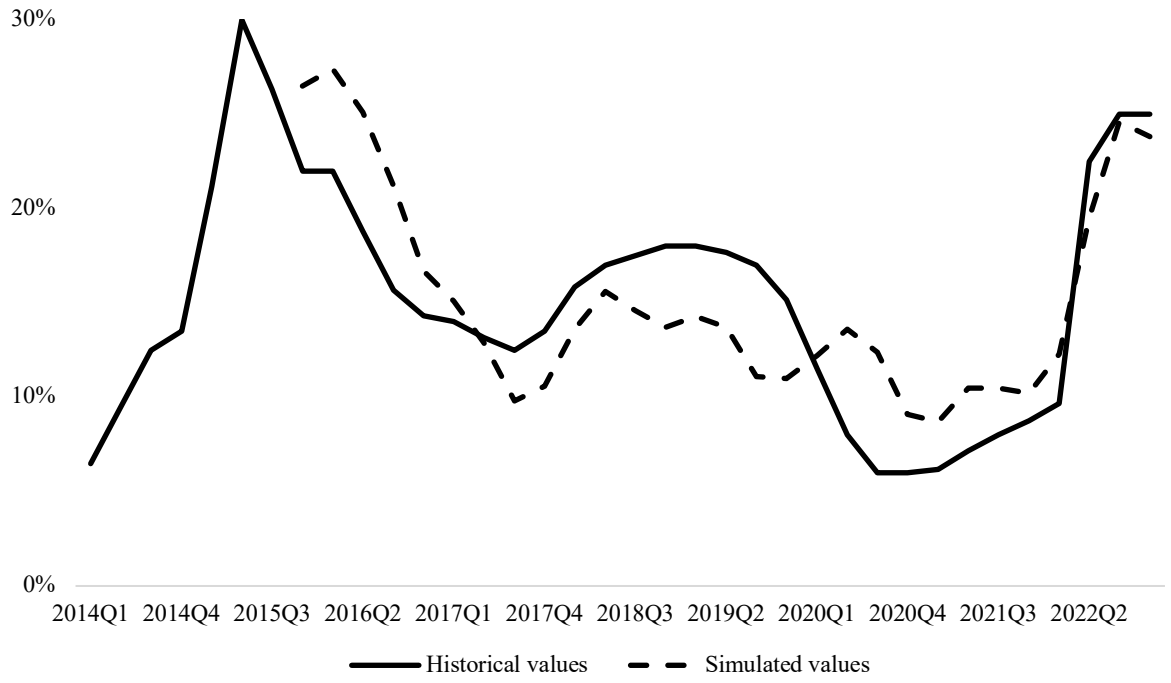
Source: made by the author using EViews

Figure I.4. Historical and simulated values of the GDP gap to potential output



Source: made by the author using EViews

Figure I.5. Historical and simulated value of the key policy rate, %



Source: made by the author using EViews

Appendix J

Table J.1. Sources of predictive values of the exogenous variables

Variable code	Name	Modelling	Units
PCPI	Weighted CPI of countries main trade partners: China, Poland, Turkey, Italy, the Netherlands, Egypt, India, Germany, Romania, the USA, Slovakia, Hungary, Austria, Czech Republic	ARIMA (4,2,4)	%
DEBT_TO_GDP	Government debt to real GDP	ARIMA (4,2,4)	-
REER	Real effective exchange rate is the weighted average of a country's currency in relation to an index or basket of other major currencies	ARMA (2,4)	-
FOR_DEBT	Gross foreign debt	ARIMA (3,2,4)	mln USD
EMPL_R	Employment rate, in % to population of age 15-70	ARIMA (1,1,3)	%
TOT	Terms of trade (index of export prices to index of import prices	ARMA (4,1)	-
NR	Neutral interest rate is the rate at which monetary policy is neither stimulating nor restricting economic growth	ARIMA (1,1,1)	%

Source: made by the author using EViews

Appendix K

Table K.1. Predictive values of exogenous variables under basic scenario

Variable code	Q1 2023	Q2 2023	Q3 2023	Q4 2023
PCPI	16,93%	16,29%	15,56%	14,15%
WAR	1	1	1	1
DEBT_TO_GDP	4,95	4,92	4,91	4,84
REER	0,96	0,97	0,98	1,01
FOR_DEBT	133 051,19	134 441,65	129 295,16	137 210,13
EMPL_R	42,84%	43,15%	45,12%	46,15%
TOT	0,75	0,75	0,77	0,81
CPI_TARGET	5%	5%	5%	5%
NR	15%	15%	15%	15%
DUMMY1	0	0	0	0
DUMMY2	0	0	0	0

Source: made by the author based on the ARIMA-models

Table K.2. Predictive values of exogenous variables under alternative scenario №1

Variable code	Q1 2023	Q2 2023	Q3 2023	Q4 2023
PCPI	16,93%	16,29%	16,56%	16,15%
WAR	1	1	1	0
DEBT_TO_GDP	4,95	4,92	4,91	4,84
REER	0,96	0,97	0,98	1,02
FOR_DEBT	133 051,19	134 441,65	129 295,16	129 210,13
EMPL_R	42,84%	43,15%	45,12%	49,15%
TOT	0,74	0,75%	0,77%	0,87%
CPI_TARGET	5%	5%	5%	5%
NR	15%	15%	15%	12%
DUMMY1	0	0	0	1
DUMMY2	0	0	0	1

Source: made by the author based on the ARIMA-models

Table K.3. Predictive values of exogenous variables under alternative scenario №2

Variable code	Q1 2023	Q2 2023	Q3 2023	Q4 2023
PCPI	16,93%	16,94%	17,26%	17,53%
WAR	1	1	1	1
DEBT_TO_GDP	5,05	5,08	5,12	5,15
REER	0,96	0,96	0,97	0,98
FOR_DEBT	133 789	134 967	136 120	137 820
EMPL_R	38,95	39,13	39,25	39,54
TOT	0,72	0,72	0,72	0,75
CPI_TARGET	5%	5%	5%	5%
NR	15%	15%	15%	15%
DUMMY1	0	0	0	0
DUMMY2	0	0	0	0

Source: made by the author based on the ARIMA-models

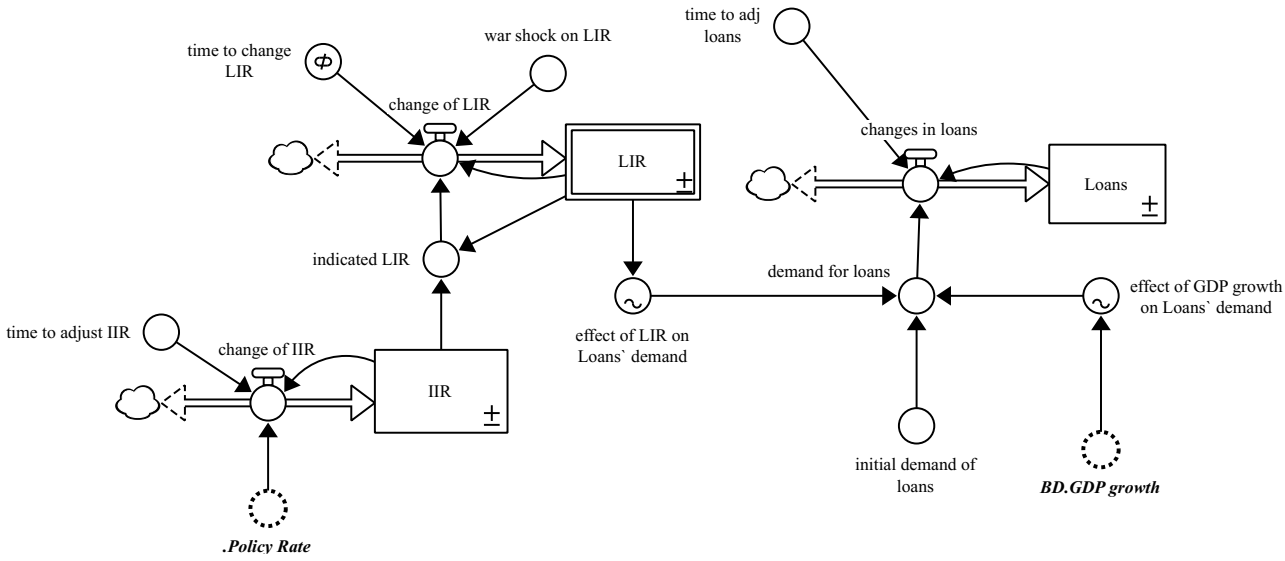
Table K.4. Predictive values of exogenous variables under alternative scenario №3

Variable code	Q1 2023	Q2 2023	Q3 2023	Q4 2023
PCPI	17,43%	17,84%	18,55%	18,99%
WAR	1	1	1	0
DEBT_TO_GDP	5,03	5,01	5,05	5,06
REER	0,94	0,96	0,97	0,95
FOR_DEBT	132 051,19	133 441,65	134 495,16	136 210,13
EMPL_R	39,05%	39,12%	39,24%	38,20%
TOT	0,69	0,69	0,68	0,68
CPI_TARGET	5%	5%	5%	5%
NR	15%	15%	15%	15%
DUMMY1	0	0	0	0
DUMMY2	0	0	0	0

Source: made by the author based on the ARIMA-models

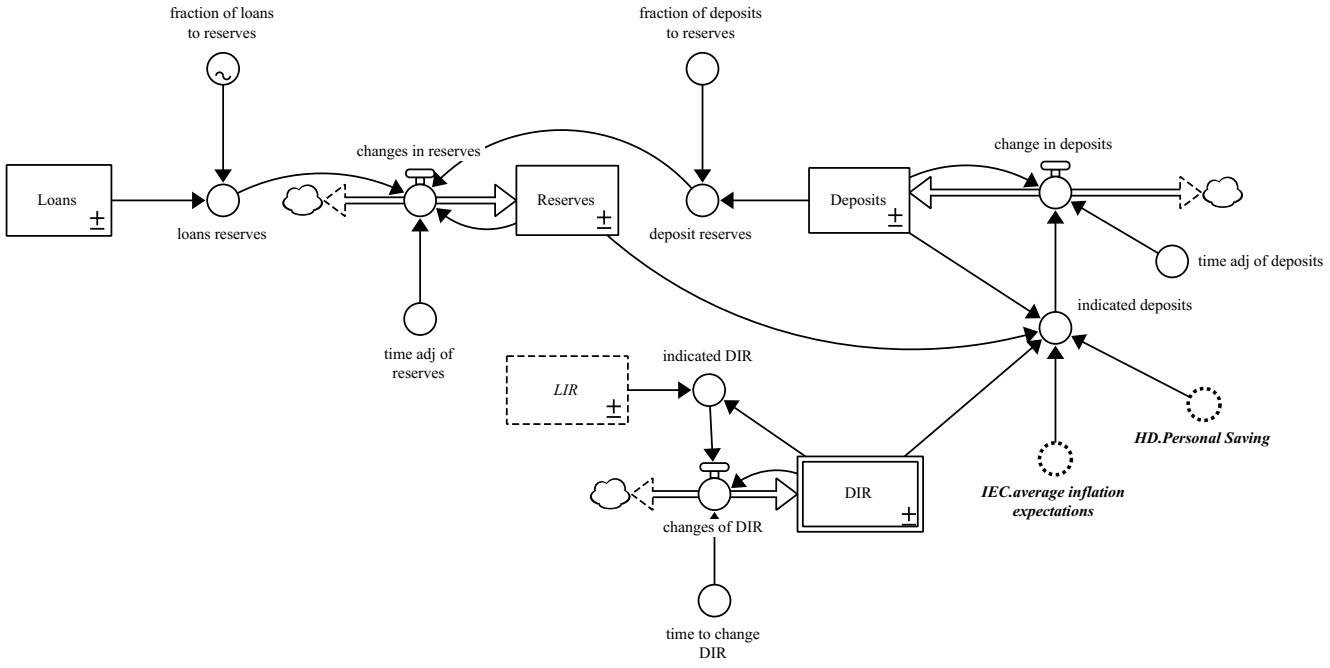
Appendix L

Figure L.1. Representation of the first part of the interest rate channel in Ukraine using the System Dynamics modeling



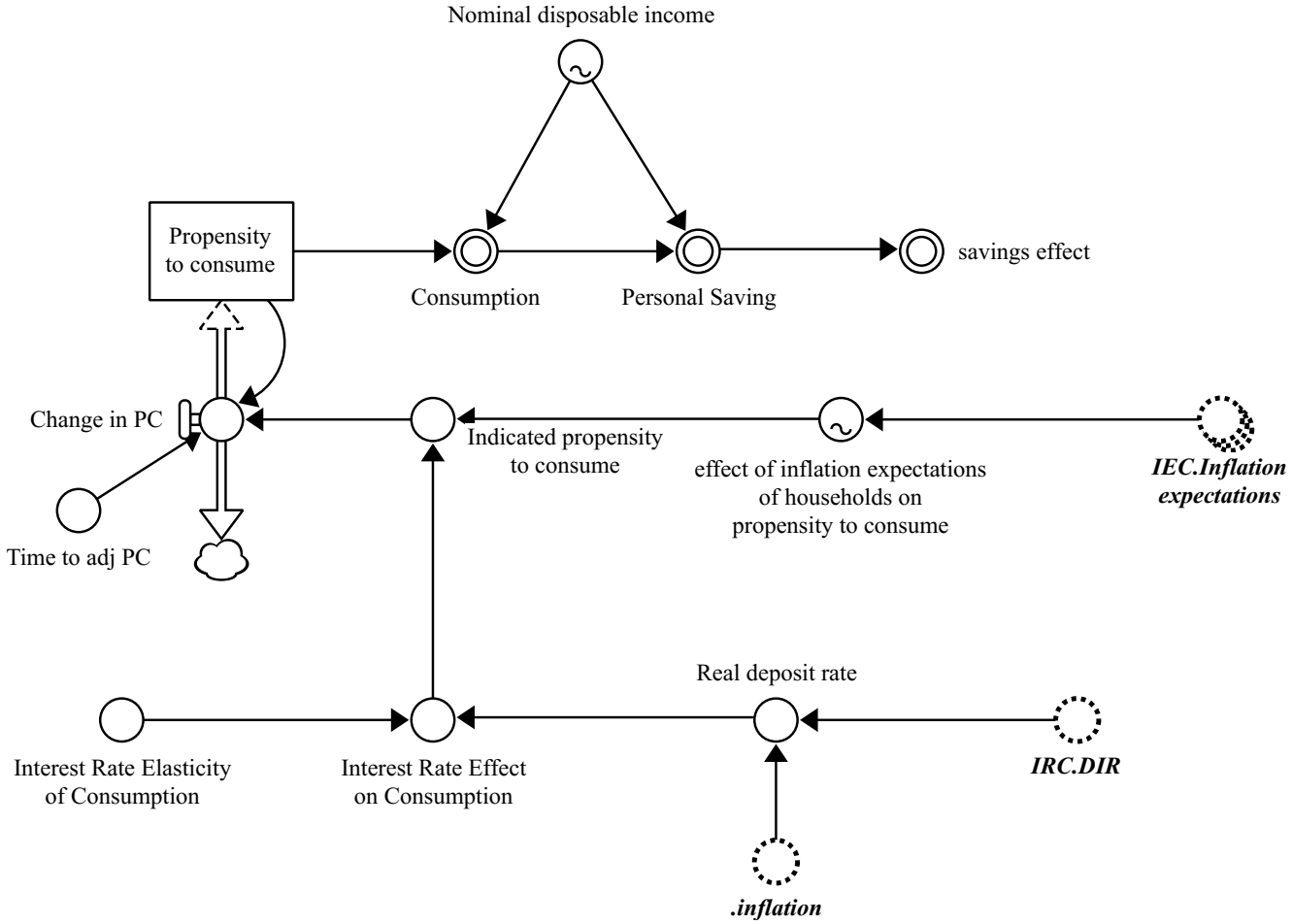
Source: made by the author using tools of the System Dynamics in Stella Architect

Figure L.2. Representation of the second part of the interest rate channel in Ukraine using the System Dynamics modeling



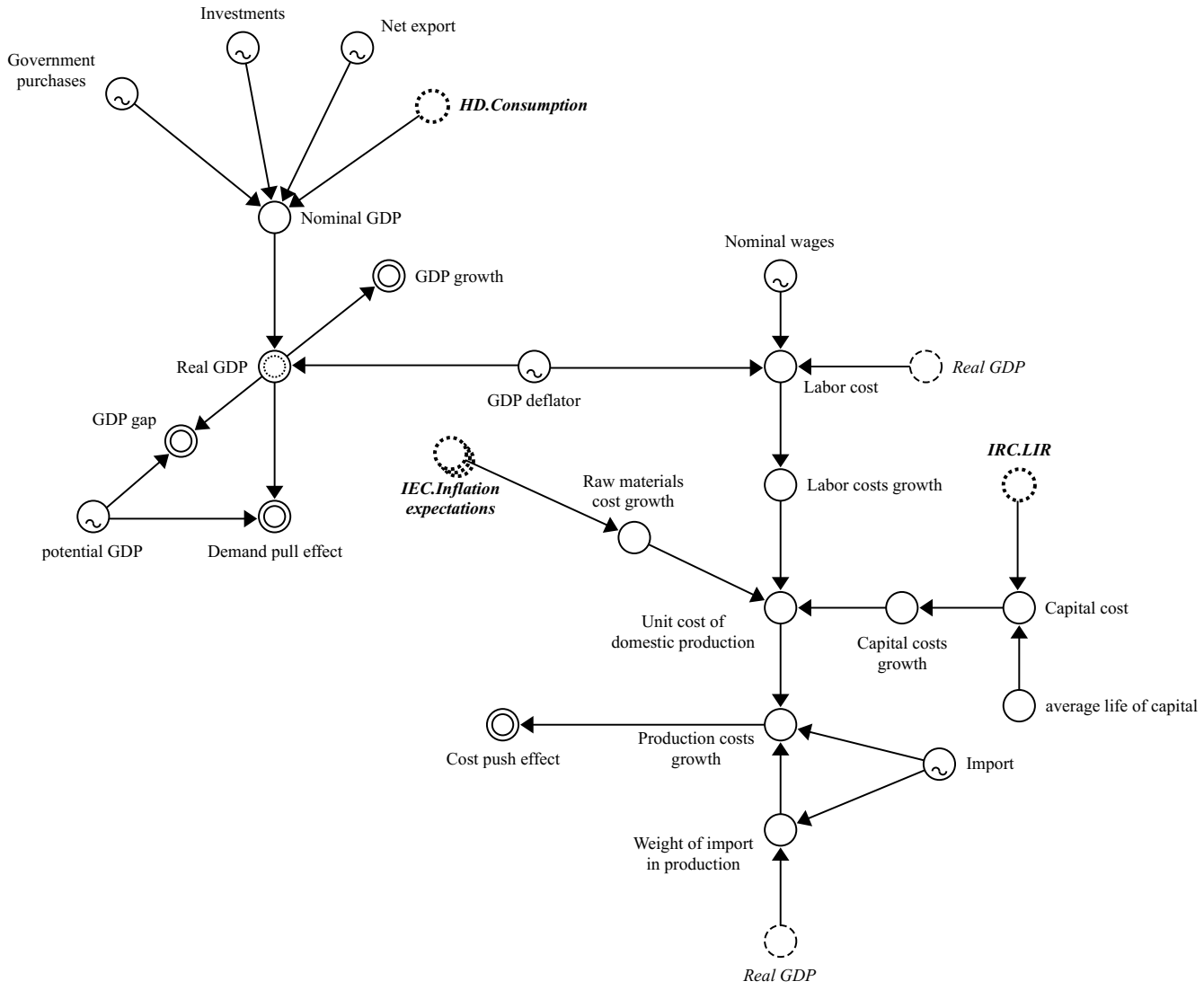
Source: made by the author using tools of the System Dynamics in Stella Architect

Figure L.3. Representation of the household demand structure in Ukraine using the System Dynamics modeling



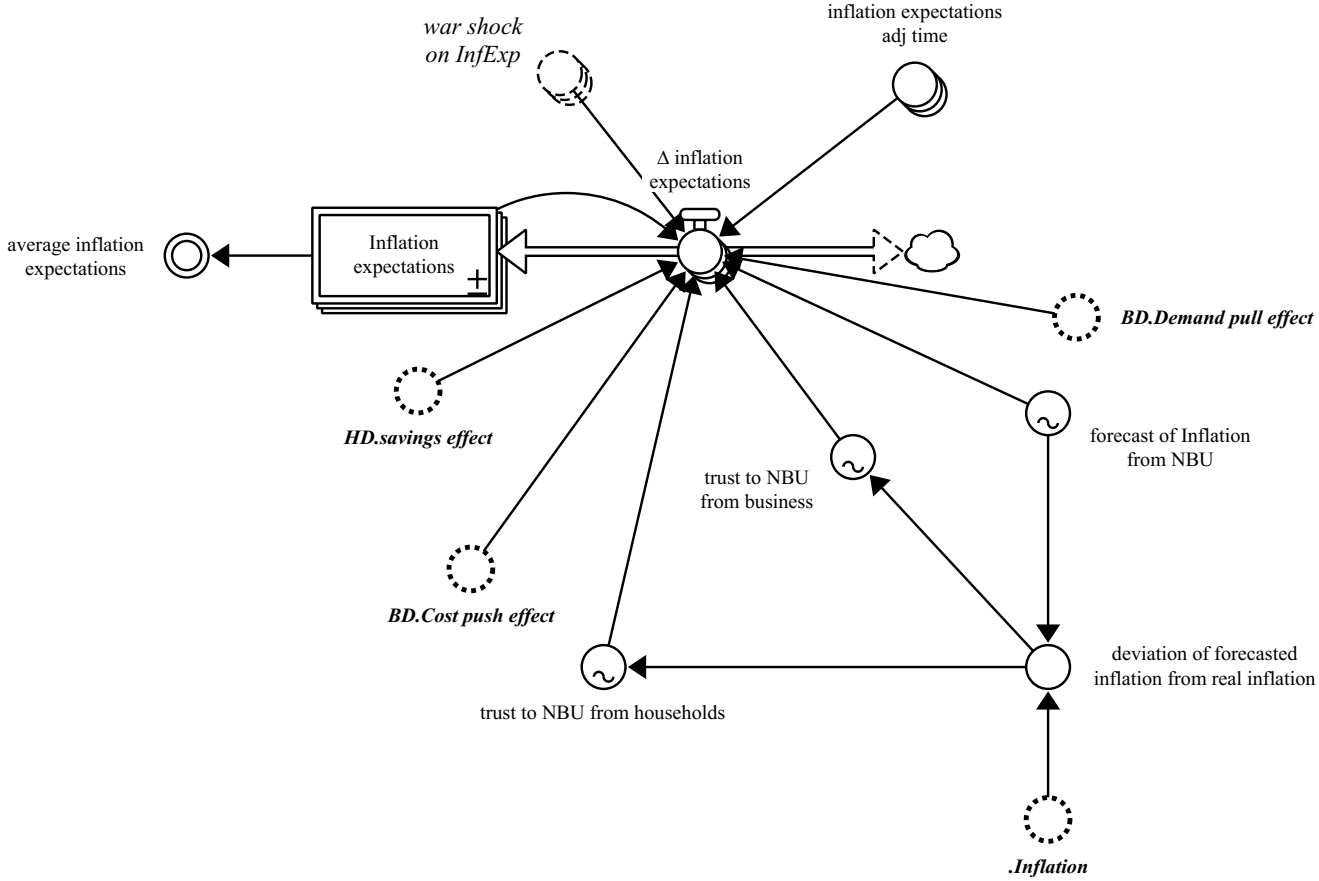
Source: made by the author using tools of the System Dynamics in Stella Architect

Figure L.4. Representation of the business demand structure in Ukraine using the System Dynamics modeling



Source: made by the author using tools of the System Dynamics in Stella Architect

Figure L.5. Representation of the inflation expectations channel in Ukraine using the System Dynamics modeling



Source: made by the author using tools of the System Dynamics in Stella Architect

Appendix M

Table M.1. Equations of the System Dynamics model

Variables	Equation	Units
Top-Level Model:		
Inflation(t)	Inflation(t - dt) + (Δ_inflation) * dt	%
Policy_Rate(t)	Policy_Rate(t - dt) + (Δ_policy_rate) * dt	%
Δ_inflation	((IEC.average_inflation_expectations-Inflation)/inflation_adj_time)+war_shock	%/year
Δ_policy_rate	((indicated_policy_rate-Policy_Rate)/policy_rate_adj_time)+war_shock_of_policy_rate	%/year
Alternative_scenario	1	dmnl
Base_case_scenario	0	dmnl
historical_policy_rate	GRAPH(TIME) Points: (2014,000, 6,5), (2015,000, 14,0), (2016,000, 22,0), (2017,000, 14,0), (2018,000, 14,5), (2019,000, 18,0), (2020,000, 13,5), (2021,000, 6,0), (2022,000, 9,0), (2023,000, 25,0)	%
indicated_policy_rate	11,97+0,31*inflation_gap-0,47*BD.GDP_gap	%
inflation_adj_time	0,5	year
inflation_gap	Inflation-inflation_goal	%
inflation_goal	GRAPH(TIME) Points: (2016,000, 12,0), (2017,000, 8,0), (2018,000, 6,0), (2019,000, 5,0), (2020,000, 5,0), (2021,000, 5,0), (2022,000, 5,0), (2023,000, 5,0)	%
inflation_historical_values	GRAPH(TIME) Points: (2014,000, 0,5), (2015,000, 24,9), (2016,000, 43,3), (2017,000, 12,4), (2018,000, 13,7), (2019,000, 9,8), (2020,000, 4,1), (2021,000, 5,0), (2022,000, 10,0), (2023,000, 26,6)	%
policy_rate_adj_time	0,75	Year
war_shock	IF Base_case_scenario = 1 THEN "war_shock_(base_case_scenario)" ELSE IF Alternative_scenario = 1 THEN "war_shock_(alternative_scenario)" ELSE "war_shock_(base_case_scenario)"	%/year

Continuation of Table M.1

Variables	Equation	Units
"war_shock_(alternative_scenario)"	IF TIME > 2022 AND TIME < 2023 THEN 30 ELSE IF TIME >=2023 AND TIME < 2023,5 THEN -10 ELSE 0	%/year
"war_shock_(base_case_scenario)"	IF TIME > 2022 AND TIME < 2023 THEN 30 ELSE IF TIME >=2023 AND TIME < 2024 THEN -10 ELSE 0	%/year
war_shock_of_policy_rate	IF TIME >= 2022 AND TIME < 2023 THEN 15 ELSE 0	%/year
Business demand:		
average_life_of_capital	10	year
Capital_cost	SMTH1(IRC.LIR; 1)/average_life_of_capital	%/year
Capital_costs_growth	SMTH1(Capital_cost/HISTORY(Capital_cost; TIME-0,25); 1)	dmnl
Cost_push_effect	SMTH1(Production_costs_growth; 1)	dmnl
Demand_pull_effect	(Real_GDP/Potential_GDP)	dmnl
GDP_deflator	GRAPH(TIME) Points: (2016,00, 38,9), (2017,00, 17,1), (2018,00, 22,1), (2019,00, 15,4), (2020,00, 8,2), (2021,00, 10,3), (2022,00, 25,1), (2023,00, 34,3), (2024,00, 22,9), (2025,00, 13,4), (2026,00, 8,7)	dmnl
GDP_gap	((Real_GDP-Potential_GDP)/Potential_GDP)*100	%
GDP_growth	Nominal_GDP/HISTORY(Nominal_GDP; TIME-1)	dmnl
Government_purchases	IF .Base_case_scenario = 1 THEN "Government_purchases_(base_case)" ELSE IF .Alternative_scenario = 1 THEN "Government_purchases_(alternative_scenario)" ELSE "Government_purchases_(base_case)"	UAH/year
"Government_purchases_ (alternative_scenario)"	GRAPH(TIME) Points: (2016,00, 392103000000,0), (2017,00, 462626000000,0), (2018,00, 640486000000,0), (2019,00, 770514000000,0), (2020,00, 786780000000,0), (2021,00, 854817000000,0), (2022,00, 1016423000000,0), (2023,00, 1984794000000,0),	UAH/year

Continuation of Table M.1

Variables	Equation	Units
"Government_purchases_ (alternative_scenario)"	(2024,00, 2360025914157,1), (2025,00, 2363942125255,0), (2026,00, 1943461366518,7)	UAH/year
"Government_purchases_ (base_case)"	GRAPH(TIME) Points: (2016,00, 392103000000,0), (2017,00, 462626000000,0), (2018,00, 640486000000,0), (2019,00, 770514000000,0), (2020,00, 786780000000,0), (2021,00, 854817000000,0), (2022,00, 1016423000000,0), (2023,00, 1984794000000,0), (2024,00, 2156429564424,6), (2025,00, 1969951771046,0), (2026,00, 1871454182493,3)	UAH/year
Import	IF .Base_case_scenario = 1 THEN "Import_(base_case)" ELSE IF .Alternative_scenario = 1 THEN "Import_(alternative_scenario)"ELSE "Import_(base_case)"	UAH/year
"Import_ (alternative_scenario)"	GRAPH(TIME) Points: (2016,00, 1097854000000,0), (2017,00, 1341115000000,0), (2018,00, 1662128000000,0), (2019,00, 1919862000000,0), (2020,00, 1959945000000,0), (2021,00, 1702946000000,0), (2022,00, 2289881000000,0), (2023,00, 2712325000000,0), (2024,00, 3526022500000,0), (2025,00, 4760130375000,0), (2026,00, 6188169487500,0)	UAH/year
"Import_(base_case)"	GRAPH(TIME) Points: (2016,00, 1097854000000,0), (2017,00, 1341115000000,0), (2018,00, 1662128000000,0), (2019,00, 1919862000000,0), (2020,00, 1959945000000,0), (2021,00, 1702946000000,0), (2022,00, 2289881000000,0), (2023,00, 2712325000000,0), (2024,00, 3390406250000,0), (2025,00, 4407528125000,0), (2026,00, 5509410156250,0)	UAH/year
Investments	IF .Base_case_scenario = 1 THEN "Investments_(base_case)" ELSE IF .Alternative_scenario = 1 THEN "Investments_(alternative_scenario)" ELSE "Investments_(base_case)"	UAH/year
"Investments_ (alternative_scenario)"	GRAPH(TIME) Points: (2016,00, 270895000000,0), (2017,00, 212591000000,0), (2018,00, 316841000000,0), (2019,00, 518201000000,0), (2020,00, 595194000000,0), (2021,00, 661801000000,0), (2022,00, 788599000000,0),	UAH/year

Continuation of Table M.1

Variables	Equation	Units
"Investments_ (alternative_scenario)"	(2023,00, 654629000000,0), (2024,00, 599236398658,0), (2025,00, 690924104550,2), (2026,00, 889232368989,2)	UAH/year
"Investments_ (base_case)"	GRAPH(TIME) Points: (2016,00, 270895000000,0), (2017,00, 212591000000,0), (2018,00, 316841000000,0), (2019,00, 518201000000,0), (2020,00, 595194000000,0), (2021,00, 661801000000,0), (2022,00, 788599000000,0), (2023,00, 654629000000,0), (2024,00, 661971134811,7), (2025,00, 851408275095,0), (2026,00, 1070367615929,3)	UAH/year
Labor_cost	(Nominal_wages/(1+GDP_deflator/100))/Real_GDP	dmnl
Labor_costs_growth	Labor_cost/HISTORY(Labor_cost; TIME-0,25)	dmnl
"Net_export_ (Alternative_scenario)"	GRAPH(TIME) Points: (2016,00, -51926000000,0), (2017,00, -165162000000,0), (2018,00, -229438000000,0), (2019,00, -310497000000,0), (2020,00, -320079000000,0), (2021,00, -63886000000,0), (2022,00, -72021000000,0), (2023,00, -871762000000,0), (2024,00, -617118750000,0), (2025,00, -503934600000,0), (2026,00, -366065700000,0)	UAH/year
"Net_export_(base_case)"	GRAPH(TIME) Points: (2016,00, -51926000000,0), (2017,00, -165162000000,0), (2018,00, -229438000000,0), (2019,00, -310497000000,0), (2020,00, -320079000000,0), (2021,00, -63886000000,0), (2022,00, -72021000000,0), (2023,00, -871762000000,0), (2024,00, -493695000000,0), (2025,00, -387642000000,0), (2026,00, -281589000000,0)	UAH/year
Net_exports	IF .Base_case_scenario = 1 THEN "Net_export_(base_case)"ELSE IF .Alternative_scenario = 1 THEN "Net_export_(Alternative_scenario)" ELSE "Net_export_(base_case)"	UAH/year
Nominal_GDP	Government_purchases+Investments+Net_exports+HD.Consumption	UAH/year
Nominal_wages	GRAPH(TIME) Points: (2014,000, 294602599673,0), (2015,000, 352611373861,0), (2016,000, 422042375438,0), (2017,000, 505144700000,0), (2018,000, 673865800000,0), (2019,000, 838321100000,0), (2020,000, 963428000000,0), (2021,000, 1048837600000,0), (2022,000, 1225656900000,0), (2023,000, 1371440719170,0)	UAH/year

Continuation of Table M.1

Variables	Equation	Units
Potential_GDP	GRAPH(TIME) Points: (2016,00, 1428323070980,0), (2017,00, 2052909336810,0), (2018,00, 2701854248622,3), (2019,00, 3546477645577,6), (2020,00, 4335138555476,7), (2021,00, 4721985225206,5), (2022,00, 4450153995506,9), (2023,00, 3838291230012,1), (2024,00, 4645147885022,0), (2025,00, 5456445475014,3), (2026,00, 6487025581420,0)	UAH/year
Production_costs_growth	(1-Weight_of_import_in_production)*Unit_cost_of_domestic_production + Weight_of_import_in_production*(Import/HISTORY(Import; TIME-1))	dmnl
Raw_materials_cost_growth	SMTH1(IEC.Inflation_expectations[Business]/HISTORY(IEC.Inflation_expectations[Business]; TIME-0,25); 1)	dmnl
Real_GDP	Nominal_GDP*(1-(GDP_deflator/100))	UAH/Year
Unit_cost_of_domestic_production	SMTH1(Labor_costs_growth*Raw_materials_cost_growth*Capital_costs_growth; 1)	dmnl
Weight_of_import_in_production	(Import)/Real_GDP	dmnl
Households demand:		
Propensity_to_consume(t)	Propensity_to_consume(t - dt) + (- Change_in_PC) * dt	dmnl
Change_in_PC	(Propensity_to_consume-Indicated_propensity_to_consume)/Time_to_adj_PC	dmnl/year
Consumption	Nominal_disposable_income*Propensity_to_consume	UAH/year
effect_of_inflation_expectations_of_households_on_propensity_to_consume	GRAPH(IEC.Inflation_expectations[Households]) Points: (5,00, 0,95), (7,00, 0,9506), (9,00, 0,9522), (11,00, 0,9558), (13,00, 0,9634), (15,00, 0,975), (17,00, 0,9866), (19,00, 0,9942), (21,00, 0,9978), (23,00, 0,9994), (25,00, 1)	dmnl
historical_values_of_propensity_to_consume	GRAPH(TIME) Points: (2014,000, 0,92), (2015,000, 0,98), (2016,000, 0,98), (2017,000, 0,99), (2018,000, 0,99), (2019,000, 0,99), (2020,000, 0,99), (2021,000, 0,98), (2022,000, 0,99), (2023,000, 0,99)	dmnl

Continuation of Table M.1

Variables	Equation	Units
Indicated_propensity_to_consume	0,98^(effect_of_inflation_expectations_of_households_on_propensity_to_consume*Real_deposit_interest_rate_effect_on_Consumption)	dmnl
Interest_Rate_Elasticity_of_Consumption	-0,5	dmnl
Nominal_disposable_income	IF .Base_case_scenario = 1 THEN "Nominal_disposable_income_(base_case)" ELSE IF .Alternative_scenario = 1 THEN "Nominal_disposable_income_(alternative)" ELSE "Nominal_disposable_income_(base_case)"	UAH/year
"Nominal_disposable_income_(alternative)"	GRAPH(TIME) Points: (2016,00, 1772016000000,0), (2017,00, 2051331000000,0), (2018,00, 2652082000000,0), (2019,00, 3248730000000,0), (2020,00, 3744060000000,0), (2021,00, 4045191000000,0), (2022,00, 4698611000000,0), (2023,00, 3289027700000,0), (2024,00, 3375508479480,0), (2025,00, 3866567187785,6), (2026,00, 443815661993 9,7)	UAH/year
"Nominal_disposable_income_(base_case)"	GRAPH(TIME) Points: (2016,00, 1772016000000,0), (2017,00, 2051331000000,0), (2018,00, 2652082000000,0), (2019,00, 3248730000000,0), (2020,00, 3744060000000,0), (2021,00, 4045191000000,0), (2022,00, 4698611000000,0), (2023,00, 3289027700000,0), (2024,00, 3875508479480,0), (2025,00, 4566567187785,6), (2026,00, 513815661993 9,7)	UAH/year
Personal_Saving	Nominal_disposable_income-Consumption	UAH/year
Real_deposit_interest_rate_effect_on_Consumption	(((Real_deposit_rate-INIT(Real_deposit_rate))//INIT(Real_deposit_rate))*Interest_Rate_Elasticity_of_Consumption)	dmnl
Real_deposit_rate	IRC.DIR-.Inflation	%
savings_effect	Personal_Saving/HISTORY(Personal_Saving; TIME-1)	dmnl
Time_to_adj_PC	0,5	year

Continuation of Table M.1

Variables	Equation	Units
Inflation expectations channel:		
Inflation_expectations[Households](t)	Inflation_expectations[Households](t - dt) + (Δ_inflation_expectations[Households]) * dt	%
Inflation_expectations[Business](t)	Inflation_expectations[Business](t - dt) + (Δ_inflation_expectations[Business]) * dt	
Δ_inflation_expectations[Households]	((trust_to_NBU_from_households*(forecast_of_Inflation_from_NBU-Inflation_expectations[Households])*HD.savings_effect)/inflation_expectations_adj_time[Households])+war_shock_on_InfExp[Households]	%/year
Δ_inflation_expectations[Business]	((trust_to_NBU_from_business*(forecast_of_Inflation_from_NBU-Inflation_expectations[Business])*BD.Cost_push_effect*BD.Demand_pull_effect)/inflation_expectations_adj_time[Business])+war_shock_on_InfExp[Business]	%/year
average_inflation_expectations	Inflation_expectations[Business]*0,5+Inflation_expectations[Households]*0,5	%
deviation_of_forecasted_inflation_from_real_inflation	.Inflation-forecast_of_Inflation_from_NBU	%
forecast_of_Inflation_from_NBU	GRAPH(TIME) Points: (2016,00, 15,0), (2017,00, 20,0), (2018,00, 16,0), (2019,00, 10,0), (2020,00, 5,0), (2021,00, 8,0), (2022,00, 10,0), (2023,00, 26,6), (2024,00, 14,8), (2025,00, 9,6), (2026,00, 6,0)	%
historical_values_of_business_expectations	GRAPH(TIME) Points: (2016,000, 22,2), (2017,000, 15,6), (2018,000, 11,0), (2019,000, 9,0), (2020,000, 5,1), (2021,000, 7,7), (2022,000, 9,5), (2023,000, 23,3)	%
historical_values_of_households_expectations	GRAPH(TIME) Points: (2016,000, 21,5), (2017,000, 17,1), (2018,000, 13,3), (2019,000, 12,1), (2020,000, 8,8), (2021,000, 9,5), (2022,000, 12,3), (2023,000, 13,2)	%
inflation_expectations_adj_time[Economic_agents]	0,25	year

Continuation of Table M.1

Variables	Equation	Units
trust_to_NBU_from_business	GRAPH(deviation_of_forecasted_inflation_from_real_inflation) Points: (-10,00, 1,0000), (-8,33333333333, 0,9419), (-6,66666666667, 0,8862), (-5,00, 0,8327), (-3,33333333333, 0,7814), (-1,66666666667, 0,7322), (0,00, 0,6851), (1,66666666667, 0,6398), (3,33333333333, 0,5964), (5,00, 0,5548), (6,66666666667, 0,5148), (8,33333333333, 0,4765), (10,00, 0,4398), (11,6666666667, 0,4045), (13,3333333333, 0,3707), (15,00, 0,3383), (16,6666666667, 0,3072), (18,3333333333, 0,2774), (20,00, 0,2488), (21,6666666667, 0,2213), (23,3333333333, 0,1950), (25,00, 0,1697), (26,6666666667, 0,1455), (28,3333333333, 0,1223), (30,00, 0,1000)	dmnl
trust_to_NBU_from_households	GRAPH(deviation_of_forecasted_inflation_from_real_inflation) Points: (-10,00, 1,0000), (-7,89473684211, 0,9717), (-5,78947368421, 0,9419), (-3,68421052632, 0,9104), (-1,57894736842, 0,8773), (0,526315789474, 0,8423), (2,63157894737, 0,8055), (4,73684210526, 0,7667), (6,84210526316, 0,7258), (8,94736842105, 0,6826), (11,0526315789, 0,6372), (13,1578947368, 0,5893), (15,2631578947, 0,5388), (17,3684210526, 0,4855), (19,4736842105, 0,4294), (21,5789473684, 0,3703), (23,6842105263, 0,3080), (25,7894736842, 0,2423), (27,8947368421, 0,1730), (30,00, 0,1000)	dmnl
"war_shock_(alternative_scenario)"[Households]	IF TIME>=2022,25 AND TIME < 2024 THEN -20 ELSE IF TIME>2024 AND TIME <2025 THEN 5 ELSE 0	%/year
"war_shock_(alternative_scenario)"[Business]	0	%/year
"war_shock_(base_case)"[Households]	IF TIME>=2022,25 AND TIME < 2024 THEN -20 ELSE 0	%/year
"war_shock_(base_case)"[Business]	0	%/year
war_shock_on_InfExp[Economic_agents]	IF .Base_case_scenario = 1 THEN "war_shock_(base_case)" ELSE IF .Alternative_scenario = 1 THEN "war_shock_(alternative_scenario)" ELSE "war_shock_(base_case)"	%/year

Continuation of Table M.1

Variables	Equation	Units
Interest rate channel:		
Deposits(t)	Deposits(t - dt) + (change_in_deposits) * dt	UAH
DIR(t)	DIR(t - dt) + (changes_of_DIR) * dt	%
IIR(t)	IIR(t - dt) + (change_of_IIR) * dt	%
LIR(t)	LIR(t - dt) + (change_of_LIR) * dt	%
Loans(t)	Loans(t - dt) + (changes_in_loans) * dt	UAH
Reserves(t)	Reserves(t - dt) + (changes_in_reserves) * dt	UAH
change_in_deposits	(indicated_deposits-Deposits)/time_adj_of_deposits	UAH/Year
change_of_IIR	(.Policy_Rate-IIR)/time_to_adjust_IIR	%/year
change_of_LIR	((indicated_LIR-LIR)/time_to_change_LIR)+war_shock_on_LIR	%/year
changes_in_loans	(demand_for_loans-Loans)/time_to_adj_loans	UAH/year
changes_in_reserves	((loans_reserves+deposit_reserves)-Reserves)/time_adj_of_reserves	UAH/year
changes_of_DIR	(indicated_DIR-DIR)/time_to_change_DIR	%/year
demand_for_loans	(initial_demand_of_loans*effect_of_GDP_growth_on_Loans`_demand*effect_of_LIR_on_Loans`_demand)	UAH
deposit_reserves	Deposits*fraction_of_deposits_to_reserves	UAH
Deposits(t)	Deposits(t - dt) + (change_in_deposits) * dt	UAH
effect_of_GDP_growth_on_Loans`_demand	GRAPH(BD.GDP_growth) Points: (0,500, 1,0000), (0,631578947368, 1,0116), (0,763157894737, 1,0231), (0,894736842105, 1,0347), (1,02631578947, 1,0462), (1,15789473684, 1,0636), (1,28947368421, 1,0723), (1,42105263158, 1,0896), (1,55263157895, 1,1012), (1,68421052632, 1,1127), (1,81578947368, 1,1243), (1,94736842105, 1,1387), (2,07894736842, 1,1503), (2,21052631579, 1,1676), (2,34210526316, 1,1879), (2,47368421053, 1,2110), (2,60526315789, 1,2399), (2,73684210526, 1,3208), (2,86842105263, 1,4191), (3,000, 1,5000)	dmnl

Continuation of Table M.1

Variables	Equation	Units
effect_of_LIR_on_Loans`_demand	GRAPH(LIR/HISTORY(LIR; TIME-1)) Points: (0,300, 1,5000), (0,420, 1,3422), (0,540, 1,2329), (0,660, 1,1358), (0,780, 1,0468), (0,900, 0,9618), (1,020, 0,9133), (1,140, 0,8728), (1,260, 0,8243), (1,380, 0,8040), (1,500, 0,8000)	dmnl
fraction_of_deposits_to_reserves	IF TIME < 2023 THEN 0,05 ELSE 0,15	dmnl
fraction_of_loans_to_reserves	GRAPH(TIME) Points: (2016,000, 0,3), (2017,000, 0,45), (2018,000, 0,5), (2019,000, 0,5), (2020,000, 0,4), (2021,000, 0,3), (2022,000, 0,25), (2023,000, 0,3)	dmnl
historical_values_of_deposits	GRAPH(TIME) Points: (2016,000, 843296599991,0), (2017,000, 881004148157), (2018,000, 932295000000,0), (2019,000, 957002000000,0), (2020,000, 1074184000000,0), (2021,000, 1352618000000,0), (2022,000, 1510280000000,0), (2023,000, 1829536000000,0)	UAH
historical_values_of_DIR	GRAPH(TIME) Points: (2014,000, 17,24), (2015,000, 20,47), (2016,000, 20,93), (2017,000, 17,74), (2018,000, 14,33), (2019,000, 16,08), (2020,000, 15,18), (2021,000, 8,78), (2022,000, 8,98), (2023,000, 13,43)	%
historical_values_of_IIR	GRAPH(TIME) Points: (2014,000, 7,15), (2015,000, 15,57), (2016,000, 25,22), (2017,000, 17,36), (2018,000, 15,92), (2019,000, 19,22), (2020,000, 18,35), (2021,000, 7,89), (2022,000, 7,67), (2023,000, 19,8)	%
historical_values_of_LIR	GRAPH(TIME) Points: (2014,000, 14,1), (2015,000, 15,1), (2016,000, 17,5), (2017,000, 14,9), (2018,000, 15,8), (2019,000, 17,4), (2020,000, 14,9), (2021,000, 12,0), (2022,000, 12,9), (2023,000, 19,6)	%
historical_values_of_loans	GRAPH(TIME) Points: (2016,000, 1009768000000,0), (2017,000, 1005923000000,0), (2018,000, 1036745000000,0), (2019,000, 1118860000000,0), (2020,000, 1033430000000,0), (2021,000, 960597000000,0), (2022,000, 1065347000000,0), (2023,000, 1036129000000,0)	UAH
historical_values_of_reserves	GRAPH(TIME) Points: (2016,000, 321303000000,0), (2017,000, 484383000000,0), (2018,000, 511062000000,0), (2019,000, 556445000000,0), (2020,000, 492229000000,0), (2021,000, 388477000000,0), (2022,000, 308349000000,0), (2023,000, 368091000000,0)	UAH

Continuation of Table M.1

Variables	Equation	Units
indicated_deposits	(11,35-0,01*DIR-0,02*IEC.average_inflation_expectations-0,39*(Reserves)-1,11*(HD.Personal_Saving)+1,47*(HISTORY(Deposits; TIME-1)))	UAH
indicated_DIR	-11,7+0,65*HISTORY(DIR; TIME-1)+1,03*LIR	%
indicated_LIR	17,06+0,41*IIR-0,55*HISTORY(LIR; TIME-1)	%
initial_demand_of_loans	1009768000000,0	UAH
loans_reserves	Loans*fraction_of_loans_to_reserves	UAH
time_adj_of_deposits	1	year
time_adj_of_reserves	0,25	year
time_to_adj_loans	1	year
time_to_adjust_IIR	0,4	year
time_to_change_DIR	0,25	year
time_to_change_LIR	0,25	year
war_shock_on_LIR	IF TIME > 2022 THEN 10 ELSE 0	%/year

Source: made by the author based on the NBU`s data and articles and its future assumptions