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# Магістерська робота

ОСВІТНІЙ СТУПІНЬ - МАГІСТР

на тему: «**МОНЕТАРНА ПОЛІТИКА НБУ В УМОВАХ ЕКОНОМІЧНОЇ НЕСТАБІЛЬНОСТІ / MONETARY POLICY OF THE NBU IN CONDITIONS OF ECONOMIC INSTABILITY**»

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з оцінкою «_____»

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# CONTENT

# INTRODUCTION

**Relevance of the topic.** For over three decades of independence, the Ukrainian economy went through numerous challenges, which caused instability, inflation, currency devaluation, and many other economic downturns. In this volatile environment, the significance of the role of the central bank cannot be overstated. The National Bank of Ukraine, as the main authority responsible for the monetary policy in the country, plays a crucial role in navigating the Ukrainian economy through the instability complexities. The NBU`s effective management of monetary policy in challenging conditions not only impacts the day-to-day lives of citizens of the country but also significantly affects the long-term economic prospects of the country as a whole, financial resilience, and positioning in the international arena. Monetary policy is an essential element of national security in general, which affects social, environmental, and other aspects of society's life.

A significant contribution to the study of monetary policy was made both by Ukrainian and Western scientists, in particular, the analysis of the monetary policy is presented in the works of R. Prymostki, N. Versal, V. Mishchenko, A. Somyk, S. Nikolaychuk, S. Fridman, M. Skrypnychenko, N. Slav'yuk, S. Glushchenko, Yu. Horodnichenko, O. Koibon, G. Simola, and others. Despite the numerous existing scientific research, analysis of the conduct of monetary policy in economic instability, particularly the application of its instruments, becomes particularly relevant due to the government`s urgent need to stabilize the macroeconomic and financial situation, due to the negative impact of the crisis caused by the full-scale war. Fundamental and complex analysis of the monetary policy during economic instability is an important component for the successful implementation of monetary decisions and avoiding mistakes in extremely difficult conditions during the war.

**The purpose** of the study is to conduct research on the effectiveness of the monetary policy of the NBU during economic instability, macroeconomic analysis of the monetary policy outcomes, and identify the main changes due to the military invasion of the Ukrainian territory.

**The object** of study is the monetary policy of the NBU.

**The subject** of study is the management of the monetary policy of the NBU during economic instability.

**The tasks** of the study are to:

- To analyze the theoretical aspects of conducting monetary policy in Ukraine and other countries under conditions of economic instability.
- To identify the impact of the economic instability of the monetary policy of NBU.
- To analyze the outcomes from the utilization of the monetary instruments by the NBU during the economic instability.
- To identify the main changes and challenges for the monetary policy in Ukraine in the condition of the uncertainty.
- To determine effective monetary instruments in conditions of economic instability with the help of the developed system-dynamic macroeconomic model of Ukraine and the econometric models.
- To generate the short-term forecast for inflation, exchange rate, and other key economic indicators.
- To provide recommendations for the improvement of the monetary policy of the NBU during economic instability.

**The research methods** used for this study are statistical analysis for the monetary policy outcomes overview, econometrics analysis with the use of ARIMA and VECM modeling method for analysis of the main economic indicators and forecasting the key policy rate and exchange rate, and system dynamics approach for analysis of the feedback structure of the economic environment in Ukraine and policy implementation. The system's approach includes alternative scenario analysis.

**The information base** of the study consists of the Constitution of Ukraine, the laws of Ukraine, regulatory acts of the Cabinet of Ministers of Ukraine, resolutions and statistical materials of the National Bank of Ukraine, the Ministry of Finance of Ukraine, the State Statistics Service of Ukraine, the National Commission for Securities and the Stock Market, the results of scientific research of foreign and

domestic scientists on monetary policy, Internet resources.

**The scientific novelty** of the research results is covered in an attempt to expand the known theoretical base regarding the monetary policy structure and used instruments in economic instability, determining the strengths and weaknesses of the current monetary policy directions. With the use of system dynamic and econometric modeling methods, research was conducted on the effect of the instability in the economic environment on the effectiveness of the monetary policy instruments.

Based on the analysis results, the problems and inefficiencies in the current NBU monetary policy were revealed, which poses a risk to the economic environment in Ukraine. Furthermore, with the use of the econometric ARIMA modeling methods and the Taylor rule was defined the effective key policy rate for the 2024 year and proposed the directions for exchange rate management. To decrease risks were developed recommendations on improving the current monetary policy instruments and NBU performance in general.

**The structure** of the paper consists of an introduction, 3 chapter, conclusions, references, and annexes. The first chapter discusses the theoretical and methodological basis for studying the monetary policy of the National Bank of Ukraine and economic instability, with an overview of the development and adaptation of the monetary policy system in Ukraine during its independence through various challenges.

The second chapter contains the research with the use of system-dynamic, statistical, and econometric instruments about the effect of the conditions in the macroeconomic environment on the effectiveness of the monetary policy implementation and its results.

The third chapter presents the risks and problems of the current monetary policy and, the foreign experience of the monetary policy implementation in the economic instability. Furthermore, the chapter contains the prospects for the implementation of the national monetary policy in the conditions of economic instability with a set of recommendations for the future directions of the monetary policy.

# CHAPTER 1. THEORETICAL AND METHODOLOGICAL BASIS FOR STUDYING THE MONETARY POLICY OF THE NATIONAL BANK OF UKRAINE AND ECONOMIC INSTABILITY

## 1.1 The monetary policy of the National Bank of Ukraine: essence and channels

In the modern world, countries are trying to succeed in economic development to provide favorable living conditions for their citizens and the country. The economy itself is a highly dynamic and complex system constantly influenced by the actions and behaviors of various economic players, including individuals, businesses, financial institutions, and government. The interactions and decisions these players make contribute to the overall dynamism and, at times, instability of the economy. It is essential to prevent high fluctuations in the economic environment, and one of the main roles of economic policy implementation with regulation purposes in Ukraine plays the central bank – the National Bank of Ukraine (hereinafter – NBU). From the international side, the International Monetary Fund defines a central bank as "an autonomous body that performs currency regulation functions and issues a country's currency" [48]. According to research by economists Kenneth Rogoff and Carmen Rinehart, the central bank is "an institution responsible for formulating and implementing monetary policy and ensuring financial stability." [9]. On the domestic level, Barida N.P. notes in his studies that "the Central Bank has become such a unique state regulator, which was entrusted with the performance of exclusive functions of regulating the economy and using the provided tools to fulfill tactical, intermediate, and long-term goals to ensure economic stability and sustainable development of the state's economy." [22].

In Ukraine, the Legal basis of activity of the NBU is defined in the Law "On the National Bank of Ukraine". According to the Legislation, "The National Bank of Ukraine is the central bank of Ukraine, a special central body of state administration, the legal status, tasks, functions, powers and principles of organization of which are

determined by the Constitution of Ukraine, this Law and other laws of Ukraine" [45]. The National Bank is an economically independent body that carries out expenses at the expense of its revenues, and in rare cases also at the expense of the State Budget of Ukraine. It is a legal entity with separate property, which is the object of state ownership. The National Bank is not responsible for the obligations of the authorities, and mutual responsibility between the National Bank and the authorities arises only for voluntarily assumed obligations. Furthermore, NBU and financial institutions are not responsible to each other for their obligations, except when such obligations are accepted voluntarily.

NBU plays a crucial role in managing and executing monetary policy in Ukraine. Monetary policy is important for stabilizing the economic environment in the country, providing a fundamental financial basis for stable socio-economic development of the country as a whole and each of its subjects. It determines the direction of regulation of money circulation, emission of monetary units, and control over the banking system, which affects inflation, credit conditions, and general financial stability. Monetary policy plays a significant role in ensuring the efficient operation of the monetary and financial sector and also affects various spheres of life of citizens and enterprises. By regulating the volume of money circulation and setting key interest rates, the central bank can influence inflationary processes, ensuring price stability and improving the economic situation in the country.

The NBU performs various functions and has three main goals (Figure 1.1.) aimed at ensuring the financial stability and economic development of the country:

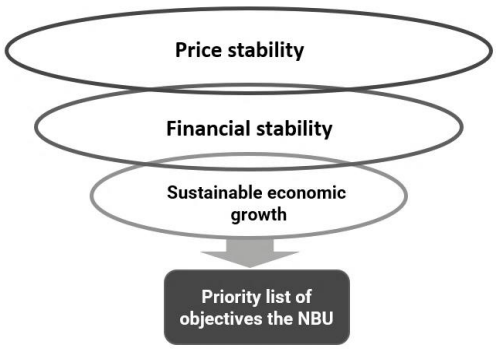


**Figure 1.1.** Priority list of objectives the NBU

*Source: made by the author based on data [45; 56; 57]*

1. Price stability. The legislation of Ukraine "On the National Bank of Ukraine" defines the priority of goals in the performance of the main function of the National Bank of Ukraine, which, according to the Constitution of Ukraine, consists in ensuring the stability of the national monetary unit. The main priority of monetary policy is to achieve and maintain price stability. The NBU defines price stability as “a situation when prices rise so insignificantly that citizens do not think about inflation when making credit decisions, investing in business, or saving” [56]. High inflation leads to a decrease in business, population, and state incomes, an increase in production costs, and an increase in the cost of loans and their servicing, which creates uncertainty about future prices. This hurts economic growth, as large fluctuations in inflation do not attract long-term investments. Therefore, it is important to create low and stable inflation for sustainable economic growth. The National Bank has an important role in this context. It directs its efforts to create an environment where inflation is not a cause of concern for households and businesses. This leads to the strengthening of confidence in the national currency, the growth of its use, and the preservation of the real value of incomes and savings of the population. Low nominal interest rates support investment activity and economic growth, and economic agents adequately assess risks and are prepared for exchange rate fluctuations.

2. Financial stability. According to the defined goals of NBU: “The NBU also promotes financial stability and sustainable economic growth unless it compromises the price stability objective” [56]. For the efficient functioning of the economy, central banks should pay attention not only to ensuring price stability but also to promoting financial stability. According to the legislation, the National Bank is given this very important goal as its second priority.

3. Sustainable economic growth. From the perspective of long-term development, the stability of the national currency is impossible without ensuring sustainable economic growth. Consequently, the third goal of the National Bank is to help maintain a steady rate of economic growth and support the Government's economic policy.

Thus, the effective monetary policy of the NBU is implemented thanks to the use of various instruments. It is important to consider that each of these instruments has its characteristics and affects different aspects of the economy.

**Table 1.1.** Main NBU monetary policy instruments

| *Advantages* | *Disadvantages* |
|---|---|
| Instrument: **Definition and regulation of mandatory reserve norms for banks**<br>Based on determining the mandatory amount of monetary assets that banks must keep in the central bank (percentage of client deposits the bank should keep as reserves). | |
| • ***Liquidity control:***<br>Allows the central bank to control the level of liquidity, contributing to the stability of the financial system.<br>• ***Regulation of Money Circulation:***<br>Affects money circulation, which can be a tool for managing inflation.<br>• ***Reduction of Banking System Risks:***<br>Reduces risks in the system, especially in case of unexpected outflows of deposits.<br>• ***Macroprudential Policy tool:***<br>Used to reduce risks in banking and stabilize the financial system. | • ***Lending restrictions:***<br>May limit banks' ability to lend, affecting economic growth and investment.<br>• ***Cost for Banks:***<br>This represents a cost to banks in the form of lost revenue, as these funds cannot be used to lend and generate profits.<br>• ***Distortion of Market Forces:***<br>This may lead to distortion of market forces as banks determine their activities according to established norms rather than actual demand.<br>• ***The instability of the Big Banks:***<br>An increase in reserves can lead to uneven exposure to different banks, especially large ones, which can contribute to their instability. |
| Instrument: **Interest policy**<br>Determines the level of interest rates in the financial system to influence money circulation, inflation, and economic growth. | |
| • ***Inflation Control:***<br>Changing interest rates allows the central bank to influence the level of inflation, restraining its increase or stimulating its decrease.<br>• ***Regulation of Economic Growth:***<br>Interest rate policy can stimulate or reduce economic growth. Lower rates encourage lending and investment, while higher rates can dampen economic activity.<br>• ***Liquidity Management:***<br>Regulation of liquidity in the banking system through changes in interest rates affects the availability of money in the economy.<br>• ***Investment attractiveness:***<br>High interest rates make financial instruments more attractive to investors and capital savers. | • ***Detachment From Reality:***<br>Interest rate policies may not always accurately reflect economic conditions and risks.<br>• ***Can Rig Financial Markets:***<br>Constant changes in interest rates can cause fluctuations in financial markets and create instability.<br>• ***Dependence on the reaction of the markets:***<br>Interest rate policy decisions can depend on the reaction of markets and investors, creating unpredictable effects.<br>• ***Impact on Indebtedness:***<br>High rates can complicate the financial situation for debtors and consumers, making it difficult to manage the debt burden. |
| Instrument: **Refinancing of banks**<br>NBU delivers financial support to banks by providing them with additional liquidity or low-cost credit support. | |

Continuation of Table 1.1

| | |
|---|---|
| • ***Liquidity of the Banking System:***<br>Refinancing provides additional liquidity to banks, which contributes to their stability and ability to issue loans.<br>• ***Lending incentives:***<br>Can promote more active lending, which supports economic growth.<br>• ***Control of Interest Rates:***<br>• Can influence market interest rates through refinancing conditions and regulating the cost of loans and investments. | • ***Unequal Impact:***<br>Refinancing may affect different banks and economic sectors differently, increasing the risk of inequality.<br>• ***Potential Addiction:***<br>Dependence on refinancing can reduce banks' incentives to independently raise resources and manage liquidity.<br>• ***Can Create Excessive Liquidity:***<br>• Excessive refinancing can lead to an increase in the total amount of liquidity in the system, potentially causing other problems. |
| *Advantages* | *Disadvantages* |
| Instrument: **Currency interventions** — The interventions of the central bank in the foreign exchange market influence the value of the national currency. | |
| • ***Stabilization of the Exchange Rate:***<br>Currency interventions can help maintain a stable exchange rate.<br>• ***Export Competitiveness:***<br>Can be used to support export competitiveness by influencing the value of the currency.<br>• ***Inflation Control:***<br>Can affect inflationary pressures, especially when a cheaper currency leads to higher import prices.<br>• ***Foreign Trade Support:***<br>Foreign exchange interventions can stimulate exports and support foreign trade. | • ***May Lead to Currency Wars:***<br>Can cause tension in international relations and lead to currency wars between countries.<br>• ***Inefficiency in the Long-Term Perspective:***<br>In the long run, currency interventions may be ineffective in addressing structural imbalances.<br>• ***Risk of Loss of Reserves:***<br>May lead to a loss of reserves, which may be difficult to replace.<br>• ***Distortion of International Trade:***<br>Can lead to distortion of international trade and violation of free market principles. |
| Instrument: **Securities transactions —** The active actions of the central bank to buy and sell securities on the secondary market. | |
| • ***Bank Liquidity Control:***<br>Open market operations allow the central bank to influence the level of liquidity in the banking system.<br>• ***Regulation of Interest Rates:***<br>Changing the volume of operations can affect the level of interest rates.<br>• ***Cash Flow Management:***<br>Open market operations are an effective tool for controlling money circulation in the economy.<br>• ***Stimulation of Economic Growth:***<br>Lower interest rates through transactions can encourage lending and investment, which spurs economic growth. | • ***Risk of Adverse Effects:***<br>The wrong intervention can lead to adverse effects on the financial market and the economy.<br>• ***May Promote Blistering:***<br>Too active transactions can create conditions for the formation of financial bubbles and instability.<br>• ***Limited Efficiency At Low-Interest Rates***:<br>In short-term conditions, operations may have a limited impact on the economy and stimulate lending.<br>• ***Possibility of Inflation Growth:***<br>A too-active reduction of interest rates can lead to an increase in inflationary pressures.<br>• ***Negative Impact on Financial Institutions:***<br>Low-interest rates can hurt the profitability of financial institutions. |

Continuation of Table 1.1

| Instrument: **Issue of own debt obligations** — This instrument is based on the issuance and sale by the central bank of its debt securities. | |
|---|---|
| • ***Flexibility:***<br>A central bank can use different types of debt obligations to achieve different goals.<br>• ***Effectiveness:***<br>Debt issuance can be a more effective tool than other monetary policy tools, such as changing reserve requirements or interest rates.<br>• ***Transparency:***<br>• Debt issuance is a more transparent instrument than other monetary policy instruments. | • ***Risks:***<br>Debt issuance can be risky, leading to losses for the central bank.<br>• ***Market impact:***<br>• The issue of debt obligations can have a significant impact on the securities market. |

*Source: made by author based on data [45;29]*

In addition, monetary policy also includes other strategies and tools to ensure the stability of prices, the financial system, and the health of the economy as a whole. For example, NBU sets interest rates and regularly adjusts them to reflect inflation and the credit market. Furthermore, the central bank can determine the regulating rules for credit institutions, control money circulation, and carry out international currency operations to maintain stability in the exchange market. This comprehensive approach allows the NBU to adapt its strategy to changes in the financial environment and contribute to the effective functioning of the national economy.

In conclusion, the NBU is an important player in the Ukrainian economic system for conducting monetary policy to protect the stability and development of the country`s economy. The NBU works independently within the legislation framework and focuses on three key processes: price stability, financial stability, and sustainable economic growth. The NBU aims to maintain low and stable inflation, keeping confidence in the national currency and preserving the real value of incomes and savings. NBU builds strategies to manage liquidity, regulate money circulation, and ensure the financial system's stability through various monetary policy instruments, such as defining mandatory reserve norms, interest rate policies, and currency interventions. In general, the adaptive and comprehensive monetary policy of the National Bank of Ukraine contributes to economic stability, sustainable growth, and financial resilience in the country.

## 1.2. Development of the monetary policy of NBU through the period of independence

After gaining independence in 1991, Ukraine entered a new stage of development, actively building its economy. Changes in the political sphere with the need to form a market economy required the development of new methods of economic management and the creation of effective institutions and infrastructure. Uncertainty and lack of experience made this process difficult and caused numerous problems. During the period of transformation, the Ukrainian economy encountered mistakes and difficulties that arose as a result of both objective circumstances and subjective mistakes. One of the important tasks was the creation of the monetary sector, which was the responsibility of the NBU. The National Bank was responsible for ensuring the effective influence of monetary policy, using its tools and controlling the activities of economic entities in the monetary sector with the main goal to achieve economic growth in the country, which required solving several challenges and obstacles on the way to stability (Figure 1.2.).

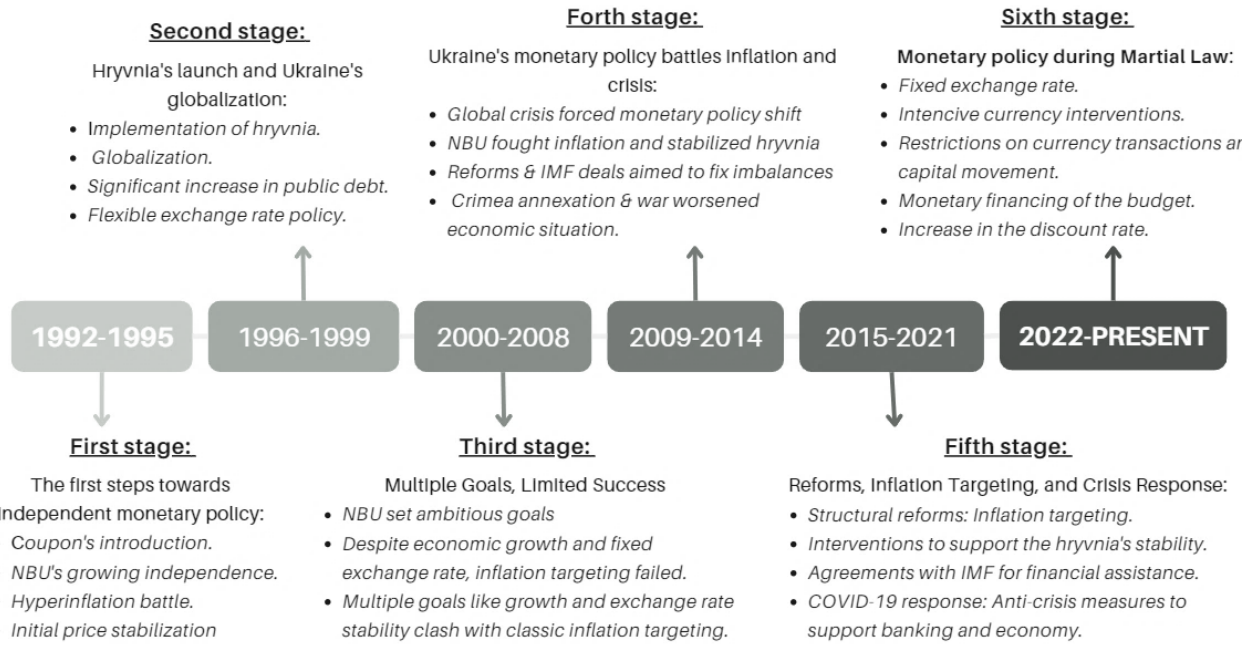


**Figure 1.2.** Phases in the evolution of Ukraine's monetary policy.

*Source: made by the author based on data [3, 26, 30, 35, 36, 47, 54]*

The Ukrainian monetary system went through several stages of development during the years of independence. The period of 1991-1992 was *a preparatory stage*

of this long way. At that time, Ukraine stayed under the influence of command-administrative management methods, which limited its ways of managing the monetary and credit system. Ukraine did not have its currency and was significantly dependent on russian rubles. Also, during this period, coupons were implemented, they circulated together with rubles in cash circulation, aimed at formalizing Ukraine's exit from the ruble zone.

The years 1992-1995 belonged to the *first stage* of independent monetary policy in Ukraine, this period began with the introduction of the Ukrainian coupon-karbovants (coupon) into circulation. For the next four and a half years, this coupon was the country's main payment instrument. The NBU gradually gained independence in its actions, using the experience of Germany and facing the task of curbing hyperinflation, which reached 10,000% per year. Key events and reforms took place during this period, for example, the fixed exchange rate, the definition of the main functions of the foreign exchange market, and the role of the NBU in the economy. In 1995, the National Bank abandoned preferential lending to the Government, the securities market began to function, and the budget deficit was financed through domestic state loan bonds (OVDP). Also, 1995 can be called as the beginning of price stabilization, where the consumer price index dropped to 282%.

The *second stage* of the development of the monetary and credit system of Ukraine was in the period from 1996 to 1999, key events took place, starting with the monetary reform in 1996, which led to the introduction of its national currency - the hryvnia. The reform was soft, it did not involve a radical change in the country's monetary system but only consisted of the denomination (the denomination of money decreased by five orders of magnitude) and a name change. The NBU successfully fulfilled its main task, it provided the country with stability in the monetary sector. From 1996 to 1999, Ukraine faced globalization for the first time, recognizing the underestimation of its place in the world economy. The financial crisis in 1998 and fluctuations in global demand were a clear signal of the need for adaptation. The country counted on the possible “easy” loans and the emission of hryvnia, but these illusions were dispelled. A consequence of inefficient financial policy was a significant increase in public debt. The pivotal point of monetary policy was the exchange rate, in

particular the regime of currency corridors, which were revised regularly, switching to a floating regime in 2000.

The *third stage* of monetary policy development in Ukraine (2000-2008) defined new tasks and priorities for the NBU. Among the goals set were the transition to the regime of direct inflation targeting, support of economic growth, ensuring the stability of the exchange rate, and the transition to full convertibility of the national currency. Unfortunately, not all planned tasks were completed. Even with the positive economic growth of Ukraine and the fixation of the exchange rate, the NBU failed to implement the inflation-targeting policy. The key aspect of monetary policy is avoiding the simultaneous achievement of several goals, because inflation targeting, according to the classic version, is incompatible with targeting the exchange rate and GDP growth rates.

In the *fourth stage*, in the period from 2009 to 2014, Ukraine faced significant economic challenges, which required a transformation of monetary policy. As a result of the global financial crisis of 2008, the NBU took numerous measures to stabilize the economy. During this period, central banks faced the challenges of high inflation, exchange rate instability, and fiscal pressure. The global economic crisis has significantly affected Ukraine, in particular its foreign trade, the stability of the national currency, and general economic indicators. One of the key features of monetary policy during this period was the focus on inflation targeting. NBU took measures to curb inflationary pressures and ensure price stability. Another important element was currency policy, which included interventions in the foreign exchange market to support the national currency - the hryvnia. In addition, monetary decisions included structural reforms and cooperation with international financial institutions, which played an important role in economic stabilization. Ukraine concluded agreements with the International Monetary Fund (IMF) to eliminate economic imbalances and implement the necessary reforms. Despite these efforts, the country has faced serious economic and political challenges, including russia's annexation of Crimea in 2014 and the war in eastern Ukraine. These geopolitical factors have significantly complicated the economic situation, which affected international trade, investor confidence, and overall economic stability.

In the period from 2015 to 2021, Ukraine was experiencing its *fifth stage* and continued to struggle with the consequences of the war on the east, implement the necessary economic reforms, and withstand external pressure. The NBU actively implemented various measures to overcome these problems. One of the main tasks during this period was to continue the structural reforms aimed at stabilizing the economy and stimulating sustainable growth. To achieve the goal of ensuring price stability, the NBU introduced an inflation-targeting regime in 2015, which was defined as follows: "The essence of the inflation targeting regime lies in the public announcement of quantitative targets for inflation and the central bank's commitment to reach them over the medium term. Monetary policy decisions rely on the inflation forecast. The interest rate is the main monetary tool and operational benchmark under this monetary regime. If the inflation forecast is above the target, a monetary policy tightening is applied to restrain inflation – that is, the interest rate is raised. And vice versa, if the inflation forecast is below the target, a monetary policy easing is used, which implies lowering the interest rate" [47]. The NBU de facto adopted inflation targeting in 2016, after extensive preparations to establish the necessary prerequisites for the implementation of this regime. The targeted inflation rate was slowly going to 5% (Figure 1.3).

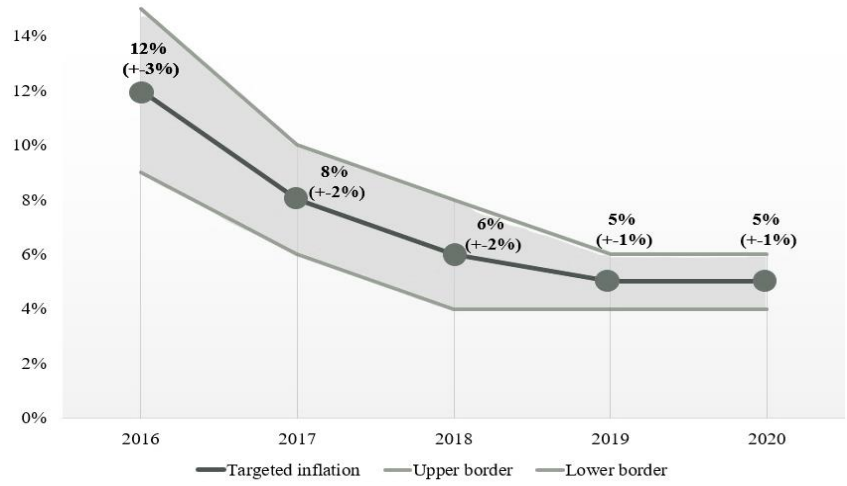


**Figure 1.3.** Quantitative inflation targets

*Source: made by the author based on data [47;54]*

Exchange rate policy was an important component of the monetary policy at that time, which included interventions in the foreign exchange market to ensure the stability of the national currency, the hryvnia. During this period, Ukraine continued

to seek international support and concluded agreements with the IMF. These agreements aimed to correct economic imbalances, provide financial assistance, and support the implementation of necessary reforms. COVID-19 has a huge impact on the economy of the country as well. During the quarantine, the NBU promptly took measures to reduce the negative effects of the pandemic on the financial and credit sectors and the economy of Ukraine in general. A wide range of anti-crisis measures aimed directly at supporting the banking sector.

In 2022, Ukraine's economy experienced a full-scale invasion shock, which opened the *sixth stage* of the development of Ukraine's monetary policy. The NBU took decisive measures to stabilize the economy after the start of a full-scale war with russia. The NBU's monetary policy played an important role in fighting inflation and supporting the hryvnia value. More about monetary policy during Martial Law will be discussed in the following chapter.

In summary, since gaining independence in 1991 Ukraine's path went through dynamic economic development, shaped by political changes. The transition period faced uncertainty and various mistakes and difficulties caused by economic crises, pandemics, and war. The evolution of the monetary policy of Ukraine can be divided into several stages, each of which corresponds to separate economic and geopolitical conditions. Key components of the monetary policy development history are the introduction of the hryvnia in 1996, attempts at inflation targeting reform from 2000 to 2008, challenges related to the global financial crisis from 2009 to 2014, and the adoption of inflation targeting in 2015. The long struggle with geopolitical events, economic reforms, and external pressure lasted from 2015 to 2021, when the National Bank of Ukraine actively implemented measures, in particular, the inflation targeting regime. The impact of COVID-19 added another level of complexity, requiring rapid response and active support of NBU. The start of the full-scale invasion in 2022 initiated a new phase, which necessitated decisive measures by the National Bank of Ukraine to stabilize the economy in wartime conditions. During these stages, Ukraine has demonstrated resilience and the ability to adapt and eliminate economic disbalances.

## 1.3. Structural changes in monetary policy in light of the economic instability

For the 32 years of its independence, Ukraine faced many challenges in its history, which affected its political and economic environment, and in particular – the monetary policy of the country. The National Bank of Ukraine during all of these challenges had to learn one highly important ability – being flexible and adaptive to constant changes in the environment.

With gaining independence in 1991 the National Bank had to transform the monetary policy from the former Soviet Union's framework to that of a sovereign and independent country. The first task was highly challenging - replacing the ruble with a brand-new currency - hryvnia, establishing trust in its value, and taming rampant inflation inherited from the Soviet system. But NBU rose to the occasion, they not just simply replicated existing models, they forged their path, learning from international best practices while tailoring them to Ukraine's unique circumstances. Before, 2015 hyperinflation, political instability, and global financial crises were challenging NBU again and again, but despite these events central bank managed to prepare the ground for the new structural change in the monetary policy of Ukraine. In light of these challenges, the NBU implemented the inflation-targeting regime for several reasons:

- *Stabilizing Prices:* Lowering uncontrolled inflation and fixing inflation expectations were important for building public confidence and promoting economic growth.
- *Enhanced Transparency and Credibility:* This framework provided a clear commitment to price stability, signaling discipline and attracting investments.
- *Integration with Global Markets:* Adopting a widely recognized regime helped smoother integration into the global financial system.
- *Promoting Long-Term Growth:* Stable prices contribute to a predictable environment for businesses to invest and flourish, driving economic expansion.

Implementation of the inflation-targeting regime was the right direction in the monetary system of Ukraine, but the process did not go smoothly. The imbalance of the policy of the National Bank of Ukraine is caused by the selective application of monetary instruments, insufficiently active activities of the NBU Board to restore

lending and stimulate economic activity, as well as the prevailing concentration on inflation targets with insufficient attention to maintaining sustainable rates of economic growth. The coordination of policies was complicated by a lack of coordination with the Government, leading to the inefficiency of macroeconomic indicators and the lack of a joint response to the crisis of public finances.

From 24th February 2022 Ukrainian financial system experienced a new challenge – a full-scale invasion, which put new pressure on the work of the National Bank of Ukraine. The war, an unexpected event, posed a threat to the entire economic system as the usual regulations ceased to be effective. However, plan B was already developed by the central bank and was waiting to be implemented in case of emergency. The bombing of Ukraine began at 4 am, and at 9:52 am the NBU has already published a list of measures implemented to ensure financial stability. The document contained the following key points:

- All the banks have to continue working and provide for clients free access to the safe deposit boxes;
- The NBU carries out blank refinancing of banks;
- ATMs are replenished with cash without restrictions and the NBU carries out replenishment with cash without restrictions;
- Suspend the work of the currency market of Ukraine;
- Record the course to the official;
- Limit cash withdrawals to 100,000 per day;
- Prohibit the issuance of cash in foreign currency.

Mentioned actions are necessary to ensure the reliable and stable functioning of the country's financial system, maximum support of the Armed Forces of Ukraine, and uninterrupted operation of critical infrastructure facilities. On April 15$^{th}$ 2022 NBU approved “Basic Principles of Monetary and credit policy during the period of Martial Law”, which defines the fundamental rules for the functioning of the banking system during the war. New rules brought fundamental changes to the functioning of the monetary system of Ukraine (Figure 1.4.).

| Peacetime | Martial law |
|---|---|
| Key policy rate - **main** instrument | Key policy rate - **additional** instrument |
| Prospective nature of monetary policy decision-making | Response to a rapidly changing environment |
| **Floating** exchange rate regime | **Fixed** exchange rate regime |
| **Smoothing** of exchange rate fluctuations with the help of currency interventions | Currency interventions as the **main monetary operation** |
| The course for the **abolition of currency restrictions** and the liberalization of capital movement | **Restrictions on foreign exchange transactions** and capital movements to maintain exchange rate fixation |
| **Ban** on monetary financing of the budget | **Monetary financing** of the budget |

**Figure 1.4.** Comparison of the ensuring price stability during peace time and martial law

*Source: made by the author based on data [43;44]*

Since the start of the full-scale invasion, the National Bank has announced that it remains committed to the inflation-targeting regime going forward. At the same time, under high uncertainty and in extreme conditions, the NBU forcibly introduced administrative restrictions, in particular on the foreign exchange market. In the conditions when the economy was collapsing and uncertainty and financial risks were growing, market monetary instruments, in particular the key policy rate, could not play a significant role in the functioning of monetary and currency markets. Therefore, the fixing of the exchange rate by the National Bank made it possible to avoid uncertainty for the population and business and to keep devaluation and inflationary expectations under control. The exchange rate became a price stabilizer or "nominal anchor" for the entire economy and prevented excessive inflation, which could further destabilize the macroeconomic situation. The exchange rate was fixed with the help of the NBU's interventions on the sale of currency and the establishment of administrative restrictions on currency transactions and capital movements.

In the context of martial law, the NBU gained a temporary opportunity to support

the state budget through active participation in the primary market of government securities. It is important to note that financing is provided exclusively for critical government expenditures and in limited amounts, which contributes to maintaining financial stability. The National Bank of Ukraine notes full transparency in its activities and informs the public about operations for the purchase of government securities. This is an important aspect that promotes openness and mutual understanding between the bank and the public. From July 2022, the amount of NBU OVDP redemptions was kept within the announced limits - up to 30 billion hryvnias per month. In general, during 2022, the NBU successfully implemented the purchase of military bonds of the government in the amount of 400 billion hryvnias, which testifies to the active role of the bank in financial support in the conditions of a military conflict.

From the beginning of the war until June, the NBU kept the key policy rate at 10%. Therefore, due to rising inflation, the real rate became increasingly negative, and uncertainty grew, which provoked an outflow of deposits, put pressure on the exchange rate, and generally increased the risk of financial destabilization. On June 2, the NBU increased the key policy rate to 25% at the same time expanding of the interest rate corridor from +/-1% to +/-2%. The purpose of such a sharp increase in the rate was an attempt to stop the outflow of deposits from the banking system and reduce the demand for foreign currency. On the other hand, this led to an increase in the price of loans for economic entities, increased the cost of servicing the debt, and in particular, what is important, for the Government. From the regulator's point of view, when this decision was made, the risk of financial destabilization looked much more threatening to the economy than the reduction of lending, which was not too active even in the period of low rates. From July 2023 NBU went in the direction of decreasing the key policy rate due to inflation stabilization and improving inflationary expectations, which will contribute to maintaining the attractiveness of hryvnia instruments for savings., and for the period July-December 2023 key policy rate decreased to 15%.

In 2021 NBU approved the Strategy 2025, which focused on creating maximum value for clients, which contributes to the modern development of the regulator of the financial sector of Ukraine, but due to russian invasion on the Ukrainian territory in 2023 NBU discontinued the Strategy 2025. During 2021–2022, the NBU’s overall

progressed in implementing its strategic goals on 56%.

The Strategy 2025 was replaced with the Strategy of softening currency restrictions, transition to greater flexibility of the exchange rate and return to inflation targeting (Figure 1.5.).

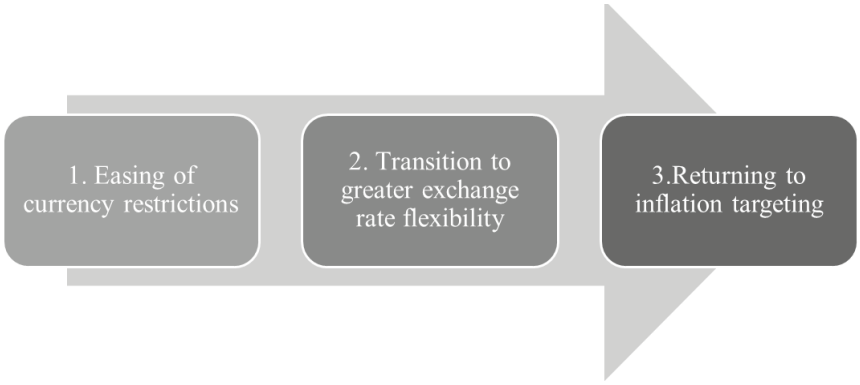


**Figure 1.5.** Key characteristics of the NBU Strategy to ease currency restrictions, move to greater exchange rate flexibility and return to inflation targeting

*Source: made by the author based on data [40]*

The first direction of the new Strategy is the easing of currency restrictions. This direction includes gradual easing, considering the impact on the exchange rate, reserves, and macroeconomic stability. This approach is not used as a substitute for macroeconomic adjustment and restrictions may be suspended or reintroduced in adverse circumstances.

On October 3, the NBU started implementing the second direction of the new Strategy and switched to a currency regime of managed flexibility, which means that the official exchange rate of the hryvnia will now be based on the exchange rate for operations on the interbank market, but not the setting by the central bank. The NBU will still be a key player in the foreign exchange market, actively monitoring the situation and compensating for the structural deficit of foreign currency. The hryvnia exchange rate will change based on the balance of demand and supply on the foreign exchange market, but the NBU plans to significantly limit exchange rate fluctuations through currency interventions, keeping it within limits that do not allow significant weakening of the hryvnia. Exchange rate stability will stay a priority task of the NBU, the new regime will strengthen the stability of the Ukrainian economy and the currency market, contribute to their better adaptation to internal and external shocks, and reduce the risks of accumulating currency imbalances that can generate long-term

maintenance of a fixed exchange rate.

To return to inflation targeting, the NBU has identified key steps for implementing this strategy. In the early stages, the NBU key policy rate will continue performing the role of a secondary instrument aimed to ensure the stability of the exchange rate regime and to protect international reserves. To strengthen monetary transmission and the attractiveness of hryvnia instruments, the NBU plans to make appropriate changes to the operational design of monetary policy, which will include the basic operations at the key policy rate with the return of a symmetric corridor of interest rates. This process will be synchronized with the key policy rate reduction cycle while keeping the attractiveness of hryvnia assets. In the next stage, inflation will assume the role of nominal anchor, and the key policy rate will gradually restore its position as the main monetary instrument. NBU plans to gradually restore the effectiveness of the monetary transmission and use the key policy rate to regulate the money market and macroeconomic indicators. The final stage of the strategy involves a return to inflation targeting, a floating exchange rate regime, and the appointment of the key policy rate as the main instrument of monetary policy. This transition is planned to be performed in close connection with the stages of softening of currency restrictions and transition to greater flexibility of the exchange rate, taking into account the support of the disinflationary trend and the improvement of inflationary expectations.

Thus, over its 32 years of independence, the National Bank of Ukraine went through numerous economic challenges, adapting its monetary policy to a dynamic environment. This journey included transitioning from the Soviet Union's monetary framework, introducing the hryvnia, fighting inflation, and conducting monetary policy during war times. In 2015 NBU adopted the inflation-targeting regime to stabilize prices, enhance transparency, integrate with global markets, and promote long-term growth. The full-scale invasion in 2022 pushed the NBU to implement emergency measures for financial stability, such as a fixed exchange rate, which served the role of a stabilizer during the crisis. Additionally, NBU temporarily supported the government budget during martial law while maintaining transparency in its operations. Strategic shifts were performed as well and included discontinuing the 2025 Strategy due to the russian invasion and adopting a new strategy focusing on

easing currency restrictions, flexible exchange rates, and a return to inflation targeting.

## Conclusions to Chapter 1

In today's global economy, to promote economic stability and sustainable development of the country is important to effectively implement monetary policy. In Ukraine National Bank of Ukraine is the key institution responsible for monetary and credit regulation, it plays a central role in shaping the country's economic environment and ensuring financial stability. NBU acts autonomously and independently in the formation and implementation of monetary policy within the defined legislative framework. According to the Law "On the National Bank of Ukraine", the NBU acts as a special central body, to which the tasks, functions, and powers are aimed to ensure the stability and development of the national economy.

The primary goal of the NBU is price stability, and monetary policy is aimed at maintaining a low and stable level of inflation. As a second goal, the NBU promote financial stability and supporting the government's economic policy. In addition, NBU follows the third goal, which is strengthening confidence in the national currency and preserving the real value of income and savings, in this way promoting economic stability and sustainable growth. To achieve the mentioned goals, NBU uses various monetary policy instruments. NBU uses a variety of tools to manage liquidity, regulate money circulation, and ensure the stability of the financial system, which can be from the regulation of banks' mandatory reserve requirements to interest rate policy, currency interventions, securities transactions, and debt issuance. Each tool has its advantages and disadvantages, requiring careful consideration to achieve desired policy results.

The evolution of Ukraine's monetary policy went through several stages, each of which is characterized by unique challenges and strategic priorities. NBU has demonstrated resilience and adaptability in its approach while moving through the challenging way of monetary policy development, from the first stage of establishing a sovereign currency and stabilizing hyperinflation to adopting inflation targeting and

dealing with the global financial crisis, COVID-19 pandemic, and war. The transition to inflation targeting in 2015 became fundamental in the structure of the monetary policy of Ukraine. However, the road to implementing this regime included many challenges, which included coordination with the government and managing inflationary expectations. The start of a full-scale war in 2022 became a significant challenge for the economy and monetary policy of Ukraine. NBU promptly introduced emergency measures to stabilize the financial system during the crisis by fixing the exchange rate and providing support to the government budget.

In conclusion, the development of the monetary policy of Ukraine during the last three decades reflects a complex interaction of internal and external factors, institutional reforms, and strategic adaptations. NBU continues to ensure stability, promote transparency, and promote the long-term prosperity of the people of Ukraine even through the numerous challenges. As the country continues to be in an uncertain economic and geopolitical environment, the NBU's ability to innovate, adapt and respond to new challenges will be critical to shaping Ukraine's economic future.

# CHAPTER 2. ANALYSIS OF THE EFFICIENCY OF MONETARY POLICY IMPLEMENTATION UNDER CONDITIONS OF ECONOMIC INSTABILITY

## 2.1. Analysis of the Ukrainian economic environment under different conditions with the use of the system-dynamic modeling instrument

Ukrainian economy was unstable during the whole period of independence, living through the economic crises and revolutions. But for the last 2 years, Ukraine has been facing a new challenge – full-scale war, which is putting extreme pressure on the country`s economy, and results in deep changes in economic elements. Every month hundreds of missiles fly into the Ukrainian sky bringing distractions and death and at the same time destabilizing the economy. Figure 2.1. shows the change in the main economic indicators with the start of the full-scale invasion.

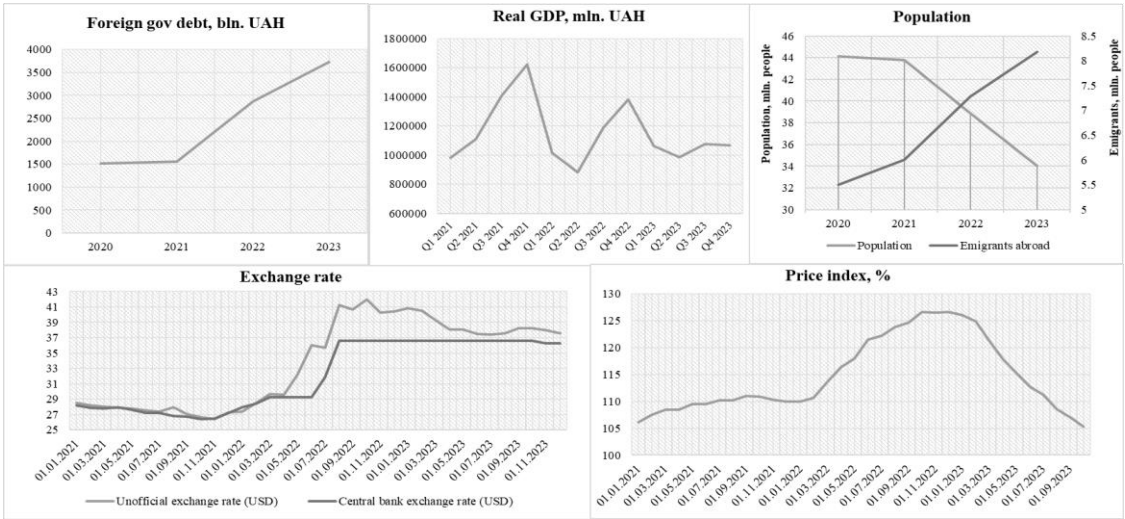


**Figure 2.1.** Macroeconomic indicators of the Ukrainian economic environment 2021 – 2023 period

*Source: made by the author based on data [49; 52]*

High inflation, significant decrease in GDP, increase in government debt and exchange rate, and emigration can be seen from the first sight. The government and the NBU are trying to smooth inflation growth using numerous instruments, but it’s a complex event, which contains a lot of factors. Furthermore, in February 2022 Central Bank fixed the exchange rate at a certain level and kept it with the use of the currency

reserves, while the real exchange rate started growing. The recent events within the Ukrainian economy highlighted the importance of investigating how the ongoing war influences it. This analysis aims to present a clear picture of how the full-scale invasion is impacting various aspects of Ukraine's economy, helping us understand its effects better. The Ukrainian economic system is a complex dynamic environment, which is highly impacted by the changes in the surrounding environment, that is why for research purposes was chosen system dynamics method for the development of an explanatory system dynamics model to understand and analyze complex systems over time. The created model allows to understand the dynamic behavior of the system and identify potential leverage points for intervention or policy development, which is crucial for monetary policy.

The development of the model was inspired by the work of David Wheat (2007) on modeling macroeconomics with system dynamics tools and quarterly reports of the NBU (2021-2023). Processing literature and reference mode description were summarized in the simplified causal loop diagram in Figure 2.2:

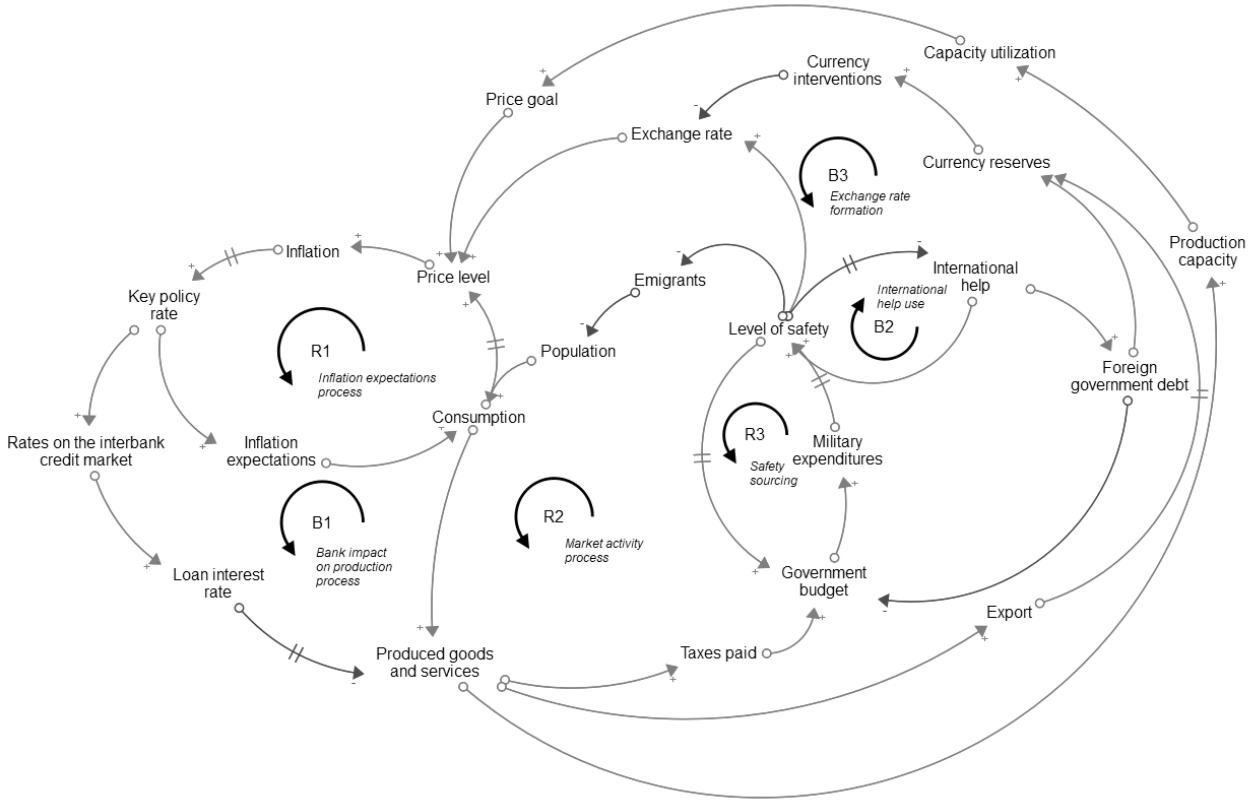


**Figure 2.2.** Causal Loop Diagram for key feedback mechanisms

*Source: made by the author on the basis of the software Stella Architect*

**Inflation expectations process (R1)**

Inflation expectations have an important influence on inflation. If people expect prices to rise in the future, they may begin to increase their spending, buying goods and services now, before prices rise. This can cause an increase in demand for goods, which in turn can lead to higher prices. To fight inflation Central Bank for certain periods decides to increase key policy rates, which can change the population's expectations about future inflation. For example, if a central bank raises the policy rate to control inflation, this may lead to the belief among citizens and businesses that the central bank is serious about fighting inflation. This can lead people to believe that inflation will be contained in the future, which in turn can reduce their expectations for price increases.

**Bank impact on production process (B1)**

Key policy rate - is one of the main instruments, which uses the National Bank of Ukraine, to manage inflation through the transmission channel. Banks set their interest rates based on this key policy rate, thereby impacting medium- and long-term interest rates that, in turn, influence production by altering the cost of business loans—higher loan costs typically result in reduced production with a certain delay for producers to perceive change. Production directly determines the available production capacity, enabling the calculation of capacity utilization. Utilizing this production capacity drives the price goal. The country's price level is targeted to align with the price goal, as a result, an increase in price goal increases the price level of the country.

**Market activity process (R2)**

The consumption signals for the producers how many goods and services they need to produce, consequently increase in consumption leads to increased production. All the producers during the production and distribution process have to pay taxes due to Ukrainian legislation, so as production increases, the amount of taxes paid increases as well. These funds bolster the government budget, consequently expanding its size. A larger budget allocation enables greater spending on military necessities, thereby increasing military expenditures. Increased investment in the military sector within a certain period enhances the country's defense capability, thereby increasing the level of safety.  A safer environment in the country convinces people to return home, which

increases the population of the country, which starts to consume more.

**Safety sourcing (R3)**

The amount of the expenditures for the country's functioning is defined by the size of the government budget, thereby bigger the budget, as more funds the government can provide for military expenditures, which, as was stated earlier, increases the level of safety. If the economy functions in an unsafe environment – it puts additional pressure on the government budget, consequently higher level of safety increases the government budget.

**International help use (B2)**

During a full-scale war, international help is extremely important for the safety of the country. All the received international help is used to buy more air defense, which increases the chances of destroying russian missiles, which increases the level of safety. The safety level within the country significantly influences the willingness of foreign countries to provide support: when a nation faces unsafe conditions, international partners tend to allocate more funds to aid the affected party, and otherwise.

**Exchange rate formation (B3)**

For this balancing loop, the first part of the connections corresponds to the “Inflation expectations (R1)” loop, but the consumption effect is shown for the produced goods and services, instead of the price level. As was mentioned in the “Market activity impact (R2)” loop, consumption increases production. Produced goods and services create a supply base for the export, so an increase in production increases the export. By selling goods and services abroad, suppliers bring currency to the country, which refills currency reserves. NBU uses currency reserves to decrease the exchange rate through currency interventions. Consequently, when a country's currency depreciates compared to a foreign one, it can lead to an increase in the price level of imported goods because now it takes more of the local currency to buy the same amount of foreign currency needed to purchase those goods.

SD model overview is shown in Annex A with separate model structures: Safety side, Foreign government debt side, Currency reserves side, Government budget side, Production side, Exchange rate side, Inflation expectations side, and Interbank side.

This model replicates a simplified version of the economic system of Ukraine and the impact of the war. To build confidence in the model and consequently, the simulation outcomes, were conducted validation tests aligned with Barlas's recommendations from 1996. The results of the model testing are presented in Annex B.

***Baseline simulation scenario: War in Ukraine with strong army support***

The first baseline simulation scenario represents current conditions in the Ukrainian environment, in particular, the full-scale invasion and since February 2022 approximately 60% of government expenditures and all international help are spent on military needs.

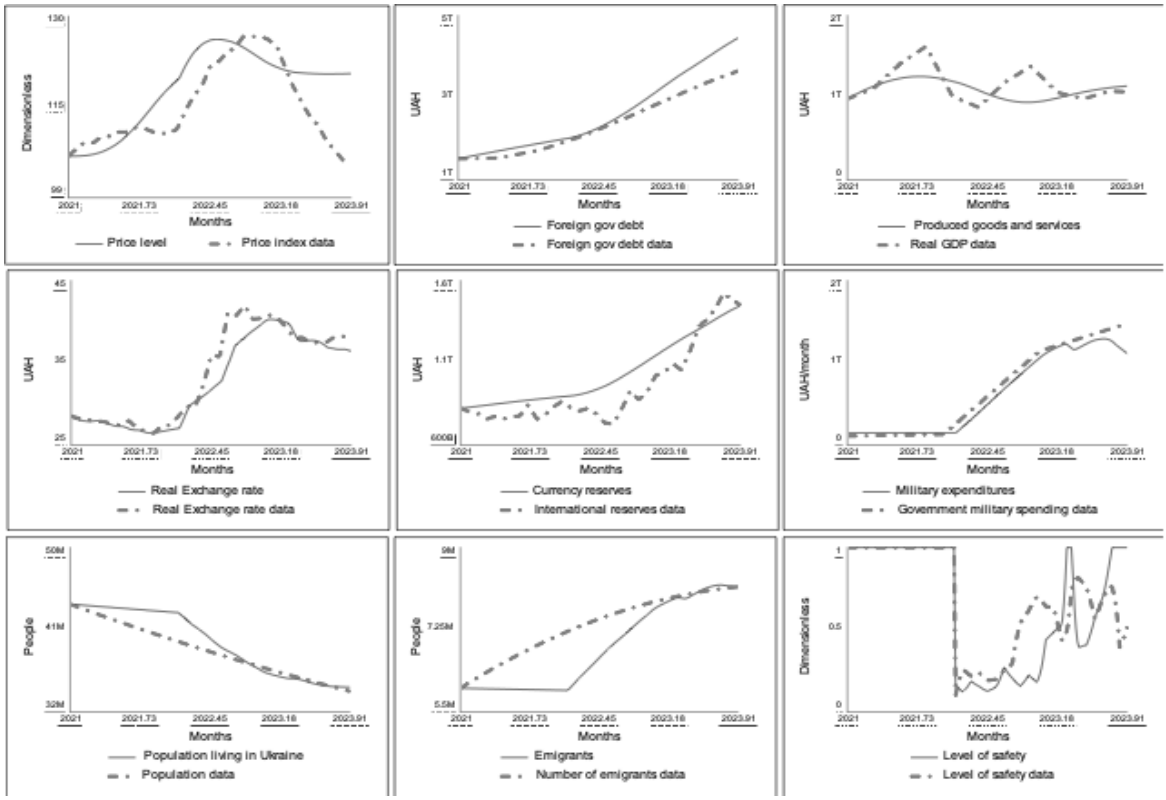


**Figure 2.3.** The behavior of key performance indicators under baseline-scenario

*Source: made by the author on the basis of the software Stella Architect*

Figure 2.3. shows the comparison of the historical behavior of the key performance indicators with the results of the simulation. Historical data replicated in the model relatively well, main trends are shown. All of the KPIs experienced changes because of the significant exogenous shock - the start of the full-scale invasion. Initially, the system was driven by the "Inflation expectation process" loop, which signalizes about the dominance of the standard process of price index formation in a stable environment. Consumers quickly reacted to inflation and changes in key policy rates, impacting the price level. At the same time, NBU was following an inflation-

targeting mechanism, adjusting key policy rates to effectively manage inflation. In the middle of 2021, the market started showing the outcome of the key policy rate change, the "Bank impact on production process" loop showed more impact, highlighting the importance of production for the price index formation. Additionally, the "Exchange rate formation" loop played a significant role, showing the successful efforts of the NBU to stabilize the national currency before the war.

The primary turning point became the start of the full-scale invasion in February 2022. The safety of the country started playing a priority role for the government, and the dominant role in the system started playing the loop of "Safety sourcing". During the war, the government prioritized citizen safety and territorial defense and allocated a significant amount of budgetary funds toward these goals. The war changed population behavior as well and resulted in increased consumption and currency purchases due to uncertainty. Moreover, with the start of the invasion, the NBU intervened in currency markets to stabilize exchange rates. As for the behavior of my main KPIs, we observe, that the Price Index, Foreign government debt, Real exchange rate, and Emigrants had exponential growth with the start of the war, this growth negatively affected on country’s functioning. However, by 2023, this growth will decelerate due to increased air defense capacity and the adaptation of the country's economy to wartime conditions.

***Deficient investment in air defense simulation scenario***

The second scenario were tested the condition of the economy when only 10% of military expenditures and international help were allocated to air defense. The results of the simulation are presented in Figure 2.4.

In the model air defense is the main instrument for providing safety in the country, which requires constant money support to renew and increase its capacity. However, when the level of funds allocated to military needs is minimal (10% in this case), it deeply affects the entire system after February 2022. Safety levels rapidly decline during the period of full-scale invasion, and stay close to 5%, which makes the environment completely unsafe. With a low level of safety, the number of people exponentially decreased from 45m to 8.5m people due to a higher death rate. Instability in the country caused constant high inflation (~30%), growth in the exchange rate (up

to 60 UAH/USD), and an increase in foreign government debt.

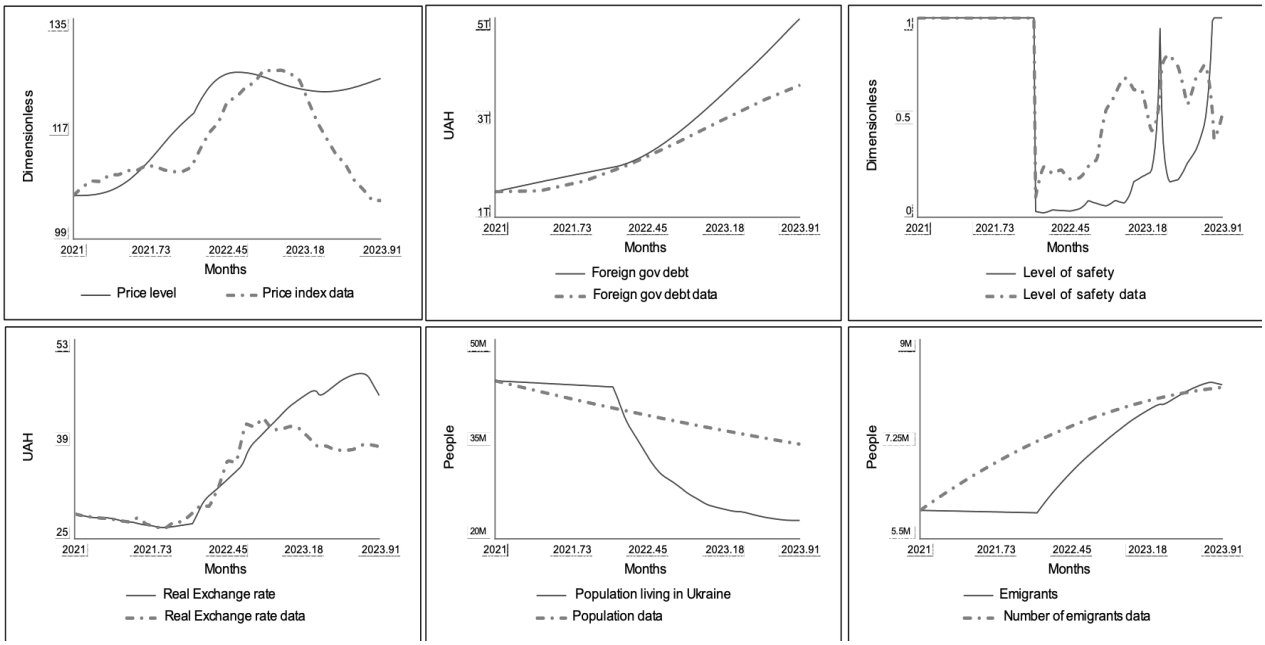


**Figure 2.4.** The behavior of key performance indicators under deficient investment in air defense simulation scenario

*Source: made by the author on the basis of the software Stella Architect*

***"If war didn`t happen" simulation scenario***

The third simulation scenario aims to show, how would the system of the Ukrainian economy function, if the war never happened. In this case, we assume, that no russian missiles flying in the Ukrainian sky, which represents no active war actions (Figure 2.5.).

We can see, that if russia did not invade Ukraine, the Ukrainian economy would have functioned in the same trajectory, as it was in 2021. Before February 2022 there was no difference in model behavior between the baseline and "If war didn`t happen" simulation scenario, although significant changes happened in the 2022-2023 period.

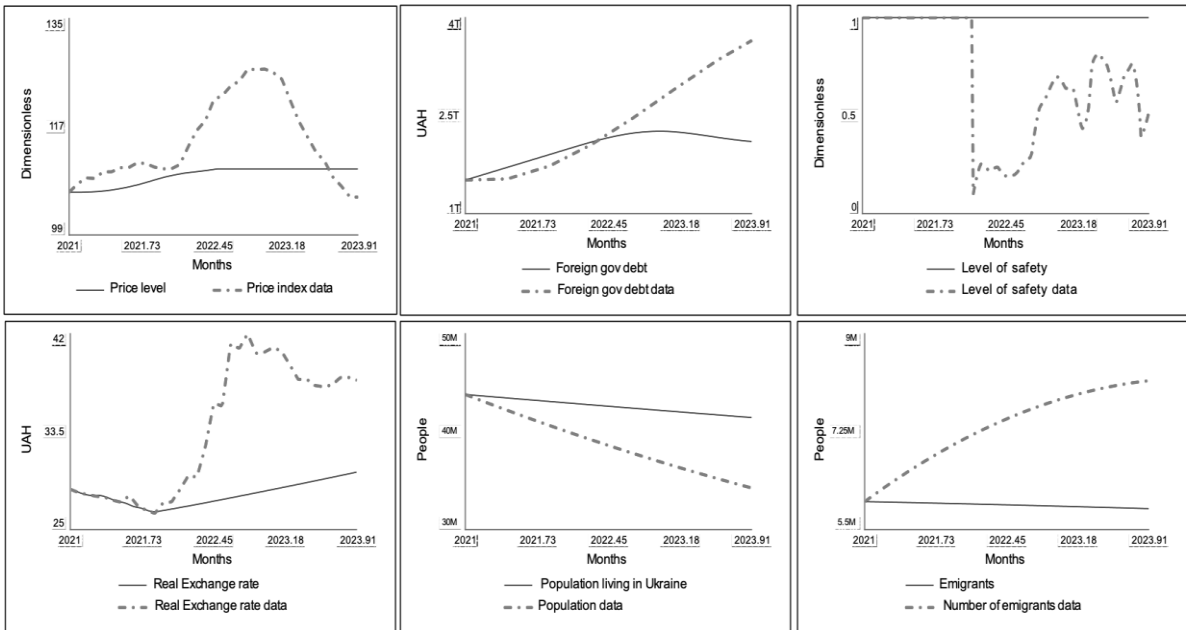


**Figure 2.5.** The behavior of key performance indicators under the “If war didn`t happen” simulation scenario

*Source: made by the author based on the software Stella Architect*

In a peaceful environment, loops related to safety considerations, such as "Market activity process," "Safety sourcing," and "International help use," become inactive, as there is no need for protective measures and safety does not directly impact economic indicators. The primary drivers remain the "Inflation expectations process" reinforcing loop and the "Bank impact on production process" balancing loop. In these conditions inflation would still be present in the Ukrainian economy and have a stable behavior, which is healthy for the economy, stable inflation works as a driver of market activity. As for the exchange rate, Ukrainian hryvnia would still slightly fall compared to the US dollar, but the national currency usually fluctuates, which is a variant of normal for Ukraine. Government debt would not significantly increase as well, which puts less pressure on the government budget. Big changes also occurred with country habitats. The Ukrainian population for the last decade had a negative net birth rate, consequently, this trend would remain the same, but without the dramatic drop, as it happened during the war.

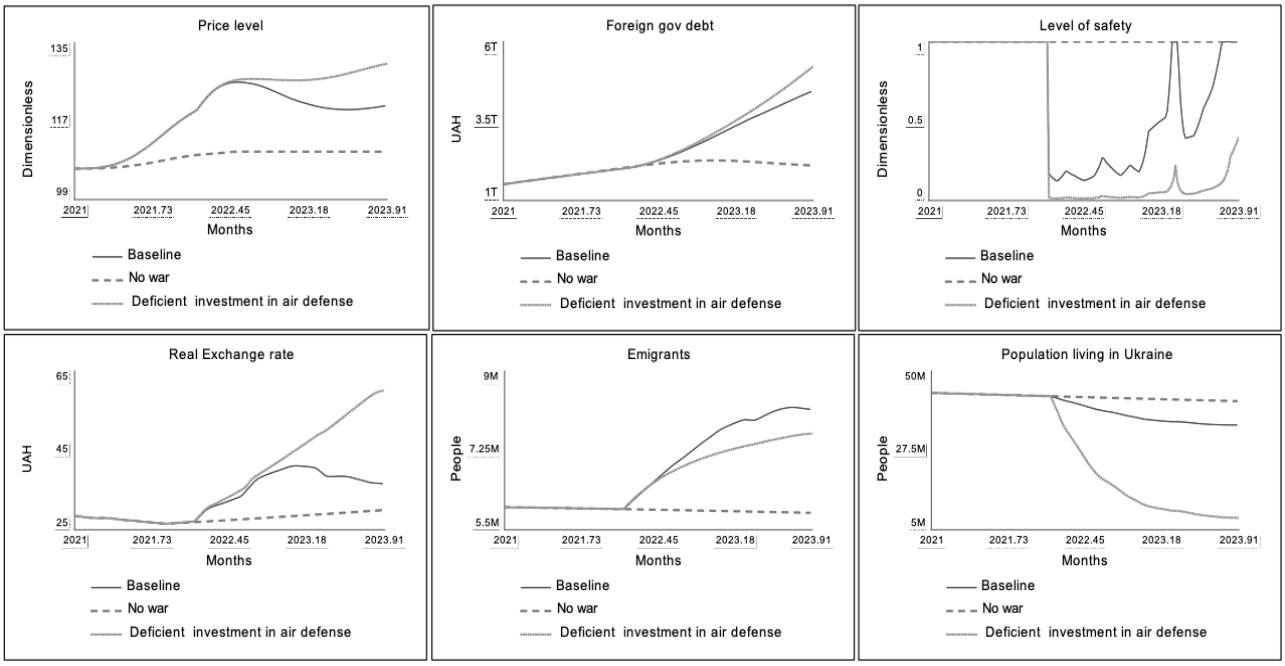


**Figure 2.6.** Comparison of the three presented simulation scenarios

*Source: made by the author based on the software Stella Architect*

All three scenarios show different system behaviors, their comparison is presented in Figure 2.6.

Conducted and described above analysis helped to understand the impact of the war in Ukraine on the functioning of the economic side of the country and its importance for the Government and Central Bank. War puts additional pressure on all economic elements, and results in devaluation of local currency, big government debt, high inflation, and the last one is especially hard affecting the population of the country. Consequently, ensuring safety becomes an important requirement for well-functioning the country's economy, and an effective defense mechanism is a fundamental element to guaranteeing this safety.

## 2.2. Evaluation of the effectiveness of monetary policy instruments of the NBU and its impact on the main key performance indicators

The start of the full-scale invasion of the territory of Ukraine fundamentally changes the economic environment of the country. The decrease in the effectiveness of market instruments and high uncertainty in the new conditions made it impossible to implement monetary policy in the traditional format of inflation targeting. The

central bank was forced to take several measures to ensure macroeconomic stability in Ukraine and prevent panic and the unfolding of an inflationary spiral in the conditions of a full-scale war. First of all, NBU fixed the exchange rate of the hryvnia to the US dollar and introduced various administrative restrictions regarding currency transactions and capital movements (more was discussed above in Chapter 1.3). All of the implemented by NBU changes and changes in the behavior of the main market players (population, businesses, foreign partners, etc.) were reflected in the outcomes of the main economic indicators.

The consequences of the start of the full-scale invasion were the disruption of supply chains, the reduction of the supply of certain goods, the increase in business costs, the physical damage to production facilities and infrastructure, as well as the temporary occupation of certain territories. High energy prices and record levels of inflation in partner countries also significantly increased price pressure in Ukraine, and as a result inflationary expectations of businesses and households increased significantly. This was reflected in the deterioration of the term structure of deposits in the banking system and the increase in costs for some durable goods, mostly imported. As a result, in 2022, consumer prices increased by 26.6% (Figure 2.7).

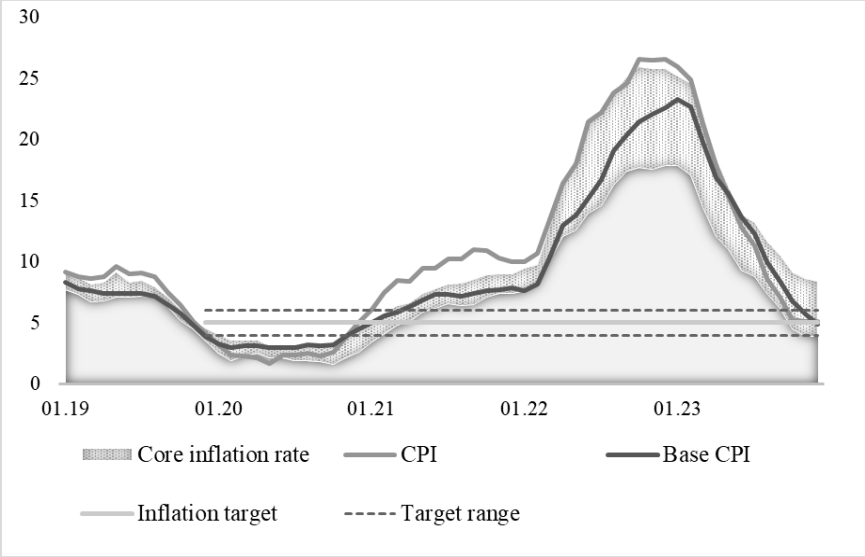


**Figure 2.7.** Consumer Price Index and estimates of the main inflationary trend

*Source: made by the author based on the data [53]*

The russian invasion of Ukraine at the end of February 2022 caused an accelerated increase in prices for most goods and services (Figure 2.8). This was the result of the destruction of supply chains, the destruction of corporate property, increased business

costs, and uneven population demand. In addition, military aggression caused an increase in pressure, which is felt not only in Ukraine but also in the context of global inflationary processes. But in 2023 economic environment started stabilizing and adapting to the stressful conditions, consequently, in January 2024 there was a slowdown in the rate of growth of food and non-food prices. The main factors of the rate reduction are the reduction of raw material costs, the restoration of production and logistics chains, the stable situation in the energy sector, as well as the improvement of inflation and exchange rate expectations from businesses and households.

With the help of a tight monetary policy at the beginning of the war, the coordinated actions of the NBU and the Ministry of Finance to activate the domestic borrowing market and reject issue financing made it possible to curb inflation. In the first half of the year, a steady positive trend of decreasing inflationary pressure in the economy was observed in Ukraine. In December 2023, the annual dynamics of consumer inflation indicators amounted to 5.1%, reaching the target range, compared to the initial indicator at the beginning of the year, which was 26%. These data on the actual dynamics of the slowdown in consumer inflation significantly exceeded the expectations of the government and market participants (Figure 2.8.).

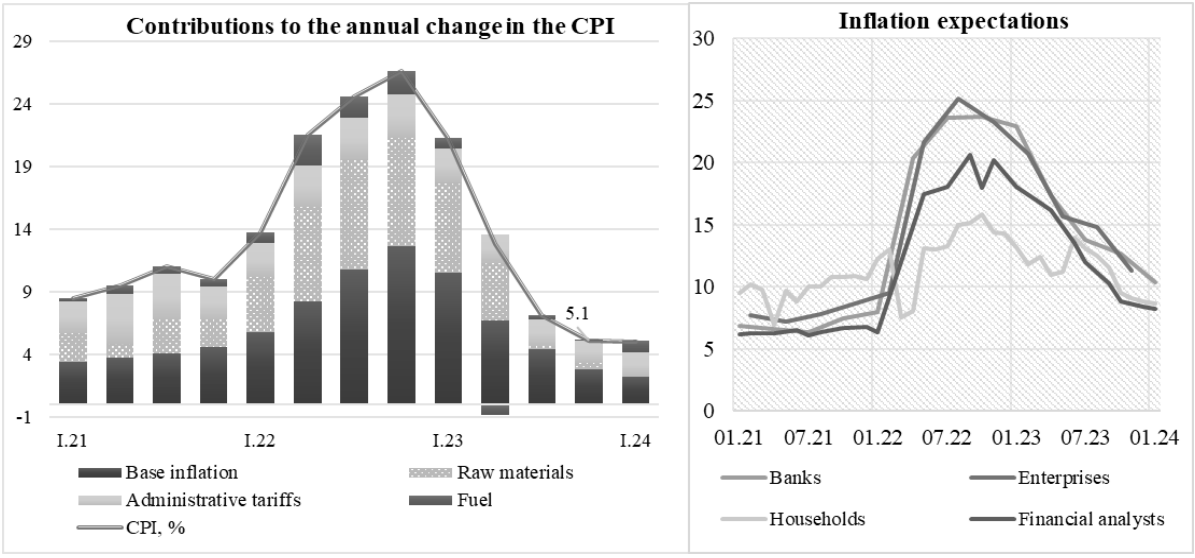


**Figure 2.8.** Contributions to the annual change in the CPI and inflation expectations

*Source: made by the author based on the data [53]*

The National Bank of Ukraine successfully managed inflation during the full-scale invasion by implementing measures such as the fixing of the exchange rate and

the use of currency interventions. Due to the decrease in the effectiveness of market instruments and the uncertainty caused by war, the exchange rate began to play the role of a nominal anchor to stabilize expectations, curb panic, control inflationary processes, and support the stable operation of banks. Currency interventions combined with restrictions on the movement of capital remained the most effective tools ensuring macro-financial stability since the beginning of the war. At the end of February 2022, the central bank fixed the dollar exchange rate at UAH 29.25 per dollar. But after 5 month of the full-scale invasion official exchange rate stopped replication the real market conditions, which caused a significant difference between the official and market exchange rates (up to 28,2%), which is presented in the Figure (2.9).

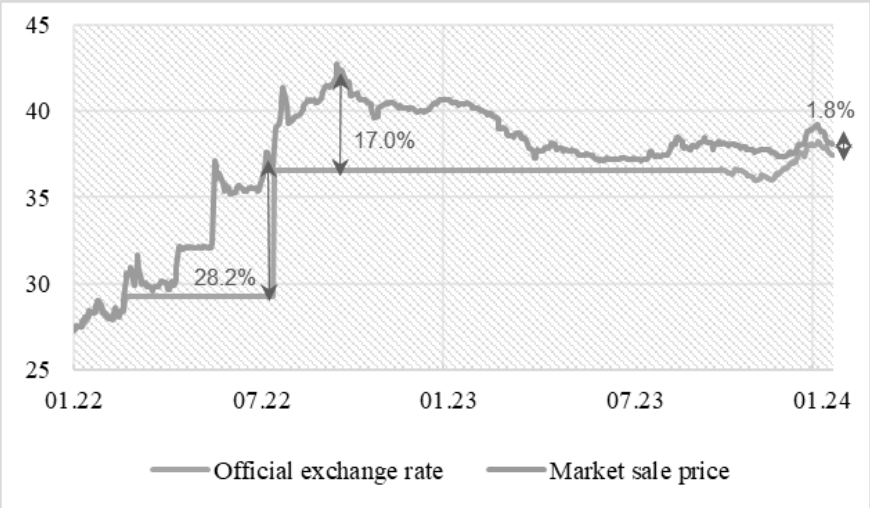


**Figure 2.9.** Official and market exchange rate UAH/USD

*Source: made by the author based on the data [55]*

NBU applies currency interventions to maintain the exchange rate at a fixed level, which leads to a reduction in international reserves (Figure 2.10). To bring the exchange rate closer to market one and decrease pressure on the currency reserves, in August 2022, a NBU decided to adjust the hryvnia exchange rate by 25% and fix it at a new level of 36.6 hryvnias per dollar.

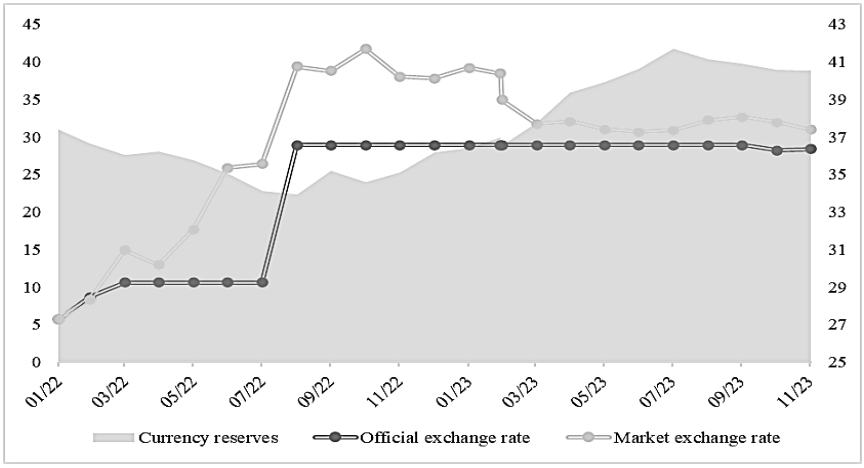


**Figure 2.10.** Currency reserves (billions of UAH) and exchange rate (UAH/USD)

*Source: made by the author based on the data [50, 51]*

Steady progress in reducing inflation, the accumulation of a significant level of international reserves, the increasing attractiveness of hryvnia deposits and OVDP made it possible to move from exchange rate fixation to managed exchange rate flexibility on the October 3rd. The official exchange rate under the regime of managed flexibility will be determined by operations on the interbank foreign exchange market. The NBU maintains a presence in the foreign exchange market and compensates for the structural deficit on it, allowing the exchange rate to fluctuate in both directions under the influence of situational changes in the demand and supply of the currency.

During two year of the full-scale invasion NBU made crucial decisions regarding the key policy rate (Figure 2.11).

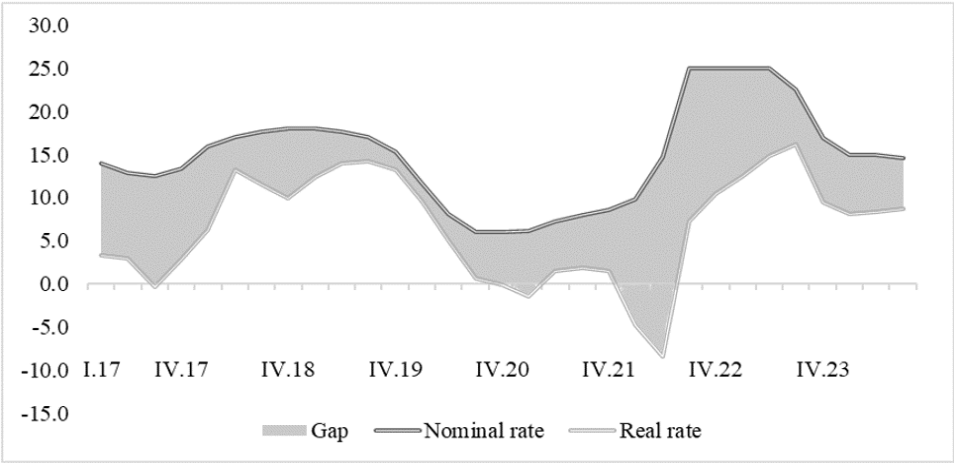


**Figure 2.11.** Key policy rate during 2017-2023 period, %

*Source: made by the author based on the data [53]*

At the beginning of the war, the NBU temporarily postponed the decision-making regarding the key policy rate. The key policy rate was kept at a stable level of 10%,

taking into account the low efficiency of transmission of changes in conditions in the psychologically tense conditions of war. Fixed exchange rates and currency interventions have become key tools for ensuring macro-financial stability. However, with the beginning of the adaptation of the economy to martial law and the return of citizens and businesses to the rational logic of decision-making, in June 2022 the NBU decided to return to an active monetary policy and increase the key policy rate by 15 percentage points to 25%. The main goal of such a move was to protect citizens' hryvnia incomes and savings, increase the attractiveness of hryvnia assets and reduce pressure on the foreign exchange market, which in turn strengthened the NBU's ability to ensure exchange rate stability and curb inflationary processes during the war.

From April 7, 2023, the new design of the monetary policy of the National Bank of Ukraine (NBU) came into force (Figure 2.12) . It is aimed at stimulating the holding of hryvnia time deposits of the population, which contributes to the stability of the financial system. Also, these changes are intended to reduce risks in the foreign exchange market and preserve citizens' savings from inflationary losses. The main changes include the reduction of the rate on overnight deposit certificates from 23% to 20% per annum and the introduction of new limited three-month deposit certificates (DS) at a fixed rate at the level of the key policy rate (25%). Banks will have the opportunity to place funds in such DSs depending on the volume (Figure 2.9).

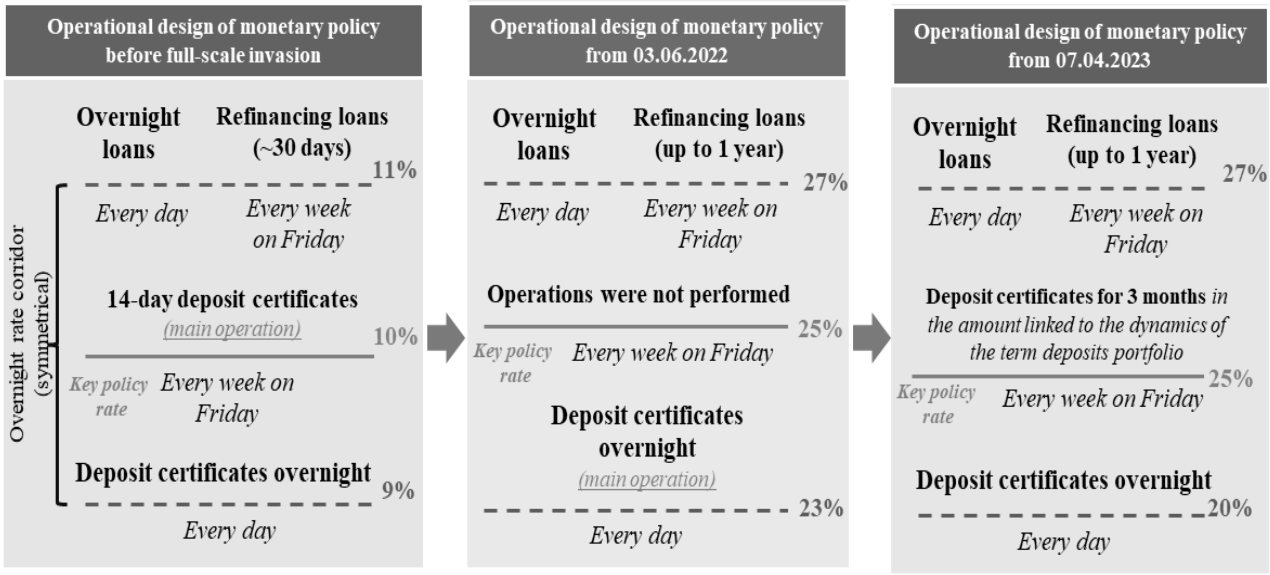


**Figure 2.12.** Operational design of monetary policy

*Source: made by the author based on the data [37]*

The positive trends created the conditions for a faster start of the key policy rate reduction cycle in mid-2023. Therefore, already in July, the NBU reduced the key policy rate by 3 percentage points to 22%. The reduction of the key policy rate took place gradually, so as not to harm the trend towards a steady decrease in inflation and the stability of the currency market. The main prerequisite for this is maintaining sufficient attractiveness of hryvnia assets, which would ensure the protection of savings. In October, the NBU set the key policy rate at the level of 16%, equalizing it with the overnight deposit certificate rate. In this way, the NBU modernized the operational design of the monetary policy according to the "lower limit" system. At the same time, rates for other operations of the NBU with banks remained unchanged. The new design of monetary policy provides an opportunity to maintain incentives to maintain the high attractiveness of hryvnia assets.

Expected moderate inflation dynamics over the forecast horizon allowed the National Bank of Ukraine (NBU) to lower the key policy rate to 15% in December. These changes played a positive role in increasing the attractiveness and maturity of hryvnia deposits, encouraged banks to compete more actively for depositors and revived activity on the interbank market. Although the devaluation pressure on the foreign exchange market increased at the end of the year, the dollarization of household deposits remained at the previous level, and this coincides with the orientation of the NBU to support the attractiveness of hryvnia instruments.

Due to a full-scale invasion, the NBU actively intervened in the process of formation of required reserves of banks to ensure the stability of the financial system in the conditions of martial law. In 2022, the National Bank of Ukraine adopted a number of measures aimed at reducing the required reserve requirements to stimulate banking activity. In particular, the reserve standards for funds in both national currency (10% to 0%) and foreign currency (from 10% to 7%) were significantly reduced, and the procedure for calculating reserves was changed. In 2023, the NBU increased the requirements for mandatory reserves of banks (5% to 10% – in national currency and from 15% to 20% – in foreign currency), in particular, canceling daily monitoring of their compliance and allowing the use of domestic state bonds debt to cover part of the reserves. The liquidity of the banking system increased significantly during the period

of the full-scale invasion (Figure 2.13). The main factor behind this increase was a significant increase in government spending, especially through the sale of foreign exchange funds and issue financing.

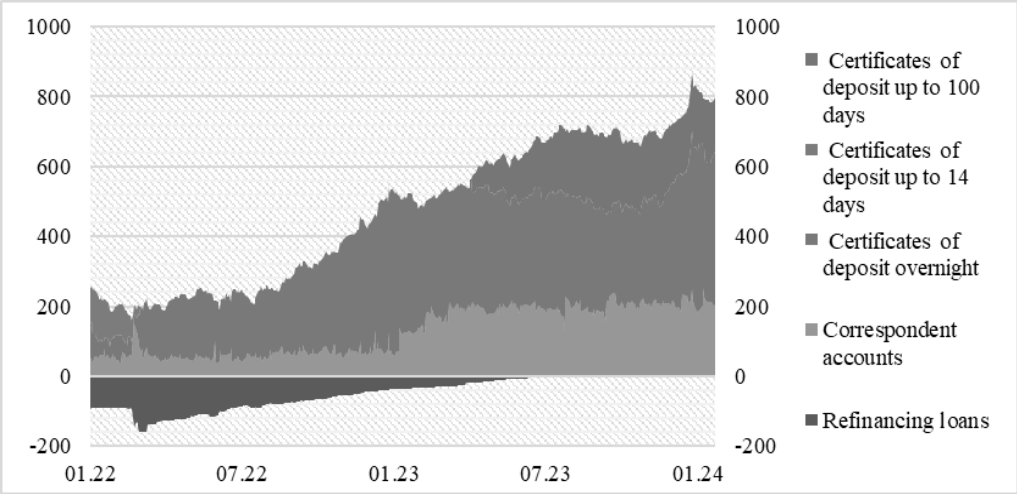


**Figure 2.13.** Liquidity of the banking system, billions UAH

*Source: made by the author based on the data [53]*

A significant increase in liquidity also creates a problem of excess hryvnia liquidity, which can lead to increased pressure on the foreign exchange market and underfunding of the real sector of the economy.

In connection with the unevenness of foreign financial aid at the beginning of the war, the NBU began to monetize the deficit by purchasing government bonds, which led to an increase in the share of government bonds owned by the NBU compared to the amount of government bonds owned by banks (Figure 2.14). However, in the second half of the year, monetization volumes were significantly reduced in order to reduce risks to macro-financial stability. Therefore, the NBU is taking measures to increase the participation of banks in the primary market of OVDP and to gradually increase the requirements for mandatory reserves in order to tie up free liquidity and reduce its negative impact on the financial system.

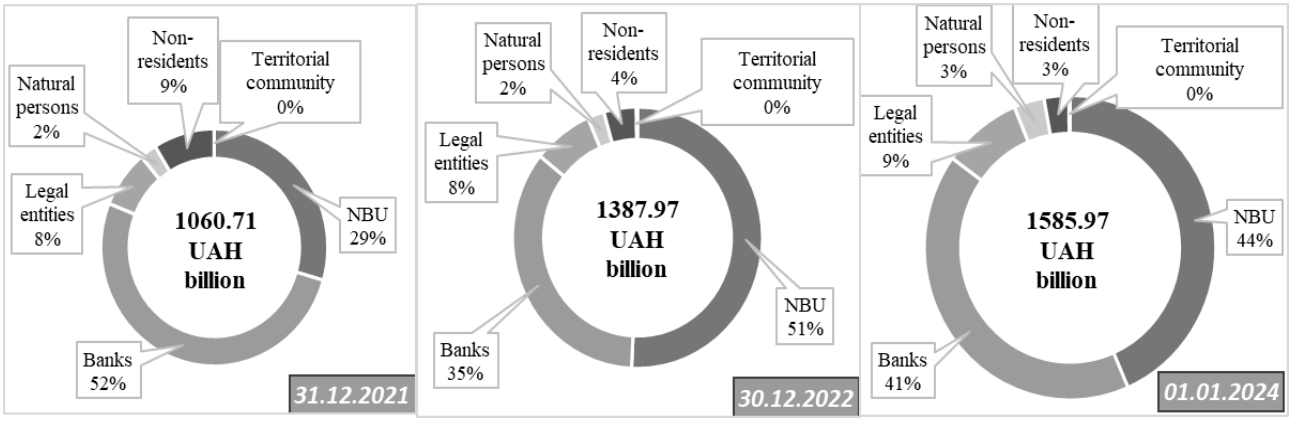


**Figure 2.14.** Domestic government bonds in circulation by outstanding nominal volume.

*Source: made by the author based on the data [46]*

From January 11, 2023, banks have been given the opportunity to include a specified list of benchmark OVDPs in covering up to 50% of the required reserves. This decision gives banks the opportunity to use government bonds as a tool for liquidity management and capital regulation in wartime conditions. This decision is intended to stimulate activity at auctions of the Ministry of Finance for the placement of government bonds, which helps to avoid direct financing of the budget deficit by the National Bank of Ukraine.

Despite the full-scale invasion, NBU raised the level of trust among the Ukrainian citizens (Figure 2.15). Before 2022, NBU was slowly earning trust with ups and downs by implementing an inflation-targeting regime and transparent communication with the public. However, fast and effective decisions of the central bank in a challenging war environment significantly changed citizens' opinion in a positive direction, and in January 2024 only 34% of the Ukrainians did not trust the NBU, compared to 53% of citizens with trust.

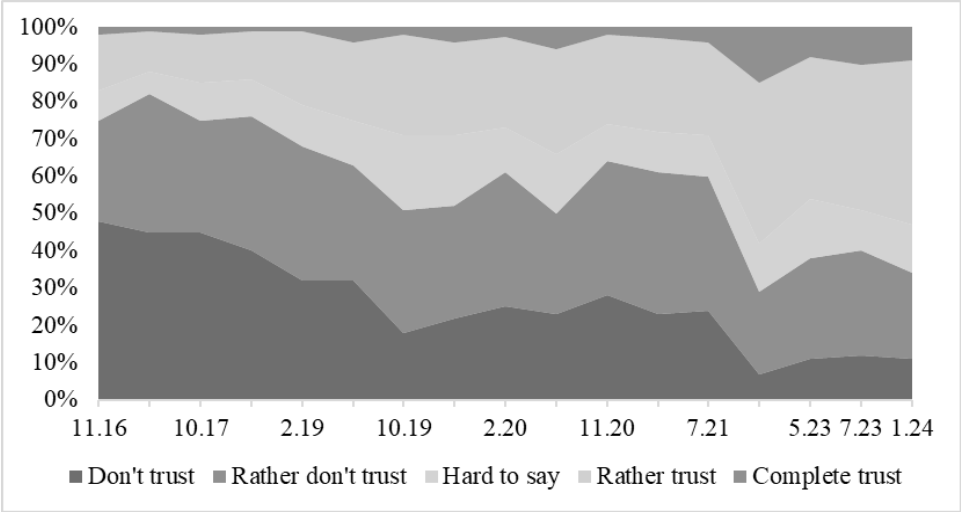


**Figure 2.15.** Contributions to the annual change in the CPI and inflation expectations

*Source: made by the author based on the data [46]*

In conclusion, the full-scale invasion of Ukraine fundamentally changed the economic environment in the country, showing the ineffectiveness of traditional inflation targeting due to market instability and uncertainty. The National Bank of Ukraine implemented various measures, including fixing the exchange rate, introducing administrative restrictions on currency transactions, and adjusting monetary policy. Despite disruptions to supply chains, increased business costs, and physical damage to infrastructure, the NBU managed to stabilize inflation by actively intervening in currency markets and adjusting the key policy rate. The central bank's efforts increased trust among Ukrainian citizens, which facilitated a gradual reduction in inflation and a stabilization of the economic environment within wartime conditions. However, challenges such as over-liquidity and uneven foreign financial aid caused adjustments to monetary policy and reserve requirements to maintain macro-financial stability. Despite these challenges, the NBU's proactive approach and effective communication strategies increased public confidence in the central bank's ability to navigate the economic challenges posed by the war.

## 2.3. Modeling the condition of the economic environment of Ukraine for the definition of the effective key policy rate and currency restrictions

The economic environment of Ukraine is living through an unstable time, being influenced by both local factors and external dynamics. In the face of ongoing full-scale invasion, structural challenges, and global economic uncertainties, NBU is responsible for navigating these complexities to ensure stability and promote sustainable growth of the Ukrainian economy. The National Bank of Ukraine is an emission center, that carries out a monetary and credit policy, strengthening the currency of Ukraine - hryvnia, and regulates and supervises the activities of commercial banks in Ukraine and non-bank financial institutions. To effectively perform its functions, NBU conducts a comprehensive analysis of the macroeconomic environment in Ukraine, which is a crucial base for defining the direction of monetary policy decisions. With the use of the analysis NBU can gather valuable insights to understand interactions among these variables, identifying stable patterns and foreseeing trends. This knowledge serves as an important input for making policy decisions, such as key policy rates, currency restrictions, the size of required reserves for the banks, etc. The results of the analysis are quarterly presented to the public in the shape of the Inflation report followed by the main monetary policy decisions.

For defining the key policy rate in the inflation targeting regime can be used rules-based approach, which seeks to have monetary policy determined by a pre-specified rule. The most famous was proposed by John Taylor in 1993 and called the “Taylor rule”, which aims to define the ideal key policy rate based on the deviation of inflation from the central bank’s target and the deviation of GDP from potential GDP. Such a policy provides more transparency and predictability of the process for business. The original rule states the following formula:

$$it = \pi t + \alpha(\pi t - \pi t^{*}) + \gamma \hat{yt} + Rt^{*} \quad (2.1)$$

where the target key policy rate is determined by the

- $\pi t$ - deviation of the actual inflation rate;
- $\pi^{*}$ - from the target inflation;

- $\alpha$ - the restricting the inflation and output gap coefficients (0.5);
- $\hat{y}t$ - the deviation of real GDP from its potential level;
- $Rt^*$ - the equilibrium level of the real interest rate;

In Ukraine targeted inflation in the inflation targeting regime at 5%. Consequently, to define the key policy rate for 2024 year has to be developed the forecast for the inflation rate and GDP gap for 2024. For this purpose was used forecasting methods based on time series, in particular ARIMA modeling, which is suitable for making operational decisions at the macro- and micro-level, it is often necessary to rely on qualitative forecast values of certain indicators, without delving into detailed analysis of the factors that influence their change. In this case, ARIMA model is one of the effective methods of forecasting are methods of forecasting based on time series.

***Inflation rate 2024***

For the forecasting of the Inflation rate for 2024 was chosen the Consumer price indices for goods and services (to the previous month) for January 2001 – February 2024 period according to the data provided by the State Statistic Service of Ukraine. At the first stage of modeling, time series have to be tested on stationarity, level of integration, and specification of the model. Testing proved, that for the provided time series level of integration is 0, the model specified with 12 AR components and 1 MA. Checking the specified ARIMA model for adequacy showed that residuals are white noise, lag polynomial lie in the unit circle, the model is stable, and predictive quality criteria show high forecast accuracy of the model. Detailed results of the testing and specification of the model are provided in Annex C.1.

The inflation forecast is presented on the Figure 2.16.

The confidence interval of this forecast model shows a low deviation of the forecast values from the real ones, which also indicates the good forecast quality of the model. According to the results of the modeling, inflation for the 2024 year in Ukraine will be increasing compared to 2023 (5.1) and by the end of the year will reach around 11.1%.

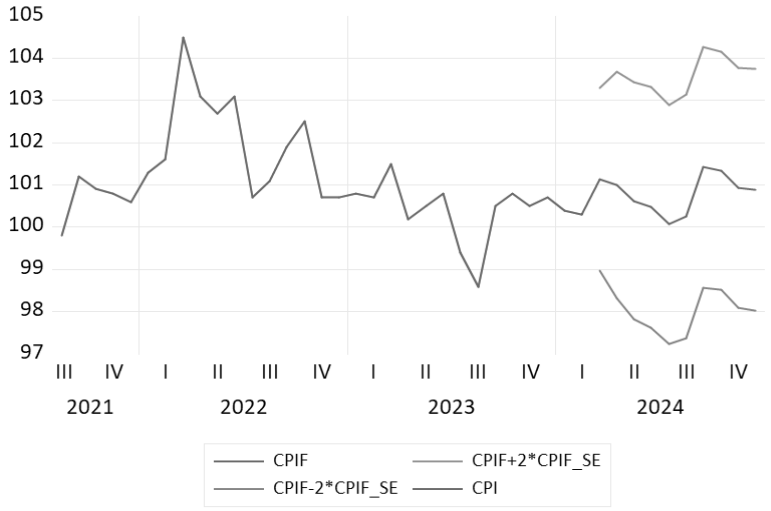


**Figure 2.16.** Predictive model "CPI" on the available sample

*Source: made by the author based on the software Eviews*

***GDP gap 2024***

The second important component to define the optimal key policy rate according to the Taylor rule is the GDP gap. This indicator represents the difference between a country's actual and potential GDP, indicating whether production underperforms or exceeds its optimal level. In the first case it can lead to deflation (because the economy produces fewer goods and services than it can consume), and in the second case lead to inflation (because the economy produces more goods and services than it can consume). To forecast the value of the GDP gap for the 2024 period was used data regarding the Real GDP and Potential GDP for the 1 quarter 2008 – 4 quarter 2023 period provided by the National Bank of Ukraine. The GDP gap for a given period was calculated by the following formula:

$$GDPgap = \frac{(RealGDP - PotentialGDP)}{PotentialGDP} * 100\% \qquad (2.2)$$

The calculations showed the value of the percentage value of the GDP gap, which is presented in Figure 2.17.

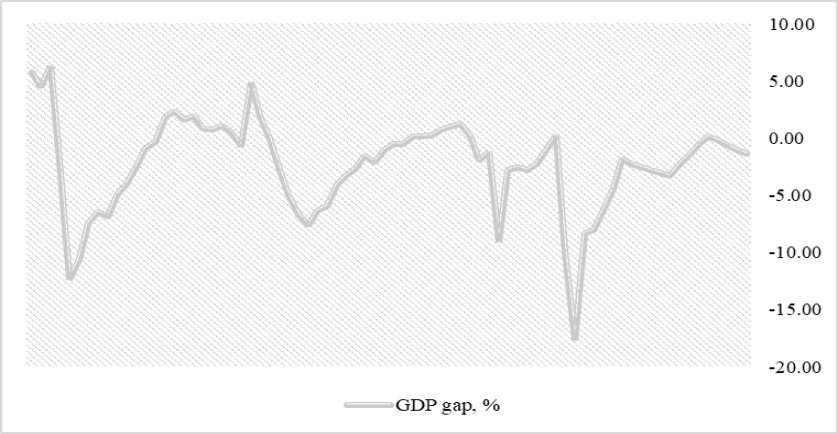


**Figure 2.17.** GDP gap for the period 2008-2023

*Source: made by the author based on the data [55]*

To prove adequacy of the developed model several tests were performed. The "GDP gap" time series is stationary on the levels and has 0 level of integration. The specification of the model showed a clear AR process with 4 AR components. Required testing and detailed model specifications are provided in Annex C.2. Results of the testing show, that residuals are white noise, lag polynomials lie in the unit circle, the model is stable, and predictive quality criteria show significant forecast accuracy of the model. The results of the modeling received the following forecast, presented on the Figure 2.18:

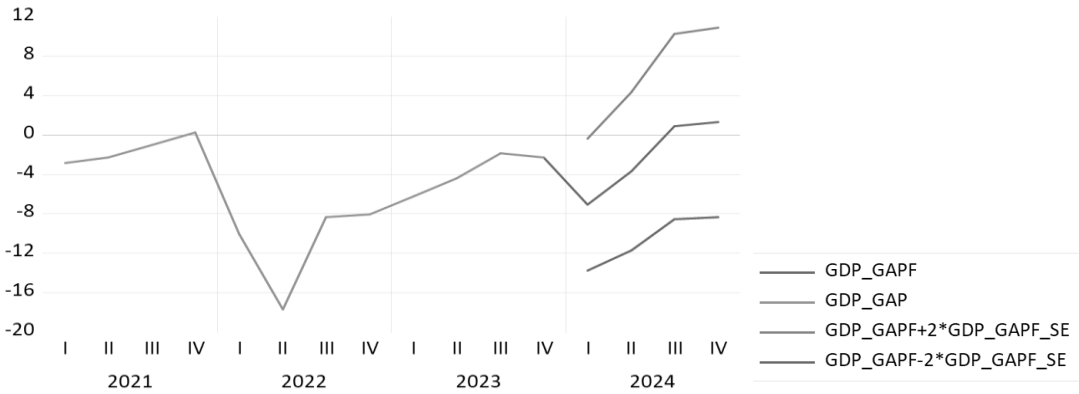


**Figure 2.18.** Predictive model "GDP gap" on the available sample

*Source: made by the author based on the software Eviews*

Based on the results of modeling, in 2024 the GDP gap will be decreasing, by the end of 2024 even the gap is expected to reach a positive value, which signalizes about the recovery of the economy, but on average, in 2024 year it value will be at -2,15%. As a result, the following data is available for calculating the key policy rate for the 2024 year:

- Prognosed inflation rate – “11.1%”;
- Prognosed GDP gap – “-2.15%”;
- Target inflation – “5%”;

Hence, according to the original Taylor rule the key policy rate for the year 2024 should be defined as:

$$r = 11.1 + 0.5*(-2.15) + 0.5*(11.1-5) + 5 = 18\% \quad (2.3)$$

In 2024 expected the growth of the inflation rate (11.1%), compared to 5.1% in 2023, which signalizes the necessity of raising the key policy rate to 18% in order to stabilize the situation on the market.

With the start of a full-scale invasion, the exchange rate started playing a more important role, compared to the pre-war period, and increased the impact on the economic environment. To understand its impact better, should be tested relation between the key policy rate and exchange rate with the use of econometric modeling. For this purpose was used the data “Official exchange rate USD/UAH” and “Key policy rate” from National Bank of Ukraine for the period February 2003 – March 2024. The tested time series are non-stationary in levels, but both are stationary in differences, that is, they have the same order of integration, which suggests the use of the VECM modeling method for conducting research. Two hypothesis is planned to be tested during the modeling research:

H1: The increase in key policy rate leads to a change in the Exchange rate formation.

H2: The increase in exchange rate leads to a change in the Key policy rate formation.

After model specification was conducted a model evaluation and adequacy testing (detailed results presented in Annex C.3), which showed that all the variables are endogenous, impulse response functions have a decreasing (to zero) nature, the residuals are white noise, and there is no correlation observed among the residuals, which proves adequacy of the model.

To explore the impact of the variables on each other, a variance decomposition was constructed, presented on the Figure 2.19.

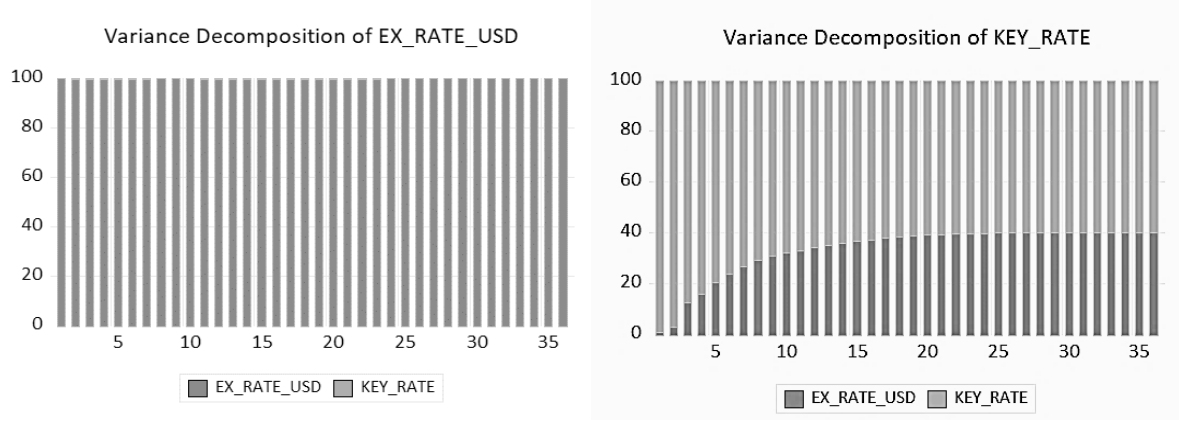


**Figure 2.19.** Graphic display of the variance decomposition of the estimated VECM model

*Source: made by the author based on the software Eviews*

Analysis of the variance decomposition, showed that the key policy rate has no influence on the change in the exchange rate, but the exchange rate has a significant impact on the change in the key policy rate in the long term with a gradual increase in influence (up to 40%) during the first 15 periods (months). The presented results prove the second hypothesis and reject the first hypothesis. This signalizes the importance of the exchange rate for the key policy rate decision-making process. Consequently, NBU has to continue monitoring and controlling the exchange rate with the implementation of the Managed flexibility of the exchange rate regime, to keep it stable on the market and increase the effectiveness of the monetary instrument key policy rate.

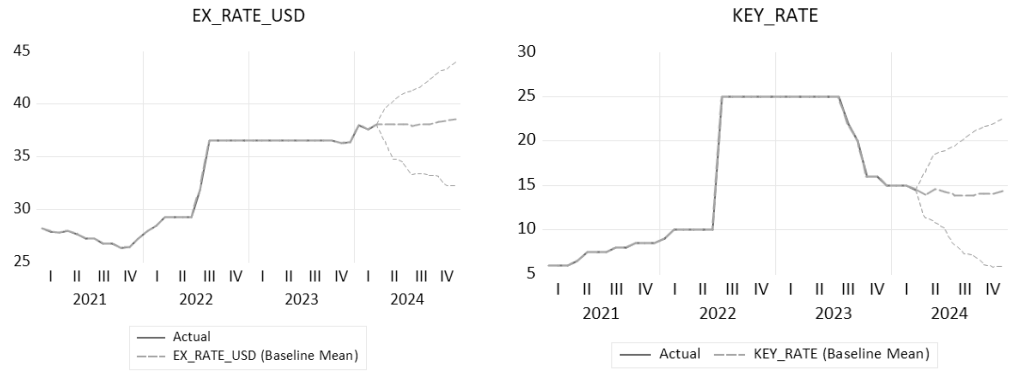


**Figure 2.20.** Graphical display of actual and forecast data calculated according to the VECM model

*Source: made by the author based on the software Eviews*

Furthermore, with the use of the developed VECM model was created forecast of the exchange rate USD/UAH and Key policy rate for the 2024 year, and results are presented in Figure 2.20.

As for the developed forecast, the hryvnia will continue to slowly depreciate in the forecasted periods, the model predicts that the exchange rate will reach the mark of 38.1 hryvnias/dollar at the end of 2024. As for the key policy rate, at the end of 2024, it is predicted that the rate value will be stable and remain at the level of 14.5% with minor fluctuations.

In conclusion, the economy of Ukraine is currently going through a period of instability, influenced by war, which led to the economic crisis. NBU plays a crucial role in maintaining stability and ensuring sustainable growth through significant challenges. The NBU conducts a comprehensive analysis of macroeconomic indicators to inform its policy decisions, as the main authority responsible for monetary policy. For the year 2024, were developed forecasts for inflation and the GDP gap to determine the appropriate key policy rate and currency restrictions. According to the Taylor rule, the key policy rate for 2024 was projected to be 18%, considering an expected increase in the inflation rate to 11.1% compared to 5.1% in 2023. This increase in key policy rate aims to stabilize the market environment and lower inflationary pressures. Additionally, the analysis highlighted the importance of the exchange rate, particularly in the war-impacted environment. Econometric modeling showed a dynamic relationship between the key policy rate and exchange rate, which affects the monetary policy decision-making. The forecast predicts a continued slow depreciation of the hryvnia, with a possible increase in the exchange rate to 38.1 hryvnias/dollar by the end of 2024. Despite these challenges, the NBU continues to navigate the economic landscape and promote stability in Ukraine.

## Conclusions to Chapter 2

The Ukrainian economy went through many challenges throughout its independence, facing economic crises, war, and pandemic. However, for the last two years, Ukraine has been facing a full-scale war, which has a massive impact on its economic structure and requires significant transformations in monetary policy. High inflation, significant decline in GDP, growing public debt, currency devaluation, and

mass emigration are visible economic consequences of the war. Despite the efforts of the government and the NBU to mitigate inflationary pressures by various means, the economic environment in Ukraine is still going through many challenges. The NBU's decision to fix the exchange rate and further interventions and policy adjustments helped to soften the consequences of the war.

Modeling the dynamics of the system visualized the complex interaction of economic variables over time. The research showed an outlining key feedback mechanism, including the effects of inflation expectations, the key policy rate, and the exchange rate, which is important for monetary policy development. Scenario simulation allows for a better understanding of the possible consequences in different conditions, showing a sharp contrast between wartime and peacetime conditions.

The assessment of the effectiveness of the NBU's monetary policy shows a significant impact of the war on the economy of Ukraine. During the war, traditional mechanisms of inflation targeting proved to be ineffective in conditions of increased uncertainty, which requires a transformation of the main monetary policy approaches. The quick reaction of the NBU helped to overcome inflationary pressures and strengthened the confidence of the population. Effective communication and strategic intervention by the central bank helped stabilize the economic environment and decreased the effect of the challenges, created by the war.

In summary, the economic landscape of Ukraine has changed due to the full-scale invasion, which pushed NBU to adopt policy measures and innovative approaches to maintain stability during the war. The NBU plays a crucial role in ensuring stability during economic challenges.

# CHAPTER 3. PROSPECTS FOR THE IMPLEMENTATION OF THE NATIONAL MONETARY POLICY IN THE CONDITIONS OF ECONOMIC INSTABILITY

## 3.1. Risks of wartime and problems of domestic monetary policy

Ukraine is a relatively young independent country, consequently Ukrainian economy is deeply sensitive to crisis events and rapid changes in the surrounding environment. The country has lived through the war through the last decade, and in 2022 the situation escalated to a full-scale invasion. During this time, the country has grappled with various challenges that have significantly impacted its domestic monetary policy and economic stability. Wartime brings numerous complications in implementing effective monetary policy for NBU. The uncertainty and volatility caused by the war proved traditional policy tools less predictable and effective, compared to stable times, due to various risks, which must be considered during the decision-making process.

And the first risk, that shook the Ukrainian economy and fundamentally changed the approach of the NBU monetary policy is *uncontrolled inflation*. During martial law, inflation becomes a hardly controlled economic event, which is deeply sensible to the combination of stressful factors, appeared by rapid changes in population behavior, government war expenses, uncertainty among consumers and businesses, currency depreciation, disruptions to supply chains, etc. In these conditions, regular market rules no longer work, and demand and supply are unpredictable, consequently, a traditional instrument, such as the key policy rate, shows its ineffectiveness, so policymakers have to alternative methods for managing inflation. Furthermore, inflation during war can have social and economic consequences, reducing purchasing power, lowering living standards, and increasing inequality. It created additional challenges for policymakers in balancing the need to support the war defense with the need to mitigate the effects of inflation on the population.

The next important risk caused by the war challenge is the high *currency*

*instability*. The constant threat of currency depreciation, driven by an increase in military expenditures, is shaking the economic environment of the country, disturbing investor confidence, and causing the outflow of capital from the Ukrainian investment market. Such currency devaluation increases inflationary pressures, complicating the NBU's work to maintain price stability. Moreover, depreciating currency leads to higher prices for imported goods and services, consequently, currency instability during wartime can increase inflationary pressures. This, can lower purchasing power of the population and reduce the standard of living for the population, particularly Ukrainians who earns fixed incomes in hryvnia or has limited access to foreign currency. NBU controls currency fluctuations by fixing the exchange rate, but such a method requires the use of the currency reserves for currency interventions, which is expensive for the policymaker, and leads to the accumulation of imbalances in the economy because an artificially strong hryvnia reduces the incomes of exporters, and consequently, the incomes of the budget.

War, inflation, and currency depreciation cause an *increase in the government debt and additional pressure on government budget expenditures*. The level of well-being of citizens and the business activity of economic entities decreased with the beginning of a full-scale war, while unemployment and inflation increased together with the national currency being devalued, and many citizens left their homes and moved to safer places. Government spending grew rapidly because of the financing of military needs and support of people who lost their homes and jobs, when the amount of received taxes and other incomes, that fill the budget fell catastrophically. This led to a significant deficit in the government budget, which was caused by the need to cover which additional financial resources. The government attracts additional resources through the grants and loans from international partners. Consequently, Ukraine's financing needs have reached an unprecedented level. The level of debt in 2022 has already significantly exceeded the amount provided for by the fiscal rule (60% of GDP) as a result of the accumulation of public debt and a sharp drop in nominal GDP. With the debt growth, in the future Ukraine will spend a larger part of its budget to service the debt and leave less funds available for other important areas. The financial consequences of the war will be felt for decades, repaying the debt and

rebuilding the economy will be a long and challenging process for Ukraine.

As it was mentioned above, the Ukrainian government budget in conditions of war highly relies on international support, hence if the war in Ukraine persists, a crucial risk to the effectiveness of monetary policy lies in *reducing international financial aid*. Disruptions in the transfer of aid or its reduction will significantly undermine the sustainability of public finances, which may worsen macroeconomic stability. The main reason for the decrease in international help is “Donor fatigue”, which happens when the war continues for a long time, donor countries become less willing to provide continued financial assistance due to limited resources, the shift of priorities, or a perception that the war is not making progress towards a resolution. War in Ukraine no longer covers the first pages of the newspapers, and all the attacks from the russian side are not that shocking anymore. In this condition, international partners don’t feel the need to provide as much help, as they did before, and choose to allocate resources to alternative priorities, which represents a risk for the Ukrainian economy. A decline in international support can also be decreased by the recession of the world economy. The economic crisis in the partner countries decreases their ability to provide help for Ukraine, and instead, they have to grapple with their own economic challenges and redirect resources to solve internal problems.

An additional risk for the monetary policy of Ukraine is represented by the *decline of the demographic situation and the outflow of human capital*, around 3 million Ukrainians (almost 10% of the population) already moved abroad. Decreasing population and emigration of skilled workers can significantly reduce tax revenue, overall economic productivity, and domestic demand. This weakens the government's ability to fund public spending and social programs, while also limiting its capacity to support the Ukrainian currency. Also, as individuals move abroad, Ukraine experiences a brain drain, leaving the economy without professional experts and delaying long-term economic development.

The next risk for the monetary policy can be caused by the *yield reduction*. The agricultural sector forms a third of the Ukrainian economy, consequently, this sector plays an important role in driving economic growth, generating employment, and contributing to export income. Reduced harvest can lead to lower agricultural

production, impacting farmers' profit, rural life quality, and overall economic activity in agrarian regions. On the higher stages of production, this decline can also ripple through related industries, like food production, further dampening economic growth, putting pressure on food prices and overall inflation, and harming trade balances, as agricultural products constitute a significant part of the country's exports, which impact the stability of the national currency. This inflation effect complicates the NBU task of keeping price stability through instruments of monetary policy.

The *introduction of bans on the import of Ukrainian products and the shelling of logistics infrastructure* as well present significant risks to monetary policy in Ukraine. These actions can disrupt supply chains, block trade flows, and weaken economic stability at the same time complicating the NBU efforts to manage inflation and promote growth. Bans on the import of Ukrainian products limit market access for Ukrainian exporters, leading to decreased demand for locally produced goods and services. This reduction in export revenue can harm businesses, reduce employment, and lower economic growth.

In the conditions of instability, for conducting effective monetary policy is deeply important for NBU to have the trust of the citizens, which in the long-term perspective will help to stabilize the economic situation. Trust ensures that citizens believe in the NBU's ability to navigate economic challenges and maintain the value of the currency. It helps to keep stability in financial markets, encourages investment, and increases consumer confidence. But during the war, the economy is deeply destabilized, people are tired from the disruptions of daily life and uncertainty about the future, so any missteps, failures of the NBU, such as increases in prices, or fluctuations in the exchange rate can decrease trust in the actions of the NBU, which represents a risk for the conducting monetary policy. In these conditions, the NBU faces the complicated task of balancing the need to solve economic challenges with ensuring public confidence.

All of the mentioned risks can escalate with further prolongation of the war, which represents one more risk for the conducting monetary policy. As the war continues, the economic and financial landscape becomes increasingly unstable. Each risk factor—whether it's currency instability, increased government debt, disruptions

to supply chains, or decrease of public trust—can intensify its impact over time. The cumulative effect of these risks poses an important challenge for the central bank in guiding the economy toward stability despite war challenges. Furthermore, the persistence of the war can lead to the depletion of the financial resources of the NBU and the government, limiting the scope for monetary policy intervention. The cost of war is only growing over time, opposite to the income from the government budget, which only decreases to growing amount of the destroyed infrastructure, killed citizens, and increasing amount of emigrants, which leads to a decrease in NBU resources for conducting monetary policy.

All of the mentioned risks above are summarized in Figure 3.1. according to the degree of influence and probability.

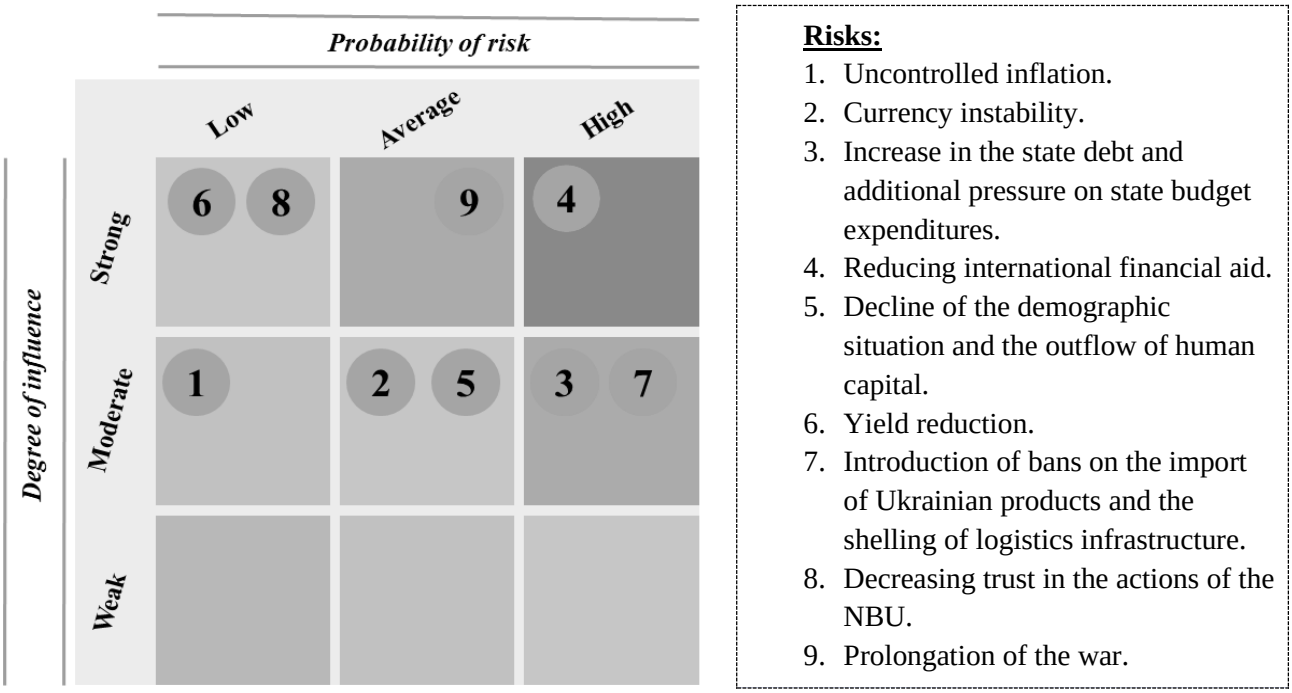


**Figure 3.1.** Probability and degree of influence of the risks for the NBU monetary policy

*Source: made by the author based on data [53]*

The strongest risk with the highest probability to happen was defined as reducing international financial aid, such as numerous international partners already announced a decrease in international help for Ukraine for 2024 (USA, Germany, EU, etc.). High risk for conducting monetary policy also represents an increase in the government debt and additional pressure on government budget expenditures, the introduction of bans

on the import of Ukrainian products, and the shelling of logistics infrastructure. Both of the risks have a direct impact on the resources available for conducting monetary policy and can deeply limit it. However, the probability of these risks was defined as moderate, such as NBU and the government are actively engaged in mitigating these threats. Prolongation of the war represents a strong risk with an average probability of happening, given Ukraine's concerted efforts to finish the war. Average probability was also defined for currency instability and decline of the demographic situation and the outflow of human capital for the same reason, as in the previous risk, but the impact was defined as moderate. Yield reduction, decreasing trust in the actions of the NBU, and uncontrolled inflation were marked with a low probability of occurrence because the NBU invests a lot of effort to prevent these events from happening.

The Ukrainian economy faces significant challenges with the start of the full-scale invasion, increasing risks to monetary policy effectiveness. Factors such as uncontrolled inflation, currency instability, increased state debt, and disruptions to supply chains caused economic instability. Moreover, a decline in international aid, demographic shifts, and the outflow of human capital pose additional risks. Furthermore, possible prolongation of the war depletes financial resources, limiting the possibilities for monetary intervention. Maintaining public trust in a stressful environment plays an important role, yet the destabilizing effects of war can decrease confidence in the NBU's actions. These risks can increase with the prolongation of war, making it harder to perform effective monetary policy. Conduction monetary policy with these challenges requires proactive measures and a balance between economic stabilization efforts and ensuring public confidence.

### 3.2. International experience in conducting monetary policy during martial law.

Each country has a unique monetary policy in the country, which adapts to the special economic and political environment, behavior of the citizens, and culture of the country. Martial law itself is a rare occurrence, so conducting monetary policy during

martial law presents exceptional challenges for central banks around the world. There is no universal operational design of monetary policy for wartime, however, there are certain patterns that help stabilize the economy in critical conditions. Each country has its own unique experience, which is determined by:

- different duration, scale of hostilities, and their consequences;
- the pre-war state and structure of the economy;
- size of international reserves and public debt;
- the level of development of financial regulators and institutions, citizens' trust, and the national currency;
- previous inflationary dynamics;
- international military, political, and financial support;
- external environment conditions.

A common and effective measure to stabilize the macro-financial situation and curb inflation is the temporary fixation of the exchange rate. This method was used by the central bank of Israel, Iraq, Georgia, and Serbia, and is now used by NBU as well.

***Israel (war of attrition 1967-1970)]***

Israel's monetary policy during the war usually aims to ensure the stability of the financial system and preserve the value of the national currency in conditions of economic and geopolitical instability. To meet this goal, the central Bank of Israel did the same move as the NBU – fixed exchange rate but kept it on the same level throughout the whole war. The exchange rate was devalued by 17% in the first year of the war and remained unchanged until the end. The next devaluation was already after the war - by 20%. During the war of attrition from 1967 to 1970, Israel's monetary policy focused on government support for investment and low interest rates. Despite a slight decline in investment in the first year of the war, averaging 16% of GDP, during the following years observed an increase to an average of 23% of GDP. Budget deficits increased significantly during the war, to around 18% of GDP, with more than 50% covered by direct central bank issuance. International grants and credit assistance formed approximately 10% of GDP, which consisted of grants and loans.

The Israeli government supported the economy by directing about 10% of

spending to expand credit support programs. Inflation during the war was stable at an average of 3.1% per year, despite the significant amount of money coming from help and credit issuance. Industrial production rose by 60% during the war, which provided steady growth in real GDP, reaching a total of +44%. The successful results of conducting monetary policy during the war for Israel showed the importance of prioritizing economic support over the problems of wartime inflation.

***Britain (First 1914-1918 and Second World War 1939-1945)***

During the First and Second World Wars Britain faced a significant economic crisis due to military actions on its territory, and the government implemented important monetary policy measures to maintain economic stability. At the start of the First World War British economy entered with the Gold Standard, but shortly government had to suspend this regime to print additional money without obligation to back it up with gold reserves to supply the war. Growing war expenses put significant pressure on the government budget, the Bank of England started purchasing government bonds and provided loans to the British government for the supply of war expenses. During the Second World War Bank of England shifted from supplying war by printing money to borrowing, the central bank decided to involve citizens in the government bonds investment national savings schemes to raise funds for the war expenses and conducted a promotion campaign for that purpose. Numerous loans were also received from international partners to cover the expenditure gap. To manage inflation, caused by the war, the Bank of England used a key policy rate as a main instrument to manage borrowing costs, and as a result - inflation. As for food inflation, government price control for essential goods and services to stabilize prices and provide equal distribution of the products. As a result of the British monetary policy during martial law, Britain successfully ended the war with a functioning economy, but large government debt, which persisted as a significant burden for monetary policy for several decades.

***Iran (Iran-Iraq War 1980-1988)***

The Iran-Iraq War of 1980-1988 posed various economic challenges and had a significant impact on Iran's monetary policy. The Iranian government took numerous measures to finance the war, stabilize local currency, and fight inflation, but these

actions led to a significant economic crisis. To finance military expenditures, the government of Iran significantly increased borrowing from the central bank or issuing new money, which led to significant inflation up to 49% in 1982. In addition, the government implemented price controls on vital goods to decrease the impact of inflation on the population, but the implemented measures did not show the expected result and led to shortages and the development of the black market. At the same time, the gap between official and unofficial foreign exchange rates of the Iranian national currency occurred and caused currency devaluation, which also had a significant impact during the war, making imports more expensive and accelerating further inflation. Additionally, the government implemented import restrictions to not let foreign currency move out of the country's economy and protect local production, which led to a shortage of goods and an increase in prices. Consequently, high inflation has become the main problem of the Iranian economy, this decreased the purchasing power of the population and caused the spread of poverty. Iran's economy has suffered an economic crisis because Iran’s trade (imports plus exports) to GDP ratio dropped to its lowest level of 14% in 1986, while Iran's foreign debt has grown significantly, making it difficult to finance imports and service debt. But after the end of the war, Iran`s economy started to recover, it was a ‘construction period’. New infrastructure was being established across the country, such as power plants, and wind and water mills. New spheres of production and investment have improved the living conditions in the country.

***Iraq (Persian Gulf War (1990-1991) and subsequent UN sanctions (1991-2003))***

Persian Gulf War and following sanctions had a significant impact on the monetary policy of the country. Since the Gulf War economic sanctions were imposed on Iraq for a long time and the major source of foreign currency - oil exports, were also restricted. As a result, the Iraqi government lacked income for the government budget, and thus faced large fiscal deficits. To finance its expenditures, the government printed money in exchange for government bonds, which caused rapid inflation and devaluation of the dinar. The government also imposed currency restrictions to control capital outflows and protect foreign currency holdings. For example, Iraq implemented

restrictions on the exchange of foreign currency and its transportation abroad. In 1993 government implemented the Dual currency system, when the Iranian rial (IRR) became the official currency, but the United States dollar (USD) was also widely used. The government put limits on the currency reserves of banks and fixed the exchange rate in foreign exchange markets. This exchange rate was often artificially undervalued to ensure the stability of export-import transactions. There was a significant gap between the official and real exchange rates, which led to the development of the black currency market.

***Yugoslavia (war 1991-2001)***

Yugoslavia's monetary policy during the 1990s was complex and chaotic because the country experienced disintegration and a series of wars. After the collapse of the old communist structure, the former republics abandoned Yugoslav currency and only Serbia tried to keep it. In 1992, the Central Bank of Serbia began printing additional dinars to pay the salaries of workers and pensioners which caused hyperinflation. At the height of the crisis, prices rose by 2 percent every hour. Money was virtually worthless which led to the deterioration of living conditions for many people, Serbian citizens bartered goods or exchanged any income or savings for any possible stable hard currency (such as German marks for example). By the end of 1994, half of the population spent between 66 and 100% of their family income only on food. The wars led to the collapse of Yugoslavia's financial system, many banks and other financial institutions were destroyed or forced to close, complicating to do business and access financial services for the public.

***Croatia (Croatian war 1991-1995)***

Croatia declared independence from Yugoslavia in 1991, which led to a war with the Yugoslav army that lasted until 1995. This period was very difficult for the Croatian economy, and monetary policy played an important role in stabilizing the financial sector and financing the war effort. To control inflation and take control over inflation in 1994 the Croatian government implemented its currency - the Croatian Kuna, instead of the Yugoslav currency. To curb high inflation, the government did not go the way of Yugoslavia (money supply growth), instead implemented a restrictive monetary policy, which included cutting government spending and increasing taxes to reduce the

budget deficit and currency restrictions to control capital outflows and protect foreign exchange reserves, and implemented measures were successful. In 1993, the inflation rate in Croatia reached 4200%. The government's tight fiscal and monetary measures helped reduce inflation to 23% in 1995. To supply war expenditures, the government sold government bonds to the public and institutional investors and involved financial assistance from international organizations and partner countries.

All the described monetary policies is summarized in Table 3.1.

**Table 3.1.** Summary of the monetary policies of various countries during wartime

| **Country** | **War Period** | **Key Monetary Policy Measures** | **Economic Outcomes** |
|---|---|---|---|
| *Israel* | War of Attrition (1967-1970) | - Fixed exchange rate;<br>- Government support for investment;<br>- Low interest rates;<br>- Direct central bank issuance;<br>- International grants and loans; | - Stable inflation (3.1% per year);<br>- Industrial production rose by 60%;<br>- Real GDP growth of +44%. |
| *Britain* | WWI (1914-1918), WWII (1939-1945) | - Suspended Gold Standard;<br>- Central bank purchasing government bonds;<br>- National savings schemes;<br>- Price control for essential goods. | - Successfully ended the wars with a functioning economy but large government debt. |
| *Iran* | Iran-Iraq War (1980-1988) | - Increased central bank borrowing;<br>- Price controls;<br>- Import restrictions;<br>- Fixed exchange rate. | - Significant inflation (up to 49%);<br>- Currency devaluation; economic crisis;<br>- Trade-to-GDP ratio dropped. |
| *Iraq* | Persian Gulf War (1990-1991) | - Printed money;<br>- Currency restrictions;<br>- Dual currency system;<br>- Fixed exchange rate. | - Rapid inflation and dinar devaluation;<br>- Development of black currency market. |
| *Yugoslavia* | Wars (1991-2001) | - Printing additional currency (dinars). | - Hyperinflation;<br>- Collapse of financial system;<br>- Living conditions deterioration |
| *Croatia* | Croatian War (1991-1995) | - Introduced Croatian Kuna;<br>- Restrictive monetary policy;<br>- Currency restrictions;<br>- Selling government bonds. | - Reduced inflation from 4200% to 23%;<br>- Stabilized financial sector. |

*Source: made by author based on data [2; 6; 7; 11; 14; 17; 18]*

Each country implements its monetary policy depending on the unique economic,

political, and social environment and surrounding factors. War represents a highly complicated challenge for the government and central bank of the country through uncertainty, physical damage, panic on the market, logistic disruption, etc. There's no universal approach to monetary policy during wartime, but certain strategies can help stabilize economies in crisis. The direction of the monetary policy is defined by duration, scale, and aftermath of the war, along with pre-war economic conditions, reserves, and debt, public trust, inflationary trends, and international support. The most common strategy to stabilize economies during wartime is temporarily fixing the exchange rate, as seen in Israel, Iraq, Georgia, Serbia, and Ukraine. First and Second World Wars Britain survived with intensive borrowing and emission of local currency, which resulted in significant debt obligations after the end of the war. During the War of Attrition, Israel maintained financial stability by fixing the exchange rate despite its devaluation, to ensure stable inflation and industrial growth. And vice versa, in the Iran-Iraq War, Iraq, and Yugoslavia, excessive money printing led to inflation and economic collapse, while Croatia adopted a restrictive monetary policy to fight hyperinflation during its independence war, which shows the importance of cautious financial management in wartime.

### 3.3. Directions for improving the monetary policy in Ukraine in the context of crisis events

For the period of independence, the Ukrainian monetary policy system went a long way in development and many changes happened, which created a significantly stable monetary system, that could survive the war, COVID, and full-scale invasion. But still, it is not perfect and certain areas have to be improved to make it more effective. Improving monetary policy in Ukraine during the full-scale invasion presents complicated challenges that require adaptive strategies to ensure stability and mitigate economic collapses.

System dynamic modeling, presented in the sud-chapter 2.1., of the economic system of Ukraine shows, that war had a significant impact on the monetary system

and economy in general, which changed the leverage points, that NBU can press to affect the situation on the market. Consequently, based on the analysis two policies were developed, which could be implemented to improve the economic situation in the country (Figure 3.2).

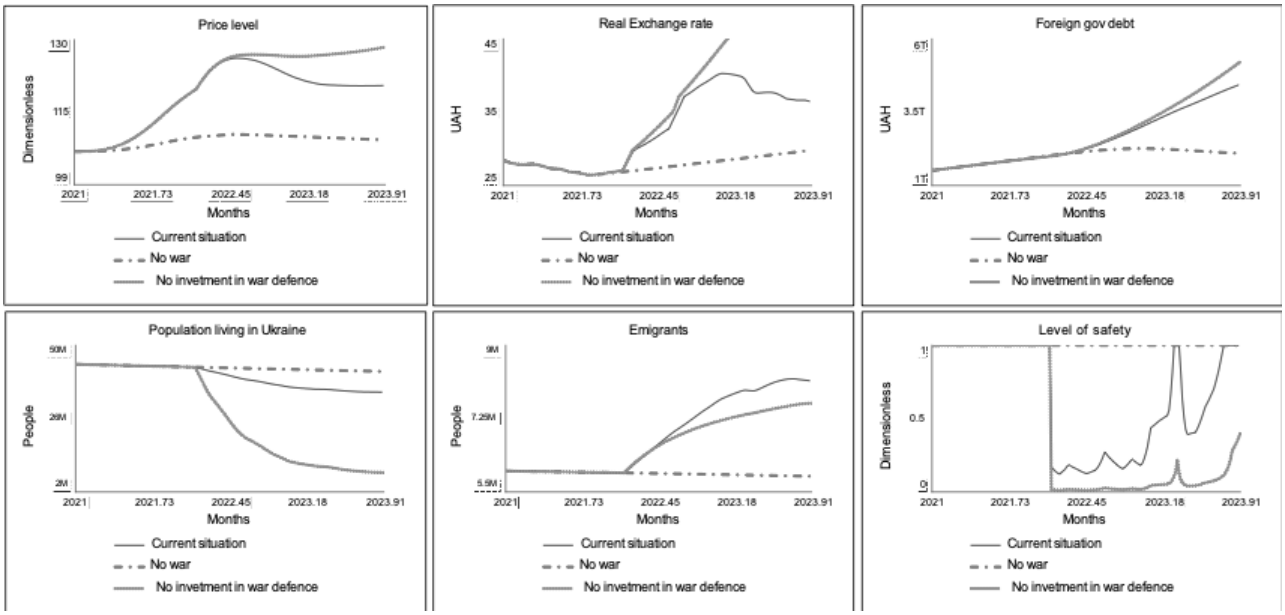


**Figure 3.2.** Comparative graph with main KPI with no war, no investment in defense, and current situation

*Source: made by the author based on the software Stella Architect*

In conditions of war, the economy functions in an unpredictable manner, and despite the government's efforts, it will never achieve the same level of success as it could have in the absence of war. Consequently, the first policy, that can be applied, is stopping russia from throwing missiles into the Ukrainian sky, which is stopping the war. This could significantly improve the economic environment of Ukraine, and current monetary policy would give better results. Of course, this policy can`t be implemented only by the Ukrainian government or NBU, its implementation must involve the help of foreign countries and changes made in the intentions of the attacking side.

During the analysis was tested policy with an increase in international help. Conceptually, an increase in international help will increase the air defense capacity, which will increase the amount of destroyed missiles, and result in increased safety. However, during the testing the efficiency of this policy showed S-shaped behavior: with the increase of international help at the start level of safety was rapidly increased

as well, but after a certain point increase slowed down and did not reach 100% safety. Thus, as many resources will be invested in air defense if the missiles still flying, it will not be possible to reach total safety in the country. At the same time, receiving international help involves that part of this has to be paid back, which increases government debt, and puts additional pressure on the government budget (through debt payments). As a result, the use of this policy can be efficient only until a certain period, after which the cost/efficiency of the policy becomes inefficient.

Besides the system dynamic analysis, econometric and statistical analysis showed changing points for the current monetary policy of the National Bank of Ukraine. After a significant inflation decrease in 2023 (to 5%), the year 2024 will be harder for the Ukrainian economy with higher inflation due to the prolongation of the war.

First of all, the main priority stays stable hryvnia, in 2024 year NBU should continue keeping the regime of managed flexibility of the exchange rate with the following relaxation of the currency and exchange rate restrictions. In the conditions of the war, the economy is deeply vulnerable to the conditions in the surrounding environment, so any negative event can cause disbalances. This direction of the monetary policy allows NBU to adjust currency to market forces within a defined range while keeping the flexibility to intervene in the foreign exchange market when needed. With the stabilization of the environment, NBU should gradually shift to a flexible exchange rate regime, which involves widening the spread within which the hryvnia can fluctuate or reducing the frequency of interventions.

With the possible risk of inflation growth in 2024, NBU should maintain precise inflation control, for example, through the change in key policy rates. According to the analysis, presented in Chapter 2.3., until the end of 2024 NBU might need to raise the key policy rate to 18% to curb inflation caused by supply chain disruptions, currency devaluation, and potential government spending increases. This increase in borrowing costs would discourage borrowing and encourage saving, thereby helping to dampen inflation. In addition, a higher key policy rate can also help make assets in the national currency more attractive, thereby potentially stopping capital outflows and stabilizing the exchange rate in economic uncertainty. This contributes to the macroeconomic stability and the strengthening of investor confidence in the Ukrainian economy.

Furthermore, an important component of a successful monetary policy is the trust of the population and its considerate actions. For that, NBU can do the following:

1. Provide *regular communication* with the population about the decisions regarding the monetary policy and their consequences for the economy in general and each individual separately. The financial sphere is a complicated topic, and for people without the respective education is hard to understand NBU actions and hard economic-based explanations (as inflation reports, for example). To make information more understandable for regular citizens, NBU should provide information in accessible language and clear explanations for the population through social media, and divide information by topic in small informative messages. In this way, individuals will receive a small portion of the information divided by topic, that resonates with their circumstances and interests.

2. To increase public support and trust, NBU should also provide *direct interactive engagement* with the public to foster a sense of inclusion and transparency. This can be realized through online forums, webinars, or Q&A sessions, where NBU representatives communicate with the public, and individuals can directly ask questions.

3. *Raising financial literacy* among the Ukrainian population can prompt individuals to make informed financial decisions, which is important for the efficient implementation of monetary policy. As a first step, NBU can collaborate with the Ministry of Education to implement lessons of financial literacy in the school program to teach children from a young age to effectively manage their finances and follow the economic sphere of their country. Next NBU can implement free online courses or workshops about financial literacy for the citizens to equip them with the necessary knowledge and skills.

An important task for the National Bank during the war is to keep the national currency stable, and an effective instrument for that task is investment involvement. Investment has many positive effects on the country's economy, particularly during the war, additional funds can support the development of new businesses or reconstruction of the destroyed ones, and create additional working places, foreign investment brings currency to the domestic economy, which strengthens the local currency. The

government and the NBU should actively work on creating a favorable investment climate, which can be done through simplifying administrative procedures, reducing bureaucracy, and improving the legal system. These measures will stimulate both national and foreign investors to invest in the Ukrainian economy. Additionally, the government and NBU can provide government guarantees (or insurance) for investment in certain sectors that are important for the Ukrainian economy, such as the energy sector, agroproduction, and IT, which will decrease the risk of war for domestic and foreign investors. In this way, investors will feel safer and be encouraged to invest money in the Ukrainian economy.

Another way to attract investments is promotion of the government bonds (OVDP), which not only bring profit to the owners of the securities but also help to support the Ukrainian economy and financial sector. NBU can use received from OVDP funds to regulate banking liquidity to ensure the stability of the banking sector, but also raising funds through OVDP may indicate to the population that the government has a clear plan for financing the war and post-war reconstruction, which may increase confidence in the Ukrainian economy in general. To attract more OVDS investors, NBU and the government should create a broad marketing campaign, that focuses on the income advantage for the citizens, low-risk investment, and help for the army. This campaign can increase trust in government bonds among the Ukrainian population, and as a result – demand for the OVDP.

The war brings one more risk for the banking sector, which is an increase in non-performing loans (NPL). The destruction of assets and collateral, and the drop in income reduce borrowers' ability to pay loans, consequently, banks have to recognize significant credit losses and increase deductions to reserves. An increase in NPLs can decrease trust in the banks or even lead to bankruptcy, which significantly destabilizes the economy. As a prevention method for this event, NBU can develop a plan of measures to encourage banks to manage NPLs and provide expert help for banks on this topic. For example, the NBU can develop an official online channel, where banks will have the possibility to apply for consultation from the NBU NPLs expert, which can assess the credit risk of the requested bank and if needed develop a plan for the bank on how to conduct balanced restructuring of the non-performing loans or another

suitable for this particular bank measure.

Furthermore, war – is an expensive event for the country, and a lot of resources are invested in defense. The main source to refill these resources is the country's economy, which functions through the businesses. But war brings destruction to the country, including the destruction of businesses, which negatively affects the economy. To help businesses recover NBU can implement targeted loan programs for businesses in important economic spheres (such as agriculture, energy, etc). With this type of loan businesses, affected by war, could take a loan from the NBU through government banks with a lower interest rate, simplified borrowing conditions, or prolonged payment period.

During the war number of people and businesses were forced to leave their homes and move to other Ukrainian regions, or abroad, but still many interactions between people and the government and NBU required the physical presence of the person in the assigned administrative office, which becomes a big challenge for displaced citizens and businesses, taking in account danger of being in administrative building during air alarm. NBU and the government already started many projects for the development of digital technologies, such as the registration of private entrepreneurs and tax payment online, the purchase of government bonds through bank applications and the Diya portal, or reimbursement for the destroyed buildings due to war. However, areas for development still exist to modernize and improve the work of NBU. For example, the central bank can use artificial intelligence (AI) technologies for analysis, fraud detection, and acceleration of routine processes. Additionally, NBU should develop a more secure protection system for ensuring data security and countering russian cyber attacks.

During the war, it is important to keep active cooperation with international partners, to ensure their support and share experiences in managing monetary policy during economic instability. International cooperation helps in creating mechanisms to support financial stability at the international level, which includes sharing information about risks and common challenges (liquidity crises and financial turbulence). Cooperation with international financial organizations and central banks of other countries increases trust in NBU in the international financial markets and the

Ukrainian economy as a whole. This can make Ukraine more attractive to foreign investors and ensure the stability of the national currency.

In conclusion, the Ukrainian monetary policy system since independence has been well-developed, which has led to significant stability of the monetary system, able to withstand such crises as war, the COVID-19 pandemic, and a full-scale invasion. However, despite these achievements, some areas need development. Improving monetary policy in Ukraine during a full-scale invasion presents complex challenges that require adaptive strategies to ensure stability and mitigate economic collapses. System dynamics modeling demonstrated the war's significant impact on the monetary system and economy, changing the leverage points that the NBU can use to influence market conditions. Therefore, based on this analysis, two policies were developed, focused primarily on ending the war, as this would significantly improve Ukraine's economic environment and allow for more effective implementation of the current monetary policy. However, the implementation of developed policy requires the involvement of foreign countries and a change in the intentions of the attacking party. In addition, econometric and statistical analyses revealed areas, that can be improved in the current monetary policy, in particular in response to increased risks of inflation due to the long-term conflict. The main priorities include the maintenance of a stable hryvnia and clear control over inflation, potentially requiring an adjustment of the key policy rate to contain inflationary pressure. In addition, building trust and understanding among the public is critical for the successful performance of monetary policy, which can be achieved through clear communication and NBU engagement initiatives. Attracting investment is an important focus of the monetary policy for stabilizing the national currency during the war. State guarantees for investments can create a favorable investment climate and stimulate both domestic and foreign investors. In addition, the promotion of government bonds (OVDP) can mobilize funds to finance the war and post-war reconstruction, as well as instill confidence in the Ukrainian economy. Addressing issues such as non-performing loans (NPLs) and supporting war-affected businesses requires targeted interventions and assistance programs. Active cooperation with international partners remains important to share experiences and provide support in managing monetary policy during times of

economic instability. Thus, continuous efforts to adapt and improve monetary policy strategies along with joint initiatives at both the national and international levels are imperative to overcome the challenges associated with the war and ensure the stability and prosperity of Ukraine's economy.

## Conclusions to Chapter 3

War in Ukraine brings formidable challenges to the effectiveness of NBU`s monetary policy. There are numerous risks, that still pose a challenge for the NBU, and require adaptivity and considerable decisions from the central bank actions. The multifaceted risks range from uncontrolled inflation with currency instability to disruptions of supply chains, and as the war persists, the resources are decreasing, which intensifies the economic vulnerability. The reliance on international financial aid can increase the burden of the government debt, which will negatively affect the economy in the future. Moreover, the outflow of the Ukrainians abroad further decreases income to the government budget, which only increases challenges for the NBU and government. The potential prolongation of the war not only escalates these risks, which even more complicates the conditions for the NBU decision making.

The most common and effective strategy to stabilize financial sector and curb inflation during the war is temporary fixation of the exchange rate, as evidenced by the experiences of Israel, Iraq, Georgia, Serbia, and Ukraine. The case of Britain during the First and Second World Wars shows the consequences for the economy in long perspective of the intensive borrowing and local currency emission to finance war expenditures, which results in debt burden. Experiences of Iran, Iraq, and Yugoslavia show consequences of excessive money printing as well, which led to hyperinflation and economic collapse in these countries. Prudent financial management in mitigating inflationary pressures with restrictive monetary policy in example of Croatia represents the successful case of the monetary policy during the war.

Despite all of the work in building an effective monetary system, that can withstand the crises, that NBU has done for the last three decades, the areas for

improvement still exist. System dynamic modeling showed a possible ending of the war and investing in the army defense can significantly improve the efficiency of the monetary policy instruments. Furthermore, econometric and statistical analyses have pinpointed areas for improvement, such as exercising precise control over inflation with a potential increase in the key policy rate to 18% in 2024. The analysis highlighted the importance of the population's trust in NBU actions, which can be strengthened through transparent communication and engagement initiatives by the NBU. Attraction of investment with government guarantees can have a positive effect on the financial sector as well. From the domestic side, promoting government bonds (OVDP) can mobilize funds for financing the war, instilling confidence in the Ukrainian economy. To support issues with NPLs and war-affected businesses NBU can use targeted interventions and assistance programs. Furthermore, it is highly important to keep active collaboration with international partners to share experiences in managing monetary policy during economic instability.

Thus the war in Ukraine significantly challenges the NBU’s monetary policy and requires adaptive and decisive actions. To overcome the challenges caused by the war and ensure the stability and prosperity of Ukraine's economy NBU has to continue to adapt and improve monetary policy strategies along with concerted initiatives at both the national and international levels.

# CONCLUSIONS

Effective monetary policy is an important component for the functioning economy, and NBU is an important player in the Ukrainian economic system, which responsibility is to protect the stability and development of the country`s economy. To fulfil its duties, NBU follows three goals with the use of various monetary policy instruments, such as key policy rate, currency interventions, bank reserves requirements etc. The primary goal is price stability, and monetary policy is to maintain low and follows the third goal, which is sustainable economic growth.

NBU went through a long way of developing and improving its monetary policy during the history of independence, which was affected by various challenging factors. During the time of economic instability, NBU works under the additional pressure, which raises the responsibility for each decision. In the crisis conditions, the regular monetary mechanisms lose its effectiveness, and NBU have to adapt and change directions of its policy directions. Introduction of the hryvnia in 1996, attempts at inflation targeting reform from 2000 to 2008, challenges related to the global financial crisis from 2009 to 2014, and the adoption of inflation targeting in 2015 and fixed exchange rate in 2022 and other methods were used by NBU to maintain functioning economy during crisis events.

Full-scale invasion in 2022 possesses new, unseen before, challenge for the central bank, so emergency measures were taken. From the first days NBU fixed exchange rate, which served the role of a stabilizer during the crisis. With the next steps, NBU provided temporary support for the government budget through purchase of government bonds, raising the reserve requirements for the banks and significant increase in key policy rate. Implemented measures proved to be effective and slowed down the economic downturn, despite the expectations.

Use of system dynamic instruments revealed that war puts additional pressure on all economic elements, and results in devaluation of local currency, big government debt, significant decline in GDP, high inflation, and the last one is especially hard affecting the population of the country. Study proved, that during the war time, safety becomes a key factor, which prevents economy from failure. Scenario simulation

allowed to better understand the sharp contrast between wartime and peacetime conditions. The changes, caused by the war, also were revealed through the statistical analysis. The invasion brough disruptions to supply chains, increased business costs, and physical damage to infrastructure, however the NBU managed to stabilize inflation by actively implementing currency interventions on the exchange markets and adjusting the key policy rate. These efforts increased trust in NBU among the Ukrainian population, which helped to gradually reduce inflation and stabilize the economic environment despite the crisis.

Econometric modeling predicts the GDP gap and inflation increase by the end of 2024, which, according to Taylor`s rule, the key policy rate must increase to 18% in 2024. The analysis also highlighted the importance of the exchange rate in the war-impacted environment and, the dynamic relationship between the key policy rate and exchange rate, which affects the monetary policy decision-making. Additionally, the forecast predicts a continued slow depreciation of the hryvnia to a possible 38.1 hryvnias/dollar by the end of 2024.

The war in Ukraine creates significant challenges for the NBU's monetary policy, which requires adaptive and decisive actions. Risks, caused by the war, include uncontrolled inflation with currency instability, disruptions of supply chains, reliance on international help, the outflow of human capital abroad, continuation of the war, etc., which complicates the NBU decision-making process.

Temporary fixation of the exchange rate, the most common and effective strategy to stabilize the financial sector and curb inflation during the war, was a strategy, used by Israel, Iraq, Serbia, and Ukraine. Historical examples of Great Britain during the World Wars, show the long-term consequences of intense borrowing and currency issuance. Similarly, active money printing in Iran, Iraq, and Yugoslavia led to hyperinflation and economic collapse, which was opposed to Croatia, whose restrictive monetary policy is a successful example of wartime inflation management.

Despite its achievements, the NBU still has areas, which can be improved to build a more resilient monetary system. Investments in defense and ending war can significantly improve the effectiveness of monetary policy, according to system dynamic analysis. Precise control for inflation with its adjustment with the use of key

policy rate, and strengthening public confidence through transparent communication are important factors on the way of the improvement. Additionally, NBU can focus on attracting investment through government guarantees, promoting government bonds, and supporting war-affected businesses, which will positively affect the economy. During the war is also important to continue cooperation with international partners to share experience in monetary policy and engage support from other countries.

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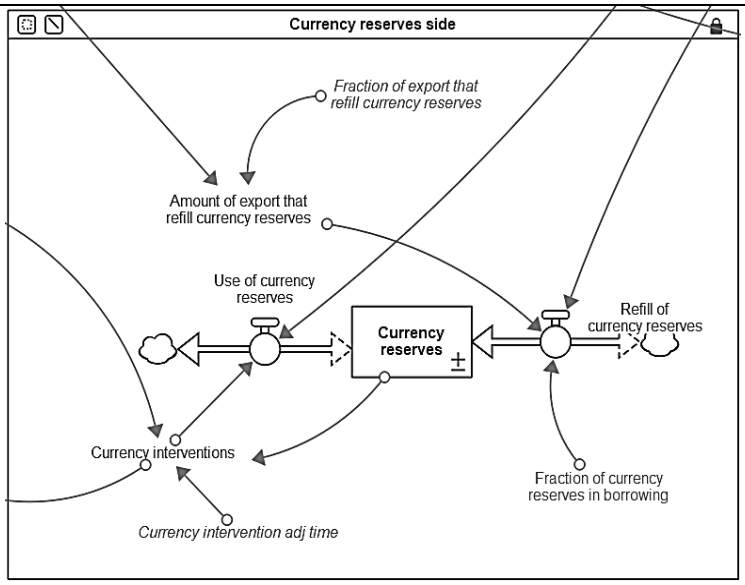
# ANNEX A

## Model documentation with model structure




Amount_of_export_that_refill_currency_reserves = Fraction_of_export_that_refill_currency_reserves*Export
UNITS: UAH/month
*Document:*
This variable represents which part of the income from the export goes to refill the currency reserves and is calculated as a multiplication of the fraction of the export that refills currency (basically the share of future currency reserves in export) on total income from export.

Currency_intervention_adj_time = 3
UNITS: months
DOCUMENT:
Application of the currency interventions is not happening right away, according to the Strategy of the National Bank of Ukraine (2023) the effect from the use of currency interventions is presented in the economy only after the quarter of the use, consequently - 3 months.

Currency_interventions = MAX(Currency_reserves*(Exchange_rate_gap-1)/Currency_intervention_adj_time, 0)
UNITS: UAH/month
DOCUMENT:
The exchange rate gap defines the necessity for the Central Bank to use currency interventions to lower the exchange rate on the market. Such as the exchange rate gap is calculated as a ratio of the real exchange rate/central bank exchange rate, which is supposed to be 1, so to calculate the needed amount of the intervention from the gap we minus 1. Such as currency reserved does not give effect right away (as it was mentioned above), so the formula divided by adjustment time. Currency interventions in Ukraine can not be negative (the Central Bank only adds currency to the economy, not takes it back), consequently, the MAX formula was used.

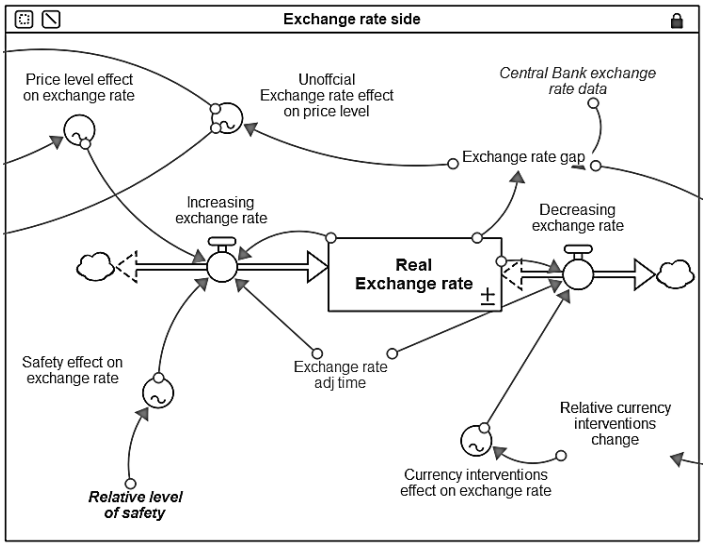
Currency_reserves(t) = Currency_reserves(t - dt) + (Refill_of_currency_reserves - Use_of_currency_reserves) * dt
INIT Currency_reserves = Initial_currency_reserves
UNITS: UTAH
DOCUMENT:
Currency reserves are the accumulated amount of international currency, which is used by the Central Bank to regulate the amount of currency on the market, and as a result - the exchange rate.

Fraction_of_currency_reserves_in_borrowing = 0.3
UNITS: Dimensionless
DOCUMENT:
Part of the funds, which were borrowed from foreign partners, goes to currency reserves to fill it, and according to the National Bank Report (2022), this part is 30%.

Fraction_of_export_that_refill_currency_reserves = 0.1
UNITS: Dimensionless
DOCUMENT:
Part of the income from export income goes to the currency reserves, and during the analysis, this value was calibrated to 10%.

Inflow
Refill_of_currency_reserves =
Borrowing*Fraction_of_currency_reserves_in_borrowing+Amount_of_export_that_refill_currency_reserves
UNITS: UAH/month
DOCUMENT:
The refill of the currency reserves is happening through the inflow of currency into the country from abroad, in particular from the income from exports and borrowing from international partners.

Outflow
Use_of_currency_reserves = Debt_payment+Currency_interventions
UNITS: UAH/month
DOCUMENT:
The National Bank of Ukraine uses currency reserves to cover debt payments for foreign government debt (if there are not enough funds in the government budget) and on currency interventions in the market to regulate the exchange rate.




Currency_interventions_effect_on_exchange_rate = GRAPH
UNITS: Dimensionless

DOCUMENT:
The variable shows the effect of the change of the currency interventions on the exchange rate. The presented effect is developed by the author based on the National Bank Strategy (2023). The effect is assumed to be linear. When there is no change in currency interventions (1), the currency intervention effect becomes 1, which means no change in the exchange rate. When the amount of currency interventions in the economy is growing, the effect on the exchange rate is going proportionately and otherwise is true, reaching a maximum at point 2.

OUTFLOW:
Decreasing_exchange_rate =
Real_Exchange_rate*Currency_interventions_effect_on_exchange_rate/Exchange_rate_adj_time
UNITS: UAH/month
DOCUMENT:
This equation models the real exchange rate by factoring in the impact of currency interventions and how the exchange rate changes with a certain delay, which represents how the exchange rate changes over time due to various factors such as market forces, economic conditions, government policies, or interventions.

Exchange_rate_adj_time = 3
UNITS: month
DOCUMENTS:
Formation of the exchange rate requires a certain period to adjust to the change in the economic environment, consequently a quarter of the year as an average adjustment time based on the National Bank Reports (2021-2023).

Exchange_rate_gap = Real_Exchange_rate/Central_Bank_exchange_rate_data
UNITS: Dimensionless
DOCUMENT:
This equation calculates the exchange rate gap by comparing the real exchange rate and defined by the Central Bank exchange rate. It measures the difference or disparity between the actual exchange rate and the rate reported by the Central Bank.

INFLOW
Increasing_exchange_rate =
MAX((Price_level_effect_on_exchange_rate+Safety_effect_on_exchange_rate),0)*Real_Exchange_rate//Exchange_rate_adj_time
UNITS: UAH/month
DOCUMENT:
This equation models the increase in the exchange rate, factoring in the impact of price level and safety on the exchange rate. It determines the potential rise in the exchange rate, considering these effects and the current real exchange rate over a specified adjustment time. The equation is defined as positive (increase; inflow), so when the effect from the combination of the factors is positive, then the inflow increases the exchange rate, when the combination is negative - then 0.

Price_level_effect_on_exchange_rate = GRAPH(Price_level/100)
Points: (0.900, 0.000), (1.010, 0.100), (1.120, 0.200), (1.230, 0.300), (1.340, 0.400), (1.450, 0.500), (1.560, 0.600), (1.670, 0.700), (1.780, 0.800), (1.890, 0.900), (2.000, 1.000)
UNITS: Dimensionless
DOCUMENT:
This parameter shows the dependency of the exchange rate on the change in the price index. The effect is assumed to be linear. If the price level remains at the same level (stable; 1), then the normal effect on the exchange rate remains at level 0.5. If the price index is growing (>1), then the exchange rate is growing due to a destabilized situation in the market. If the price level is decreasing (<1), then the exchange rate will be decreasing as well.

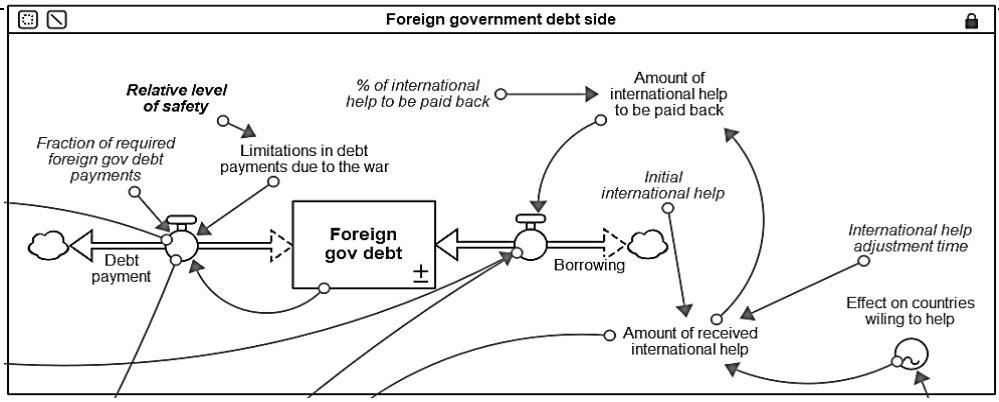
Real_Exchange_rate(t) = Real_Exchange_rate(t - dt) + (Increasing_exchange_rate - Decreasing_exchange_rate) * dt
INIT Real_Exchange_rate = Initial_Real_Exchange_rate
UNITS: UAH
DOCUMENT:
The real exchange rate represents how much costs 1 USD compared to local currency (UAH) on the market.

Relative_currency_interventions_change = Currency_interventions//INIT(Currency_interventions)
UNITS: Dimensionless
DOCUMENT:
The variable represents how much the amount of used currency interventions changed compared to initial currency interventions in January 2021.

Safety_effect_on_exchange_rate = GRAPH(Relative_level_of_safety)
Points: (0.000, 3.000), (0.100, 2.700), (0.200, 2.400), (0.300, 2.100), (0.400, 1.800), (0.500, 1.500), (0.600, 1.200), (0.700, 0.900), (0.800, 0.600), (0.900, 0.300), (1.000, 0.000)
UNITS: Dimensionles
DOCUMENT:
This effect level of safety has on the exchange rate and is assumed to be linear. When the safety level is at its maximum (1, indicating a safe environment), there's no influence on the exchange rate; it remains unaffected. However, as the safety level diminishes, it triggers a proportional surge in the demand for international currency. This heightened demand directly contributes to the escalation of the exchange rate, potentially increasing it by a factor of up to 3 as the safety level declines.

Unoffcial_Exchange_rate_effect_on_price_level = GRAPH(Exchange_rate_gap)
Points: (0.9000, 0.000), (0.9250, 0.500), (0.9500, 1.000), (0.9750, 1.500), (1.0000, 2.000), (1.0250, 2.500), (1.0500, 3.000), (1.0750, 3.500), (1.1000, 4.000), (1.1250, 4.500), (1.1500, 5.000)
UNITS: Dimensionless

DOCUMENT:
The preserved effect represents how the difference between real exchange rate affect the price level. If the exchange rate gap is absent (Central bank exchange rate = Real exchange rate), then the effect on prices remains 2 - normal conditions. If the gap is growing (Central bank exchange rate<Real exchange rate), then the effect on price level is growing, the economy is destabilized due to differences in exchange rates, and more operations happening on the market, which increases prices. If the gap is decreasing from equilibrium (Central bank exchange rate>Real exchange rate), then the effect on price level is lower, and operations on the market of buying/selling currency are driven by other factors, not the exchange rate.




"%_of_international_help_to_be_paid_back" = 0.5
UNITS: Dimensionless
DOCUMENT:
Part of the international help is received by Ukraine in the form of a loan and has to be paid back to the foreign partners. This fraction of the international help, that has to be paid back is estimated at 0.5 level in the currency modeling environment.

Amount_of_international_help_to_be_paid_back = Amount_of_received_international_help*"%_of_international_help_to_be_paid_back"
UNITS: UAH/month
DOCUMENT:
As it was stated above, part of the international help has to be paid back to the international partner, and this share calculated as the total amount of received international help multiplied by the fraction of international help, that has to be paid back.

Amount_of_received_international_help = SMTH1(Effect_on_countries_wiling_to_help*Initial_international_help, International_help_adjustment_time) {DELAY CONVERTER}
UNITS: UAH/month
DOCUMENT:
The equation in system dynamics represents the model for estimating the total aid received from international sources over time. This equation uses the SMTH1 function to calculate the cumulative effect of influencing factors on the willingness of countries to assist, scaled by the initial amount of international help pledged. The International_help_adjustment_time parameter governs the time it takes for the system to adjust to changes in these influencing factors. The {DELAY CONVERTER} indicates that the output of this equation goes through a delay converter, which accounts for any lag or delay in the response or receipt of international aid due to bureaucratic processes, negotiations, or logistical considerations. Ultimately, this equation captures the dynamic interaction between factors affecting international support and the resulting flow of aid into the country.

INFLOW
Borrowing = Budget_gap+Amount_of_international_help_to_be_paid_back
UNITS: UAH/month
This equation in system dynamics represents borrowing within the model. It considers the budget gap, which is the deficit between government revenues and expenses, along with the amount of international help that is yet to be repaid.

OUTFLOW
Debt_payment = SMTH1(Fraction_of_required_foreign_gov_debt_payments*Foreign_gov_debt*Limitations_in_debt_payments_due_to_the_war, 1)
UNITS: UAH/month
DOCUMENT:
Regularly government has to make certain debt payments to decrease government debt. The amount of required payments is calculated as a % of required government payments per month multiplied by the total amount of foreign government debt. During the war economy of the country is under pressure, thus the amount of required debt payments is decreasing during the war on the basics of agreements with international partners.

Effect_on_countries_wiling_to_help = GRAPH(Relative_level_of_safety)
Points: (0.000, 40.00), (0.100, 39.51), (0.200, 38.31), (0.300, 35.46), (0.400, 29.56), (0.500, 20.50), (0.600, 11.44), (0.700, 5.545), (0.800, 2.693), (0.900, 1.493), (1.000, 1.00)
UNITS: Dimensionless

DOCUMENT:
The effect shows how changes in safety conditions influence foreign countries' willingness to assist. When the country is safe (at a safety level of 1), international help remains stable. As safety decreases slightly, countries start considering aid, but as the situation worsens and the population suffers, there's a rapid increase in the desire to aid the defending country. However, there's a limit to the help capacity. At a certain safety threshold, the effect reaches its maximum and remains constant, implying that beyond this point, despite worsening safety, the level of external assistance won't increase further due to capacity constraints

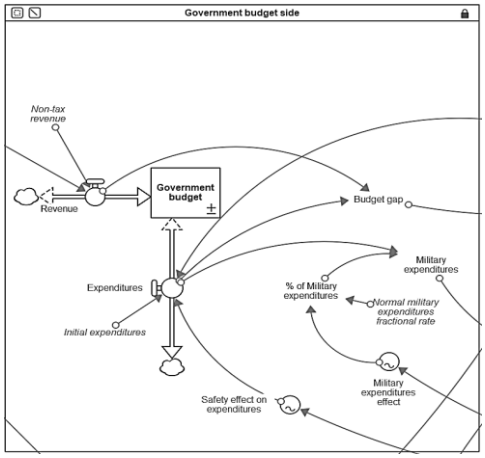
Foreign_gov_debt(t) = Foreign_gov_debt(t - dt) + (Borrowing - Debt_payment) * dt
INIT Foreign_gov_debt = Initial_foreign_government_debt_data
UNITS: UAH
DOCUMENT:
Foreign government debt represents the total amount of funds borrowed by the Ukrainian government from foreign partners and has to be paid back. With the borrowing, debt is increasing and debt payments lead to a decrease in government debt.

Fraction_of_required_foreign_gov_debt_payments = 0.1
UNITS: Dimensionless/month
DOCUMENT:
The share of foreign government debt is agreed upon with international partners during the borrowing process and defined by the government during the budget creation process. During normal conditions, the share of debt payments is 10% of foreign government debt.

Initial_international_help = 100000000000
UNITS: UAH/month
DOCUMENT:
The war in Ukraine started in 2014 and was located only in the Eastern part of the country, so regularly country was receiving international help from foreign partners.

International_help_adjustment_time = 3
UNITS: Months
DOCUMENT:
The process of approving and transferring international help from foreign countries to Ukraine takes time, and on average ukraine receives international help within 3 months after the start of the negotiation process.

Limitations_in_debt_payments_due_to_the_war = IF(Relative_level_of_safety<1)THEN 0.7 ELSE 1
UNITS: Dimensionless
DOCUMENT:
During the war economy of the country suffered from high pressure, and the government limits the amount of government payments to retain stability in the market, that amount of limitation is negotiated with international partners and usually stays at 70%.




"%_of_Military_expenditures" = Military_expenditures_effect*Normal_military_expenditures_fractional_rate
UNITS: Dimensionless
DOCUMENT:
The share of the military expenditures by the need in their use and calculated by multiplying the normal military expenditures fractional rate by the effect from the safety situation of the country.

Budget_gap = Expenditures-Revenue
UNITS: UAH/month
DOCUMENT:
The budget gap represents the variance between expenditures and revenues, indicating whether the government budget holds enough funds to cover necessary expenses. When a gap exists, it must be filled through borrowing.

Expenditures = Debt_payment+Initial_expenditures*Safety_effect_on_expenditures
UNITS: UAH/month
DOCUMENT:
The equation encapsulates how the Ukrainian budget's total expenses are determined. Debt payment stands for the allocation dedicated to repaying existing debts, a crucial aspect of financial obligations. Meanwhile, initial expenditures, representing the baseline or pre-adjustment spending, get multiplied by the safety effect on expenditures, an indicator of how safety conditions influence budgetary needs. This equation essentially demonstrates how safety levels directly impact the overall expenditure scale: increased safety might reduce expenses, while decreased safety could escalate the need for additional spending to address safety concerns and related measures.

Government_budget(t) = Government_budget(t - dt) + (Revenue - Expenditures) * dt
INIT Government_budget = 0
UNITS: UAH
DOCUMENT:
The government budget represents the accumulated amount of funds, which are used for the country's functioning purposes. The equation's elements include Revenue and Expenditures, representing the incoming and outgoing financial streams respectively.

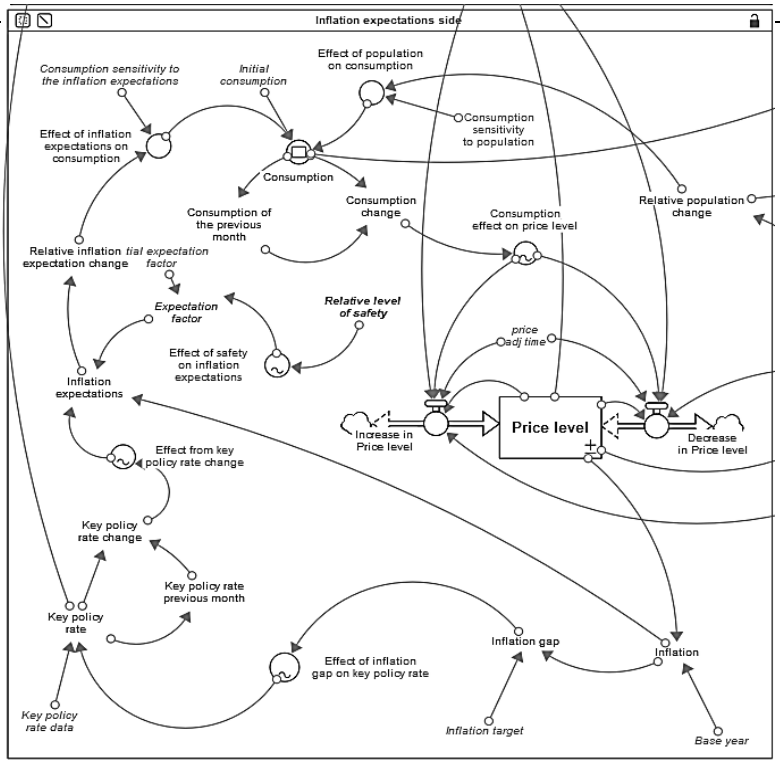
Military_expenditures = SMTH1(Expenditures*"%_of_Military_expenditures", 1)
UNITS: UAH/month
DOCUMENT:
The function takes into account the percentage of total expenditures allocated specifically to military purposes. This equation represents a dynamic process where military spending depends on the overall budget and a specified proportion allocated for defense-related expenses. As a result, fluctuations or changes in total government expenditures or the designated portion for the military would influence the military expenditure levels.

Military_expenditures_effect = GRAPH(Relative_level_of_safety)
Points: (0.000, 8.000), (0.100, 7.796), (0.200, 7.539), (0.300, 7.217), (0.400, 6.812), (0.500, 6.304), (0.600, 5.665), (0.700, 4.863), (0.800, 3.855), (0.900, 2.590), (1.000, 1.000)
UNITS: Dimensionless
DOCUMENT:
When the level of safety in the country is at 1 (total safety), there is no need to invest more money in military expenditures, then requires a minimum to support defense capacity on a satisfying level. It is assumed that this effect increases decreasingly while the level of safety goes down. If there is a threat, more money needs to be invested in the army to improve defense capability enough to destroy flying missiles. As more threads, more money has to be invested in air defense to provide safety.

Normal_military_expenditures_fractional_rate = 0.1
UNITS: Dimensionless
DOCUMENT:
In regular conditions, 10% of the government expenditures in Ukraine are invested in the army.

Revenue = SMTH1(Taxes_paid+"Non-tax_revenue", 1)
UNITS: UAH/month
DOCUMENT:
The equation signifies the estimation of the government budget's total revenue. This equation consolidates two fundamental sources of government income: taxes paid by individuals and entities, combined with non-tax revenues, such as fees, royalties, or other government-generated incomes. The SMTH1 function processes and aggregates these diverse revenue streams, resulting in the calculated total revenue available for the government budget. This formula implies that the budget's financial health directly correlates with the cumulative income derived from tax and non-tax sources, thereby impacting the government's ability to finance its operations, initiatives, and services within the specified timeframe. Any variations or shifts in tax collection or non-tax revenue generation would consequently affect the total revenue allocation for the government budget.

Safety_effect_on_expenditures = GRAPH(SMTH1(Relative_level_of_safety, 1))
Points: (0.000, 3.000), (0.100, 2.800), (0.200, 2.600), (0.300, 2.400), (0.400, 2.200), (0.500, 2.000), (0.600, 1.800), (0.700, 1.600), (0.800, 1.400), (0.900, 1.200), (1.000, 1.000)
UNITS: Dimensionless
DOCUMENT:
The effect represents how the level of safety affects the amount of total expenditures of the government budget. If the level of safety is 1, then the effect is also 1, which means that the country is functioning in a normal way and a normal amount of expenditure is needed. But when the level of safety in the country decreases, it puts additional pressure on the economy, so the government budget has to spend more money to keep the country functioning stable.




Base_year = 100
UNITS: Dimensionless
DOCUMENT:
This parameter represents the normal value of the price index, which is 100%.

Consumption =
DELAY1(Initial_consumption*(Effect_of_inflation_expectations_on_consumption+Effect_of_population_on_consumption), 3, Initial_consumption) {DELAY CONVERTER}
UNITS: UAH
DOCUMENT:
The equation represents the estimation of total consumption within the country. It uses the DELAY1 function to calculate the delayed effect of multiple factors influencing consumption: the impact of inflation expectations and population changes on the overall consumption pattern. The initial consumption establishes the baseline level of consumption, while the delay of 3 signifies the time it takes for changes in these factors to manifest in altering consumption patterns. The delay specifies that the output of this equation passes through a delay converter, accounting for any delay in observing the real impact on consumption due to behavioral shifts or market responses. This equation captures the dynamic relationship between various factors affecting consumer behavior and the resultant changes in total consumption levels over time.

Consumption_change = (Consumption-Consumption_of_the_previous_month)/Consumption_of_the_previous_month
UNITS: Dimensionless
DOCUMENT:
Consumption_change calculates the month-to-month variation in consumption within the system. It derives this change by subtracting the previous month's consumption from the current month's consumption and then dividing the result by the previous month's consumption. This formula figures out how much consumption changes from one month to the next. It helps understand if people are spending more or less and how big those changes are.

Consumption_effect_on_price_level = GRAPH(Consumption_change)
Points: (0, 0.000), (0.0006, 0.500), (0.0012, 1.000), (0.0018, 1.500), (0.0024, 2.000), (0.003, 2.500), (0.0036, 3.000), (0.0042, 3.500), (0.0048, 4.000), (0.0054, 4.500), (0.006, 5.000)
UNITS: Dimensionless
DOCUMENT:
Consumption linearly affects the price level through the consumption effect. If consumption stays on the same level (change in consumption is 0), then there is no impact performed on the price level from the consumption side (effect = 0). If consumption is growing (consumption change>0), it causes higher demand on the market, which increases the level of prices in the country, and as higher consumption - as more strong the effect. If consumption is decreasing (consumption change<0), then the level of prices is decreasing, which is caused by the negative consumption effect.

Consumption_of_the_previous_month = PREVIOUS(Consumption, 3890000000000)
UNITS: UAH
DOCUMENT:
This equation calculated the amount of consumption in the previous month.

Consumption_sensitivity_to_population = 1
UNITS: Dimensionless
DOCUMENT:
This parameter shows by how many percentage points in monthly terms a positive 1% of the population increases consumption. In this case, consumption increases/decreases proportionally to population.

Consumption_sensitivity_to_the_inflation_expectations = 0.15
UNITS: Dimensionless
DOCUMENT:
This parameter shows by how many percentage points in monthly terms a positive 1% of the inflation expectations increase consumption. In this case, this parameter is estimated to be equal to 0.15 for consumption which is the most policy-relevant consumption component.

Decrease_in_Price_level = MAX(-(Consumption_effect+Unoffcial_Exchange_rate_effect_on_price_level)*(Price_goal-Price_level)//price_adj_time, 0)
UNITS: Dimensionless/month
DOCUMENT:
This equation calculates the potential decrease in the price level based on several factors. If the combined effect of consumption and the unofficial exchange rate on the price level is significant and pushes the actual price level below the targeted price, this equation captures that decrease. However, it only considers decreases greater than zero. If the calculated decrease is less than zero, meaning there's no significant impact, or if it suggests an increase, the equation shows no change in the price level.

Effect_from_key_policy_rate_change = GRAPH(SMTH1(Key_policy_rate_change, 1))
Points: (0.005, 0.000), (0.0053, 0.100), (0.0056, 0.200), (0.0059, 0.300), (0.0062, 0.400), (0.0065, 0.500), (0.0068, 0.600), (0.0071, 0.700), (0.0074, 0.800), (0.0077, 0.900), (0.008, 1.000)
UNITS: Dimensionless
DOCUMENT:
Key policy rate change has a positive linear effect on inflation expectations. If policy rate change is positive (key policy rate is growing), then inflation expectations of the population are increasing as well, because they expect that prices are going to grow. If the policy rate change is negative (the key policy rate is decreasing), then population inflation expectations are lowered.

Effect_of_inflation_expectations_on_consumption =
Relative_inflation_expectation_change*Consumption_sensitivity_to_the_inflation_expectations
UNITS: Dimensionless
DOCUMENT:
This variable shows an effect of the inflation expectations on consumption over time. It is assumed that the effect is linear.

Effect_of_inflation_gap_on_key_policy_rate =
GRAPH(Inflation_gap*Monetary_policy_sensitivity_to_the_inflation_gap)
Points: (0.00, 1.00), (6.00, 3.90), (12.00, 6.80), (18.00, 9.70), (24.00, 12.60), (30.00, 15.50), (36.00, 18.40), (42.00, 21.30), (48.00, 24.20), (54.00, 27.10), (60.00, 30.00)
UNITS: Dimensionless
DOCUMENT:
The National Bank of Ukraine reacts to an increase in inflation through the increase in the key policy rate through the inflation gap linear effect.

Effect_of_population_on_consumption = Consumption_sensitivity_to_population*Relative_population_change
UNITS: Dimensionless
DOCUMENT:
The effect gauges how changes in the population size affect consumption within the system. It calculates this impact by multiplying the sensitivity of consumption to population changes by the relative change in population size. If there's a notable change in the population and consumption is sensitive to these variations, this equation represents the resultant effect on overall consumption trends within the model.

Effect_of_safety_on_inflation_expectations = GRAPH(Relative_level_of_safety)
Points: (0.000, 3.000), (0.100, 2.800), (0.200, 2.600), (0.300, 2.400), (0.400, 2.200), (0.500, 2.000), (0.600, 1.800), (0.700, 1.600), (0.800, 1.400), (0.900, 1.200), (1.000, 1.000)
UNITS: Dimensionless
DOCUMENT:
The effect represents how change in safety affects inflation expectations. If the level of safety is 1, then there is no effect on the inflation expectations, the mechanism works regularly. When the level of safety decreases, people start to behave irrationally, and they increase their inflation expectations. The effect is considered linear.

Expectation_factor = Effect_of_safety_on_inflation_expectations*Initial_expectation_factor
UNITS: Dimensionless
DOCUMENT:
This equation captures the influence of safety on inflation expectations within the system dynamics model. It calculates an expectation factor by multiplying the initial expectation factor by the effect of safety on inflation expectations. As the safety level fluctuates, this equation represents how it impacts the inflation expectations factor, potentially altering the anticipated inflation rates within the model's framework.

INFLOW
Increase_in_Price_level = MAX((Consumption_effect+Unoffcial_Exchange_rate_effect_on_price_level)*(Price_goal-Price_level)//price_adj_time, 0)
UNITS: Dimensionless/month
DOCUMENT:
This equation determines the increase in the price level. It calculates the maximum value between zero and a computed expression, which includes the effects of consumption and the unofficial exchange rate on the price level. These effects are multiplied by the difference between the desired price goal and the current price level, divided by the price adjustment time. This equation captures how changes in consumption and the exchange rate, compared to the target price, contribute to potential increases in the overall price level over time within the model.

Inflation = Price_level-Base_year
UNITS: Dimensionless
DOCUMENT:
Inflation is calculated by subtracting the base year's price level from the current price level. The difference between these two values represents the inflation rate, which signifies the percentage change in prices over time.

Inflation_expectations = Expectation_factor*(Effect_from_key_policy_rate_change)*Inflation
UNITS: Dimensionless
DOCUMENT:
This equation determines the level of inflation expectations by computing inflation expectations as a product of multiple factors: the expectation factor, the effect stemming from changes in the key policy rate, and the current inflation rate. These elements are multiplied together to gauge the expected inflation within the system. The expectation factor plays a significant role, acting as a multiplier to adjust and influence how changes in the key policy rate affect inflation expectations. By considering these interrelated components, the model captures the dynamic nature of how various factors contribute to forming expectations about future inflation rates within the system.

Inflation_gap = Inflation-Inflation_target
UNITS: Dimensionless
DOCUMENT:
The inflation gap represents the difference between the real inflation in the country and targeted by National Bank inflation.

Inflation_target = 5
UNITS: Dimensionless
DOCUMENT:
Ukraine accepted an inflation targeting regime, which involves setting the targeted inflation at a certain level. The National Bank of Ukraine determined targeting inflation at a 5% level.

Initial_expectation_factor = 1
UNITS: Dimensionless
DOCUMENT:
For modeling purposes, initial inflation expectations were defined at 1.

Key_policy_rate = INIT(Key_policy_rate_data)+Effect_of_inflation_gap_on_key_policy_rate
UNITS: Dimensionless
DOCUMENT:
This equation determines the key policy rate. It's composed of two primary components: the initial key policy rate and the effect of the inflation gap on the key policy rate. The effect of the inflation gap on the key policy rate serves as a modifier, influencing the key policy rate based on the discrepancy between the current inflation rate and a predefined inflation goal or target. This mechanism enables the model to simulate how changes in the inflation gap impact the adjustment of the key policy rate, reflecting the monetary policy's responsiveness to inflation dynamics.

Key_policy_rate_change = MAX((Key_policy_rate-Key_policy_rate_previous_month)//Key_policy_rate_previous_month, 0)
UNITS: Dimensionless
DOCUMENT:
This equation measures the percentage change in the key policy rate by comparing the current month's rate to the rate from the previous month.

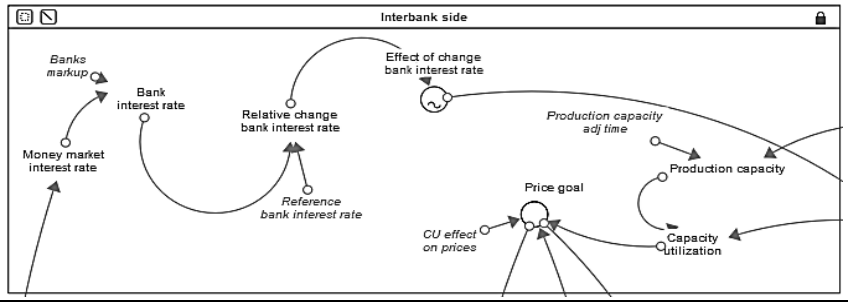
Key_policy_rate_previous_month = PREVIOUS(Key_policy_rate, 8)
UNITS: Dimensionless
DOCUMENT:
The equation calculated the key policy rate from the previous month.

price_adj_time = 1
UNITS: months
DOCUMENT:
The time it takes to update the price level. I assumed that it would take around 1 month to change the price level.

Price_level(t) = Price_level(t - dt) + (Increase_in_Price_level - Decrease_in_Price_level) * dt
INIT Price_level = Initial_price_index
UNITS: Dimensionless
DOCUMENT:
The price of a reference group of products is measured in units of national currency.

Relative_inflation_expectation_change = Inflation_expectations/INIT(Inflation_expectations)
UNITS: Dimensionless
DOCUMENT:
The variable measures the change in inflation expectations, compared to the initial value.

Relative_population_change = Population_living_in_Ukraine/INIT(Population_living_in_Ukraine)
UNITS: Dimensionless
DOCUMENT:
The variable measures the population change, compared to the initial value.




Bank_interest_rate = Money_market_interest_rate+Banks_markup
UNITS: Dimensionless
DOCUMENT:
The interest rate of Ukrainian banks uses a key policy rate to set the interest rate plus banks' markup - the additional percentage or spread that banks charge above this baseline rate when providing loans or credit to borrowers. Essentially, this equation combines these two components to determine the overall interest rate that banks offer or charge, influencing borrowing and lending activities within the economy.

Banks_markup = 3
UNITS: Dimensionless
DOCUMENT:
The bank`s markup ( the additional percentage or spread that banks charge above this baseline rate when providing loans or credit to borrowers) in Ukraine is 3.

Capacity_utilization = Produced_goods_and_services/Production_capacity
UNITS: Dimensionless
DOCUMENT:
Capacity utilization is the ratio between the produced goods and services and the production capacity. It indicates the level of productive output the economy is generating concerning its maximum potential. When the produced goods and services approach the maximum production capacity, the capacity utilization nears 100%, signifying optimal utilization of available resources. Conversely, if the produced goods and services fall below the production capacity, the utilization rate decreases, reflecting potential inefficiencies or underutilization of resources within the economy.

CU_effect_on_prices = 2
UNITS: Dimensionless
DOCUMENT:
The capacity utilization effect on prices was estimated at 2.

Effect_of_change_bank_interest_rate = GRAPH(Relative_change_bank_interest_rate)
Points: (0.000, 1.000), (0.400, 0.900), (0.800, 0.800), (1.200, 0.700), (1.600, 0.600), (2.000, 0.500), (2.400, 0.400), (2.800, 0.300), (3.200, 0.200), (3.600, 0.100), (4.000, 0.000)
UNITS: Dimensionless
DOCUMENT:
Interest rates have a negative linear effect on production - higher loan costs typically result in reduced production. Thus, if a relative change in bank interest rate is 0 (no change at all), production functioning as usual (1). But if the interest rate rises (relative change in bank interest rate>0), then production is decreasing.

Money_market_interest_rate = Key_policy_rate
UNITS: Dimensionless
DOCUMENT:
The money market rate interest rate is directly linked to the key policy rate set by the central bank.

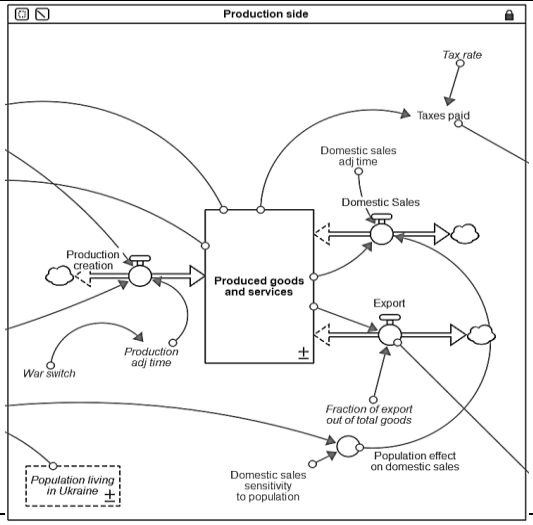
Price_goal = SMTH1(Price_level *(Capacity_utilization) ^CU_effect_on_prices, 2, Price_level)
UNITS: Dimensionless
DOCUMENT:
The price goal is based on the current price level and the impact of capacity utilization. The desired price level, referred to as the price goal, is determined by a smoothing function applied to the product of the current price level and the influence of capacity utilization raised to a certain power known as the capacity utilization effect on prices. The resulting value represents the target price level that the system aims to achieve, factoring in the level of capacity utilization's impact on pricing dynamics.

Production_capacity = SMTH1(Produced_goods_and_services, Production_capacity_adj_time, Produced_goods_and_services)
UNITS: UAH
DOCUMENT:
Production capacity is determined by the actual produced goods and services, the adjustment time for production capacity, and the initial value of produced goods and services. It implies that the model calculates production capacity by employing a smoothing process that considers the actual output of goods and services, adjusting this value over a defined time frame. This equation reflects how the system computes and adapts the production capacity over time based on the actual production levels.

Production_capacity_adj_time = 2
UNITS: month
DOCUMENT:
The time it takes to update production capacity. I assumed that it would take around 2 months to change production capacity.

Reference_bank_interest_rate = 10
UNITS: Dimensionless
DOCUMENT:
This is the bank interest rate at the start of 2021.

Relative_change_bank_interest_rate = Bank_interest_rate/Reference_bank_interest_rate
UNITS: Dimensionless
DOCUMENT:
Relative change in bank interest rates is calculated by dividing the current bank interest rate by a reference or baseline bank interest rate. It computes the deviation or relative shift of the current bank interest rate concerning a predetermined or benchmark interest rate.




OUTFLOW
Domestic_Sales = Population_effect_on_domestic_sales*Produced_goods_and_services/Domestic_sales_adj_time
UNITS: UAH/month
DOCUMENT:
Domestic sales represent the total sales of goods and services within a country's domestic market. The equation depicts the relationship between domestic sales and several influencing factors. The impact of population on domestic sales, suggests that a larger population tends to correlate with increased sales due to higher demand. The total output of goods and services generated within the country directly affects the potential for domestic sales.

Domestic_sales_adj_time = 2
UNITS: month
DOCUMENT:
The sales process happens through a certain period, starting from the storage and finishing with the customer purchase (with shipping, and time spent in the store). For the model, the time was adjusted to 2 months.

Domestic_sales_sensitivity_to_population = 1.7
UNITS: Dimensionless
DOCUMENT:
This parameter shows by how many percentage points in annual terms does a positive 1% of the population growth for the last year increased domestic sales. The sign is positive, because if the population grows, then domestic sales increase, because people start to buy more.

OUTFLOW
Export = Produced_goods_and_services*Fraction_of_export_out_of_total_goods
UNITS: UAH/month
DOCUMENT:
Part of the produced goods and services are shipping for sale abroad, in this way forming the export in the country.

Fraction_of_export_out_of_total_goods = .4
UNITS: Dimensionless/month
DOCUMENT:
According to the data, provided by the State Statistic Service of Ukraine, approximately 40% of the produced goods and services are exported abroad.

Population_effect_on_domestic_sales = Domestic_sales_sensitivity_to_population*Relative_population_change
UNITS: Dimensionless
DOCUMENT:
This variable shows the effect of the relative population change on domestic sales over time. It is assumed that the effect is linear.

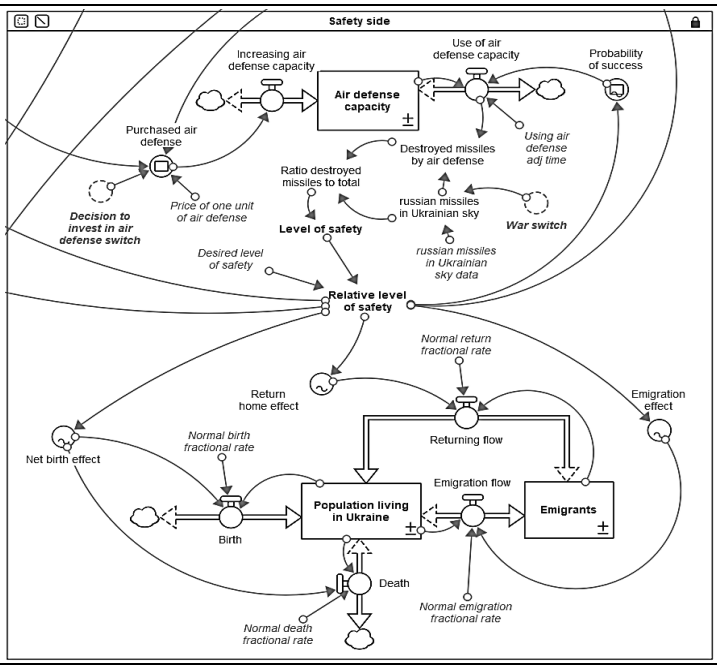
Produced_goods_and_services(t) = Produced_goods_and_services(t - dt) + (Production_creation - Domestic_Sales - Export) * dt
UNITS: UAH
INIT Produced_goods_and_services = Initial_Real_GDP
DOCUMENT:
Produced goods and services represent the stock value of all the produced goods and services in the country.

Production_adj_time = IF (War_switch=0) THEN 2 ELSE 1.5
UNITS: month
DOCUMENT:
The production process takes a certain period to create a good or service. In regular conditions, this time was adjusted to 2 months, but during the war, the demand for products rose (due to distractions), consequently, production had to work faster, and during the war, time was adjusted to 1.5 months.

INFLOW
Production_creation = Consumption*Effect_of_change_bank_interest_rate/Production_adj_time
UNITS: UAH/month
DOCUMENT:
Production creation depicts how the creation of goods and services is influenced by consumption demand, the impact of bank interest rate changes, and a time-adjusted factor. It illustrates that the rate of producing goods and services is directly linked to the level of consumption, while changes in bank interest rates affect this production rate. Additionally, the equation accounts for how production adjusts over time, capturing the gradual changes in production due to various economic or systemic shifts.

Tax_rate = .45
UNITS: Dimensionless/month
DOCUMENT:
In Ukraine from the production paid the following taxes:
- Income tax- 18%
- Single social contribution- 22%
- War tax - 1.5%
- Keal estate tax - 3.5%
In total - 45%

Taxes_paid = Produced_goods_and_services*Tax_rate
UNITS: UAH/month
DOCUMENT:
The amount of tax paid is a share of the total value of the produced goods and services.



Air_defense_capacity(t) = Air_defense_capacity(t - dt) + (Increasing_air_defense_capacity - Use_of_air_defense_capacity) * dt
INIT Air_defense_capacity = Initial_air_defense_capacity
UNITS: missiles
DOCUMENT:
Air defense capacity represents the total amount of air defense units, that are used for destroying the russian missiles

Birth = Population_living_in_Ukraine*Normal_birth_fractional_rate*Net_birth_effect
UNITS: People/Months
DOCUMENT:
Births are calculated by considering three main factors. "Population_living_in_Ukraine" represents the total number of people in the country, forming the base for potential births. "Normal_birth_fractional_rate" indicates the average birth rate under usual circumstances, establishing a baseline for expected births. The term "Net_birth_effect_from_war" signifies the negative influence of war on the birth rate, accounting for any changes in birth patterns due to the impacts of conflict, stress, or disruptions caused by wartime conditions.

Death = Population_living_in_Ukraine*Normal_death_fractional_rate*1/Net_birth_effect
UNITS: People/Months
DOCUMENT:
Death estimates the number of deaths in Ukraine based on three key factors. "Population_living_in_Ukraine" denotes the total population in the country, forming the basis for potential deaths. "Normal_death_fractional_rate" signifies the average death rate under typical conditions, establishing a baseline for expected deaths. The term "Net_birth_effect_from_war" represents the impact of war on mortality rates.

Destroyed_missiles_by_air_defense = MIN(Use_of_air_defense_capacity, russian_missiles_in_Ukrainian_sky)
UNITS: missiles/Months
DOCUMENT:
Destroyes missiles compute the number of russian missiles neutralized by Ukrainian air defense systems during air attacks. The function "MIN" calculates the minimum value between two parameters: "Use_of_air_defense_capacity," representing the extent of Ukrainian air defense capabilities utilized, and "russian_missiles_in_Ukrainian_sky," indicating the quantity of incoming russian missiles targeting Ukrainian airspace, because the number of destroyed missiles cannot be higher, then several russian missiles, even though the capacity of the army is higher.

Emigrants(t) = Emigrants(t - dt) + (Emigration_flow - Returning_flow) * dt
UNITS: People
INIT Emigrants = Initial_emigrants
DOCUMENT:
Emigrants represent a total number of Ukrainian emigrants abroad.

Emigration_effect = GRAPH(Relative_level_of_safety)
Points: (0.000, 6.000), (0.100, 5.500), (0.200, 5.000), (0.300, 4.500), (0.400, 4.000), (0.500, 3.500), (0.600, 3.000), (0.700, 2.500), (0.800, 2.000), (0.900, 1.500), (1.000, 1.000)
UNITS: Dimensionless
DOCUMENT:
The level of safety highly affects the emigration flow from the country. If level safety is one, the emigration process is happening as usual. If the level of safety is decreasing - people start to leave the country because they are afraid to stay in an unsafe environment.

Emigration_flow = Population_living_in_Ukraine*Normal_emigration_fractional_rate*Emigration_effect
UNITS: People/Months
DOCUMENT:
The emigration estimates the flow of immigrants from Ukraine based on three primary factors. "Population_living_in_Ukraine" represents the total population in the country, forming the base from which emigration might occur. "Normal_emigration_fractional_rate" signifies the average emigration rate under typical conditions, providing a baseline for expected emigration. The term "Emigration_effect_of_war" represents the impact of war on the emigration rate, accounting for increased emigration due to war-related factors such as insecurity, economic instability, or seeking safety in other regions or countries.

INFLOW
Increasing_air_defense_capacity = Purchased_air_defense
UNITS: missiles/Months
DOCUMENT:
To increase the air defense capacity government buys additional units of the air defense.

Level_of_safety = IF(Ratio_destroyed_missiles_to_total=0)THEN 1 ELSE Ratio_destroyed_missiles_to_total
UNITS: Dimensionless
DOCUMENT:
Level of safety measures how safety of the environment in the country (1 - safe environment, 0 - completely unsafe). The level of safety is measured by dividing the amount of destroyed missiles by the total amount of missiles. If no missiles are flying - then is a completely safe environment (1).

Net_birth_effect = GRAPH(Relative_level_of_safety)
Points: (0.000, 0.000), (0.100, 0.100), (0.200, 0.200), (0.300, 0.300), (0.400, 0.400), (0.500, 0.500), (0.600, 0.600), (0.700, 0.700), (0.800, 0.800), (0.900, 0.900), (1.000, 1.000)
UNITS: Dimensionless
DOCUMENT:
Safety highly affects the net birth in the country. If the level of safety is one, the birth/rate process in the country is happening regularly. If the level of safety is decreasing, then more people are dying and fewer people are born (people don't want to have children in unsafe environments), consequently the net birth is decreasing. The effect is assumed to be linear.

Normal_birth_fractional_rate = 0.003
UNITS: Dimensionless/month
DOCUMENT:
According to the data, provided by the State Statistic Service of Ukraine, the normal birth fractional rate in Ukraine is 0.3%.

Normal_death_fractional_rate = 0.023
UNITS: Dimensionless/month
DOCUMENT:
According to the data, provided by the State Statistic Service of Ukraine, the normal fraction death rate in Ukraine is 2.3%

Normal_emigration_fractional_rate = 0.01
UNITS: Dimensionless/month
DOCUMENT:
According to the data, provided on the State Statistic Service of Ukraine, the normal fractional rate in Ukraine is 1%.

Normal_return_fractional_rate = .079
UNITS: Dimensionless/month
DOCUMENT:
According to the data, provided by the State Statistics Service of Ukraine, the normal return fractional rate in Ukraine is 7.9%

Population_living_in_Ukraine(t) = Population_living_in_Ukraine(t - dt) + (Birth + Returning_flow - Emigration_flow - Death) * dt
INIT Population_living_in_Ukraine = Initial_population
UNITS: People
DOCUMENT:
The population living in Ukraine represents the total amount of people, living in Ukraine.

Price_of_one_unit_of_air_defense = 8000000000
UNITS: UAH/missiles
DOCUMENT:
The approximate price for one unit of air defense is estimated at 8 000 000 000 UAH.

Probability_of_success = GRAPH(DELAY1(Relative_level_of_safety, 2, 1))
Points: (0.000, 0.5000), (0.100, 0.5063), (0.200, 0.5217), (0.300, 0.5583), (0.400, 0.6338), (0.500, 0.7500), (0.600, 0.8662), (0.700, 0.9417), (0.800, 0.9783), (0.900, 0.9937), (1.000, 1.0000) {DELAY CONVERTER}
UNITS: Dimensionless
DOCUMENT:
The success in destroying missiles depends on the level of safety. Is the level of safety 1 - there is a 100% chance to destroy the missile. If the level of safety is decreasing, the probability of destroying missiles decreases as well, because of additional pressure, put on the people, responsible for the air defense, as more missiles in the sky - as more pressure is there

Purchased_air_defense = IF Decision_to_invest_in_air_defense_switch=1 THEN DELAY1((Military_expenditures+Amount_of_received_international_help)/Price_of_one_unit_of_air_defense, 3, Military_expenditures/Price_of_one_unit_of_air_defense) ELSE DELAY1((Military_expenditures+Amount_of_received_international_help)/Price_of_one_unit_of_air_defense, 3, Military_expenditures/Price_of_one_unit_of_air_defense)*0.1 {DELAY CONVERTER}
UNITS: missiles/Months
DOCUMENT:
To buy air defense in the model used military expenditures and received international help funds. To indicate the number of the air defense, that is possible to buy, we divide the total amount of funds, available for the purchase buy cost of one unit of air defense. During the Baseline scenario (Decision_to_invest_in_air_defense_switch=1), all of the mentioned funds are used for the purchase of air defense. During the "Deficient investment in air defense simulation scenario" (Decision_to_invest_in_air_defense_switch=0), only 10% of the available funds are invested in air defense.

Ratio_destroyed_missiles_to_total = Destroyed_missiles_by_air_defense//russian_missiles_in_Ukrainian_sky
UNITS: Dimensionless
DOCUMENT:
The ratio of the destroyed missiles represents the share of destroyed missiles out of the total amount.

| |
|---|
| Relative_level_of_safety = Level_of_safety/Desired_level_of_safety {DELAY CONVERTER}<br>UNITS: Dimensionless<br>DOCUMENT:<br>The relative level of safety shows the comparison of the level of safety in the country to the desired one. |
| Return_home_effect = GRAPH(Relative_level_of_safety)<br>Points: (0.000, 0.000), (0.100, 0.100), (0.200, 0.200), (0.300, 0.300), (0.400, 0.400), (0.500, 0.500), (0.600, 0.600), (0.700, 0.700), (0.800, 0.800), (0.900, 0.900), (1.000, 1.000)<br>UNITS: Dimensionless<br>DOCUMENT:<br>Level of safety in the country directly effects the willing of emigrants to return home. If the level of safety is 1 (totally safe), then the return rate is regurlar. If the level of safety is decreasing, less people are willing to return home because of the unsafe environment |
| Returning_flow = Emigrants*Normal_return_fractional_rate*Return_home_effect<br>UNITS: People/Months<br>DOCUMENT:<br>Returning flow is calculated through the multiplying the number of individuals who had previously left the country by the average rate at which emigrants return home under usual circumstances and the influence of war conditions on the propensity of emigrants to return to their home country. |
| russian_missiles_in_Ukrainian_sky = IF War_switch=1 THEN russian_missiles_in_Ukrainian_sky_data ELSE 0<br>UNITS: missiles/Months<br>DOCUMENT:<br>The variable represents total amount of russian, missiles, flying in Ukrainian sky. If there is a Baseline scenarion ("War switch" is on (1)), then the russian missiles = real data. Is the "No war" scenarion is on ("War switch" is off (0)), then no missiles is flying from russian side. |
| OUTFLOW<br>Use_of_air_defense_capacity = (Air_defense_capacity*Probability_of_success)/Using_air_defense_adj_time<br>UNITS: missiles/Months<br>DOCUMENT:<br>Use of air defense capacity models the utilization of air defense capacity for the destruction of russian missiles. The variable "Air_defense_capacity" represents the total capacity of the air defense system available. Multiplying this by "Probability_of_success," represents the likelihood of successful missile interception or defense, and provides an estimation of the effective use of the available air defense resources. Dividing this product by "Using_air_defense_adj_time" adjusts the time, nned to detec the missile ant destroy it. |
| Using_air_defense_adj_time = 1/15<br>UNITS: month<br>DOCUMENT:<br>The time between is needed between the detectionf the missile and its destruction. For the model this time was estimated at 1/15 month. |

# ANNEX B

## Validation tests for System-Dynamic model

***<u>Direct Structure Tests:</u>***

The structure of the economic part of the model is built based on the mentioned literature and reference mode behavior. The additional structure representing the safety side was hypothesized by me on the basics of personal experience and war outcome

data. The structure was considered realistic and was mentioned in the “Assumptions and Simplifications” part. Overall, the structure is appropriate for mode purposes and provides behavior insights. The parameters used in this model are consistent with the real-world system and were established based on findings from literature or through calibration. The model documentation contains a more extensive discussion regarding the specific values of constant parameters and their potential ranges. The model's units are dimensionally consistent with the equations, a verification corroborated by the Stella software utilized in this analysis. Direct extreme condition tests were conducted for all sub-structures of the partial model and did not reveal any unexpected and irrational behaviors in the outcomes.

***Behavior Pattern Tests***

The model reproduces behavior that is close to historical behavior patterns with certain deviations from the real data. A more detailed analysis regarding the replication of the real-world behavior pattern will described further.

***Structure-oriented Behaviour Tests***

After conducting tests using indirect extreme conditions, I added some elements to the model and made adjustments to the equations accordingly. Now, the model displays logical and sensible behavior under extreme conditions. The integration error test model was tested with different integration methods (Euler, RK4, RK2) and different time intervals (1/8,1/16,1/32, 1/64). All the runs showed reliable results, so the model was chosen DT 1/64 with the integration method Euler. Finally, a sensitivity analysis covered most of the exogenous parameters and table functions. The model is sensitive to the majority of the parameters. However, the fundamental behavior of the key performance indicators remained consistent or aligned with anticipated patterns, bolstering confidence in the model's reliability. Detailed results are presented in below.

***Sensitivity analysis***

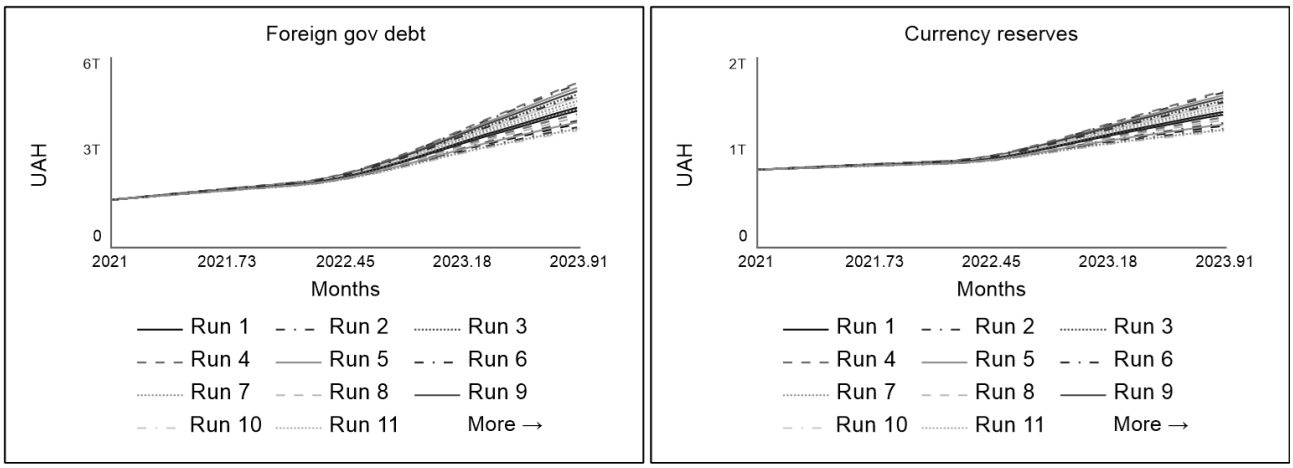
To better understand the model's parameters and equations, the sensitivity analysis was conducted on a sample of 10 important model parameters in the baseline scenario with 20 numbers of runs. Runs will be conducted for each parameter using Uniform Distribution.

***% of international help to be paid back***

Tested range: 0-1

Original value: 0.5

From a behavior point of view, the model is not sensitive to this parameter, but it is moderately sensitive from a numerical point of view. Especially sensitive in this case the Foreign government debt and currency reserved, which are directly impacted by this variable, that is expected. As more international help Ukraine receives over time, a higher range of the fluctuation of the chosen KPIs becomes.

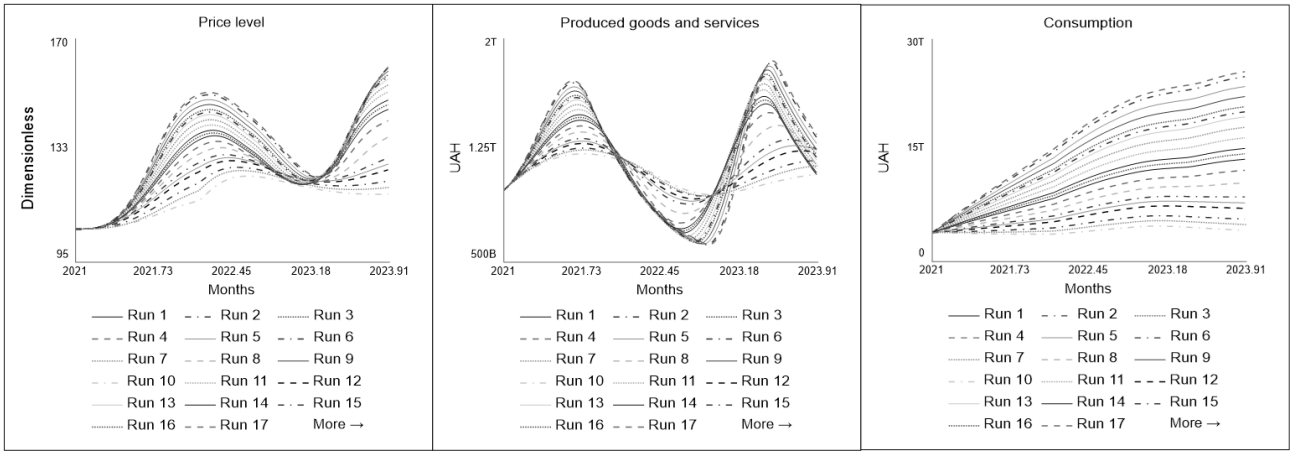



***Consumption sensitivity to population***

Tested range: 0-10

Original value: 1

During this run model showed numerical sensitivity to “Consumption sensitivity to population” The behavior showed high numerical sensitivity, Although the behavior pattern stays very similar throughout the test, numerical differences are impressive. This is expected because the population creates consumption, so consumption is highly dependent on the people. Also, consumption affects the level of prices in the country, as it was described above, and gives the signal for production.

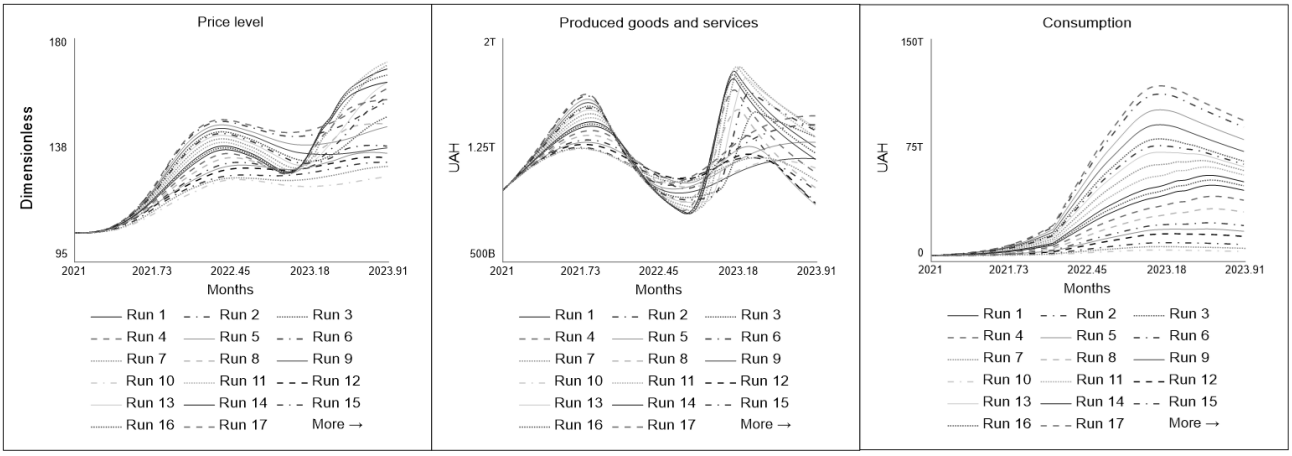



***Consumption sensitivity to inflation expectations***

Tested range: 0-5

Original value: 0.15

The model is very sensitive to this parameter in both numerical and behavioral ways. Inflation expectations highly impact the demand for products, which highly affects consumption. s parameter is considered to be a possible leverage point, even though perfectionistic behaviors are very difficult to change.

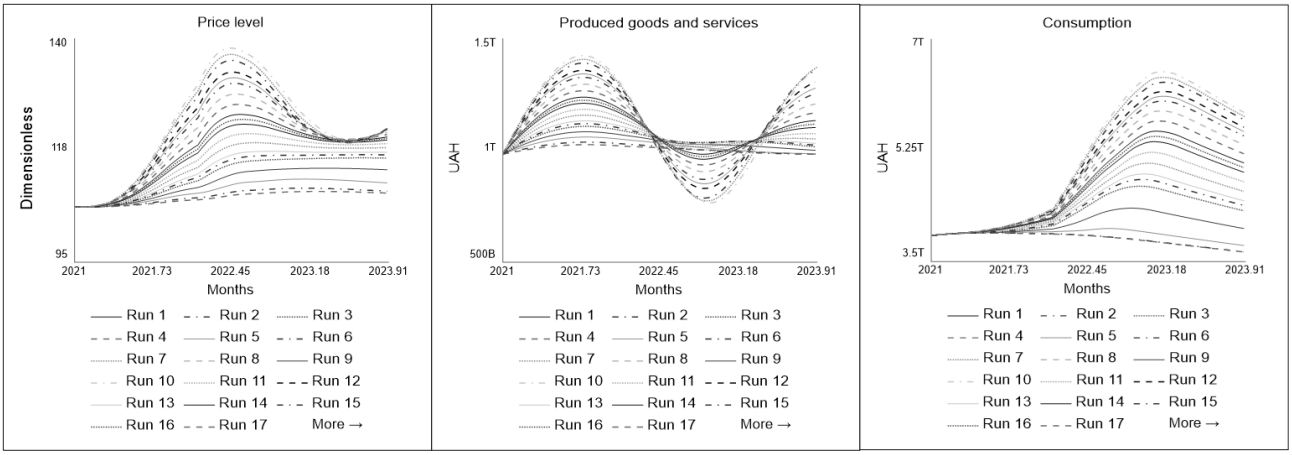



***Fraction of export out of total goods***

Tested range: 0-1

Original value: 0.4

The model is sensitive to this parameter. Although behavioral pattern stays mostly very similar, except for some runs where productivity is not coming up again at all, numerical changes are observable. Produced goods can be sold abroad, or consumed on the local market, so one excludes the other, that’s why sensitivity is present.

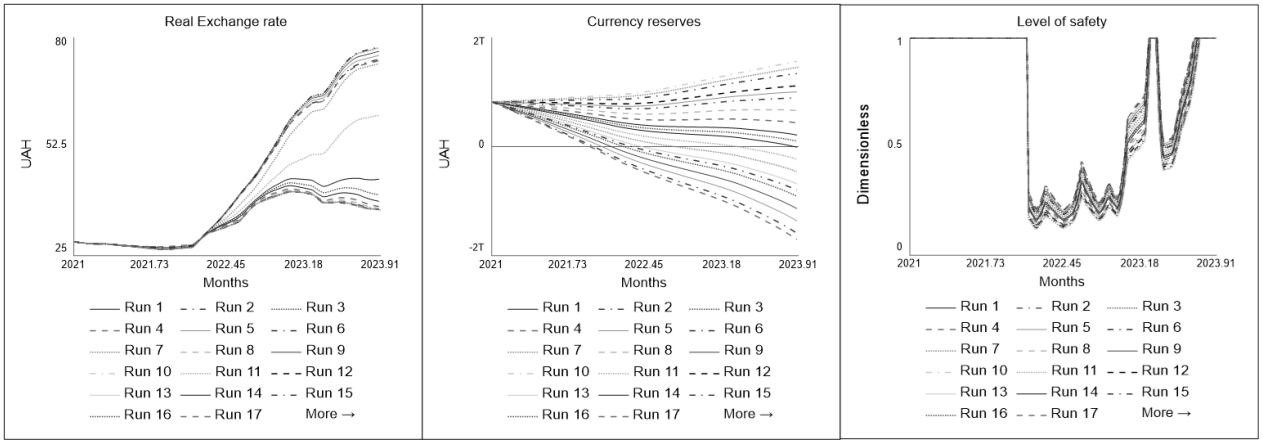



***Fraction of required foreign gov debt payments***

Tested range: 0-1

Original value: 0.1

The model is numerically sensitive to this parameter, especially concerning the indicated agile competence. Debt payments have to be paid from the budget of currency reserves, thus increase in the debt payment can dramatically decrease currency reserves and the government budget, which will lead to destabilizing of local currency and destabilizing situation will affect level of safety.



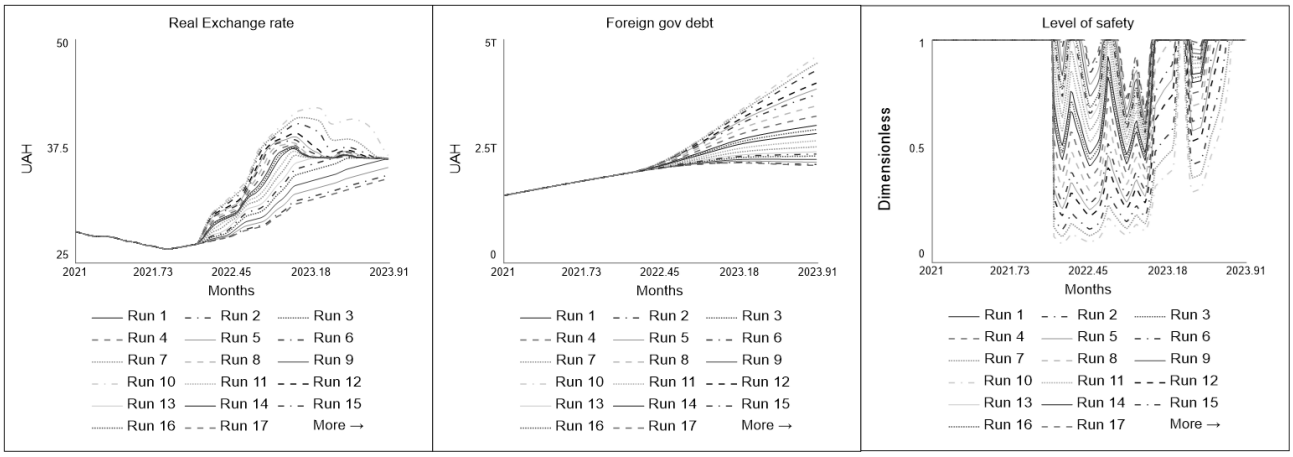

***Normal military expenditures' fractional rate***

Tested range: 0-1

Original value: 0.1

The model is numerically sensitive to this parameter. Military expenditures are crucial for the country during the war conditions, which affects the defense ability of the country, and as a result – the level of safety. Safety affects the exchange rate, as it was explained above. Military spending has a positive relation with government debt, as much spending you have, as more budget gap, and as more borrowing, you have to

do.

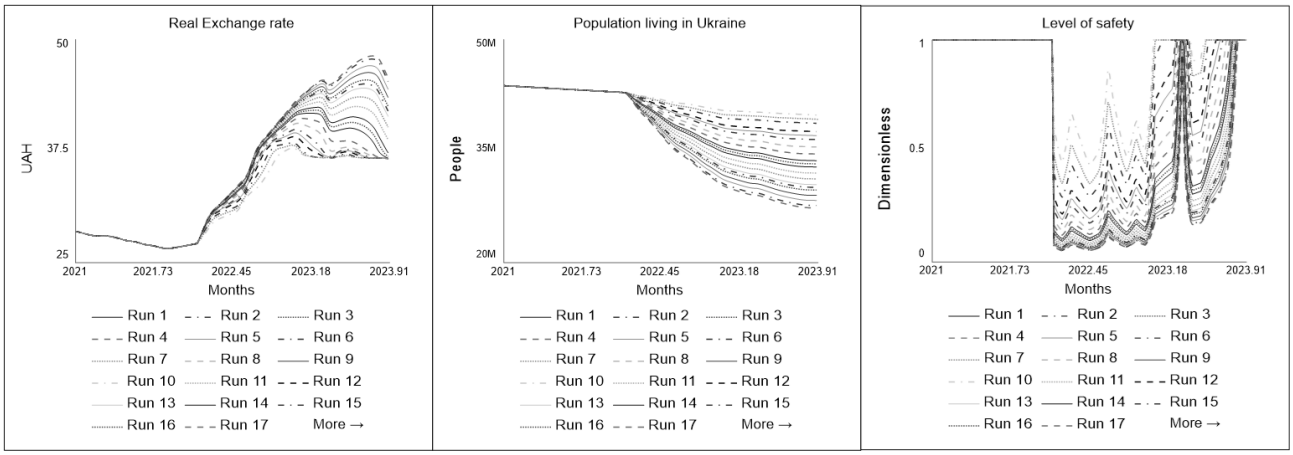



***The price of one unit of air defense***

Tested range: 1 000 000 000 – 20 000 000 000

Original value: 8 000 000 000

The model shows sensitivity to this parameter. To provide safety in the country government has to provide a decent air defense capacity, which is supplied through the purchasing of air defense. So the price of 1 unit of air defense directly affects the air defense capacity, and as a result – safety. At the same time, safety affects the population of the country (death and emigrants in particular). Instability caused by safety affects the exchange rate.




## ANNEX C

## *Annex C.1. ARIMA-model "CPI"*

**Augmented Dickey-Fuller Unit Root Test on CPI**

Null Hypothesis: CPI has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=15)

| | | t-Statistic | Prob.* |
|---|---|---|---|
| Augmented Dickey-Fuller test statistic | | -7.984883 | 0.0000 |
| Test critical values: | 1% level | -3.453823 | |
| | 5% level | -2.871768 | |
| | 10% level | -2.572293 | |

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(CPI)
Method: Least Squares
Date: 03/31/24 Time: 10:19
Sample (adjusted): 2001M02 2024M02
Included observations: 277 after adjustments

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| CPI(-1) | -0.376421 | 0.047142 | -7.984883 | 0.0000 |
| C | 37.97680 | 4.757121 | 7.983149 | 0.0000 |

| | | | |
|---|---|---|---|
| R-squared | 0.188212 | Mean dependent var | -0.004332 |
| Adjusted R-squared | 0.185260 | S.D. dependent var | 1.259766 |
| S.E. of regression | 1.137102 | Akaike info criterion | 3.102037 |
| Sum squared resid | 355.5752 | Schwarz criterion | 3.128203 |
| Log likelihood | -427.6321 | Hannan-Quinn criter. | 3.112536 |
| F-statistic | 63.75836 | Durbin-Watson stat | 1.827172 |
| Prob(F-statistic) | 0.000000 | | |

**Figure C.1.1** The output window of the results of the Dickey-Fuller test of the time series in levels for stationarity

At these levels, the CPI time series is stationary (Prob. is less than 0.05), its level of integration is 0.

Dependent Variable: CPI
Method: ARMA Maximum Likelihood (OPG - BHHH)
Date: 03/31/24 Time: 13:06
Sample: 2001M01 2024M02
Included observations: 278
Convergence not achieved after 500 iterations
Coefficient covariance computed using outer product of gradients

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| C | 100.9495 | 0.078121 | 1292.217 | 0.0000 |
| AR(1) | 0.706157 | 0.059347 | 11.89869 | 0.0000 |
| AR(2) | -0.130855 | 0.090854 | -1.440287 | 0.1510 |
| AR(5) | 0.085236 | 0.045683 | 1.865791 | 0.0632 |
| AR(6) | 0.704030 | 0.078043 | 9.021098 | 0.0000 |
| AR(7) | -0.478985 | 0.095707 | -5.004718 | 0.0000 |
| AR(8) | 0.104261 | 0.097491 | 1.069450 | 0.2858 |
| AR(9) | -0.010001 | 0.032051 | -0.312049 | 0.7553 |
| AR(10) | 0.039602 | 0.044426 | 0.891406 | 0.3735 |
| AR(11) | -0.083417 | 0.056394 | -1.479168 | 0.1403 |
| AR(12) | 0.247314 | 0.065118 | 3.797944 | 0.0002 |
| AR(13) | -0.230076 | 0.070295 | -3.273019 | 0.0012 |
| AR(16) | -0.078835 | 0.041344 | -1.906800 | 0.0576 |
| MA(6) | -0.922564 | 0.072357 | -12.75008 | 0.0000 |
| SIGMASQ | 1.044952 | 0.057460 | 18.18563 | 0.0000 |

| | | | | |
|---|---|---|---|---|
| R-squared | 0.501019 | Mean dependent var | | 100.8986 |
| Adjusted R-squared | 0.474457 | S.D. dependent var | | 1.449735 |
| S.E. of regression | 1.050976 | Akaike info criterion | | 3.011739 |
| Sum squared resid | 290.4966 | Schwarz criterion | | 3.207474 |
| Log likelihood | -403.6317 | Hannan-Quinn criter. | | 3.090266 |
| F-statistic | 18.86242 | Durbin-Watson stat | | 1.976657 |
| Prob(F-statistic) | 0.000000 | | | |
| Inverted AR Roots | .95-.07i | .95+.07i | .71+.49i | .71-.49i |
| | .50+.86i | .50-.86i | .23+.65i | .23-.65i |
| | -.06+.79i | -.06-.79i | -.50+.86i | -.50-.86i |
| | -.57 | -.70+.46i | -.70-.46i | -.99 |
| Inverted MA Roots | .99 | .49-.85i | .49+.85i | -.49-.85i |
| | -.49+.85i | -.99 | | |

**Figure C.1.2** Model specification.

**Augmented Dickey-Fuller Unit Root Test on RESID_TEST**

Null Hypothesis: RESID_TEST has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=15)

| | | t-Statistic | Prob.* |
|---|---|---|---|
| Augmented Dickey-Fuller test statistic | | -16.41618 | 0.0000 |
| Test critical values: | 1% level | -3.453823 | |
| | 5% level | -2.871768 | |
| | 10% level | -2.572293 | |

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(RESID_TEST)
Method: Least Squares
Date: 03/31/24 Time: 10:39
Sample (adjusted): 2001M02 2024M02
Included observations: 277 after adjustments

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| RESID_TEST(-1) | -0.989632 | 0.060284 | -16.41618 | 0.0000 |
| C | -0.032784 | 0.061730 | -0.531079 | 0.5958 |

| | | | |
|---|---|---|---|
| R-squared | 0.494941 | Mean dependent var | -0.002173 |
| Adjusted R-squared | 0.493104 | S.D. dependent var | 1.442385 |
| S.E. of regression | 1.026929 | Akaike info criterion | 2.898217 |
| Sum squared resid | 290.0104 | Schwarz criterion | 2.924383 |
| Log likelihood | -399.4030 | Hannan-Quinn criter. | 2.908716 |
| F-statistic | 269.4908 | Durbin-Watson stat | 1.996511 |
| Prob(F-statistic) | 0.000000 | | |

**Figure C.1.3** Results of checking the residuals of the model for white noise

According to the results of testing Prob. is 0.00, which is less than 0.05, the residuals at the levels are stationary, so they are white noise.

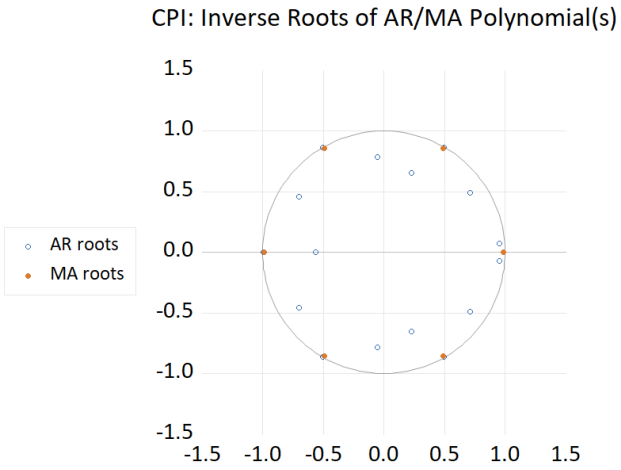



**Figure C.1.4** Graph of the values of the roots of the characteristic polynomial

According to the graph, the roots of the lag polynomial lie in the unit circle.

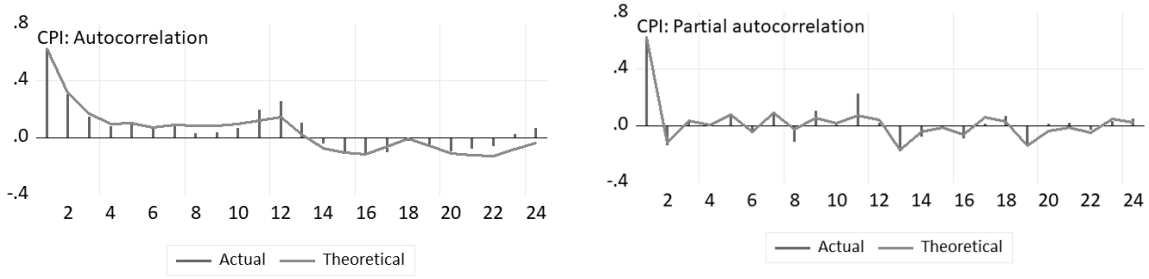



**Figure C.1.5** *ACF/PACF graphs of actual and theoretical (calculated) levels of the time series*

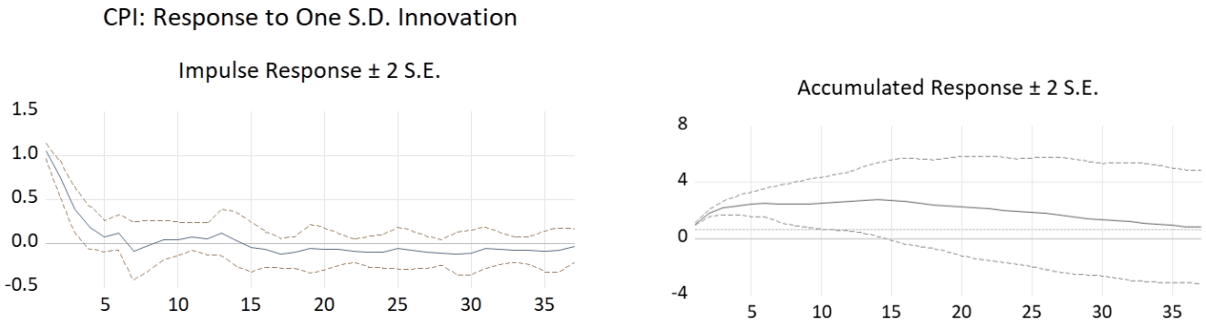



**Figure C.1.6** Impulse function of exchange rate responses to external shocks

The Figure shows damping of the impulse response function, which signalizes about stability of the model.

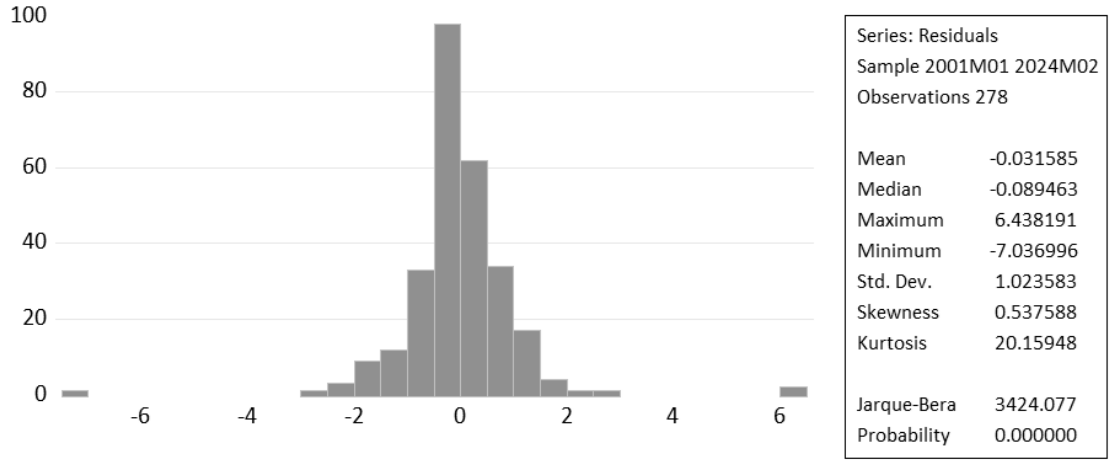



**Figure C.1.7** Descriptive statistics of model residuals.

According to the results of the Zharg-Ber test, the probability of making a mistake when rejecting the hypothesis of a normal distribution of the residuals is 0%, so the residuals are not normally distributed.

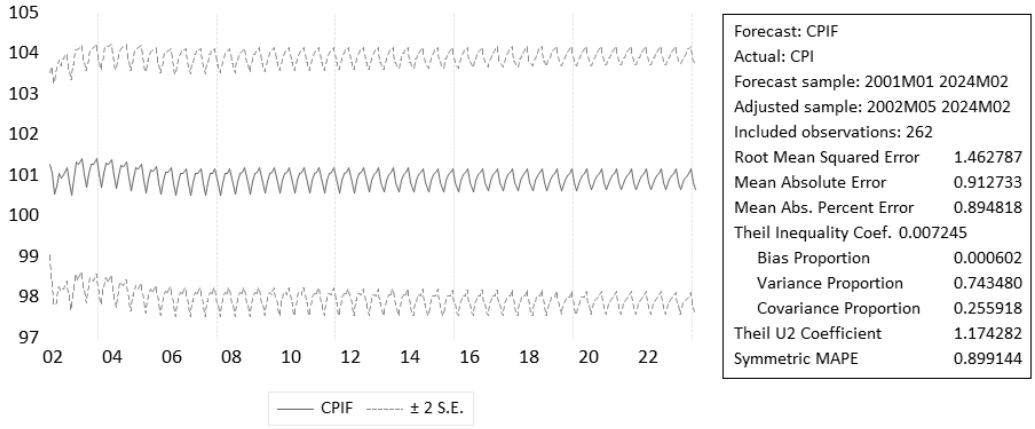



**Figure C.1.8** Forecast

Criteria of predictive quality of the model:

MARE = 0.89% - this indicator is quite low, so this model gives a high forecast accuracy.

MAE = 0.91 – the value is quite low in relation to the average value of the model, so this model gives a high forecast accuracy.

RMSE = 1.46 – this value is also quite low in relation to the average value of the model, so this model gives a high forecast accuracy.

Therefore, this model as a whole has a high forecast accuracy.

***Annex C.2. GDP gap 2024***

Augmented Dickey-Fuller Unit Root Test on GDP_GAP

Null Hypothesis: GDP_GAP has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=10)

| | | t-Statistic | Prob.* |
|---|---|---|---|
| Augmented Dickey-Fuller test statistic | | -3.469015 | 0.0121 |
| Test critical values: | 1% level | -3.538362 | |
| | 5% level | -2.908420 | |
| | 10% level | -2.591799 | |

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(GDP_GAP)
Method: Least Squares
Date: 04/01/24 Time: 12:54
Sample (adjusted): 2008Q2 2023Q4
Included observations: 63 after adjustments

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| GDP_GAP(-1) | -0.298858 | 0.086151 | -3.469015 | 0.0010 |
| C | -0.847077 | 0.431633 | -1.962491 | 0.0543 |

| | | | |
|---|---|---|---|
| R-squared | 0.164773 | Mean dependent var | -0.127778 |
| Adjusted R-squared | 0.151081 | S.D. dependent var | 3.261225 |
| S.E. of regression | 3.004788 | Akaike info criterion | 5.069522 |
| Sum squared resid | 550.7537 | Schwarz criterion | 5.137558 |
| Log likelihood | -157.6899 | Hannan-Quinn criter. | 5.096281 |
| F-statistic | 12.03406 | Durbin-Watson stat | 1.734278 |
| Prob(F-statistic) | 0.000964 | | |

**Figure C.1.9** The output window of the results of the Dickey-Fuller test of the time series in levels for stationarity

At these levels, the GDP Gap time series is stationary (Prob. is less than 0.05), its level of integration is 0.

Dependent Variable: GDP_GAP
Method: ARMA Maximum Likelihood (OPG - BHHH)
Date: 03/28/24 Time: 22:07
Sample: 2008Q1 2023Q4
Included observations: 64
Convergence achieved after 43 iterations
Coefficient covariance computed using outer product of gradients

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| C | -2.004441 | 0.947276 | -2.116006 | 0.0386 |
| AR(1) | 0.737510 | 0.084824 | 8.694566 | 0.0000 |
| AR(6) | -0.306932 | 0.198638 | -1.545182 | 0.1277 |
| AR(7) | 0.385187 | 0.176974 | 2.176509 | 0.0336 |
| AR(9) | -0.328134 | 0.085887 | -3.820530 | 0.0003 |
| SIGMASQ | 7.604830 | 1.110831 | 6.846075 | 0.0000 |

| | | | |
|---|---|---|---|
| R-squared | 0.599913 | Mean dependent var | -2.405000 |
| Adjusted R-squared | 0.565423 | S.D. dependent var | 4.394275 |
| S.E. of regression | 2.896815 | Akaike info criterion | 5.103275 |
| Sum squared resid | 486.7091 | Schwarz criterion | 5.305671 |
| Log likelihood | -157.3048 | Hannan-Quinn criter. | 5.183009 |
| F-statistic | 17.39369 | Durbin-Watson stat | 1.765471 |
| Prob(F-statistic) | 0.000000 | | |

| | | | | |
|---|---|---|---|---|
| Inverted AR Roots | .91-.26i | .91+.26i | .58+.67i | .58-.67i |
| | -.07+.94i | -.07-.94i | -.67 | -.72-.51i |
| | -.72+.51i | | | |

**Figure C.1.10** Model specification.

Augmented Dickey-Fuller Unit Root Test on RESID_TEST

Null Hypothesis: RESID_TEST has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=10)

| | | t-Statistic | Prob.* |
|---|---|---|---|
| Augmented Dickey-Fuller test statistic | | -7.254978 | 0.0000 |
| Test critical values: | 1% level | -3.538362 | |
| | 5% level | -2.908420 | |
| | 10% level | -2.591799 | |

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(RESID_TEST)
Method: Least Squares
Date: 04/01/24 Time: 12:57
Sample (adjusted): 2008Q2 2023Q4
Included observations: 63 after adjustments

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| RESID_TEST(-1) | -0.907186 | 0.125043 | -7.254978 | 0.0000 |
| C | -0.143756 | 0.346373 | -0.415032 | 0.6796 |

| | | | |
|---|---|---|---|
| R-squared | 0.463192 | Mean dependent var | -0.100276 |
| Adjusted R-squared | 0.454392 | S.D. dependent var | 3.721424 |
| S.E. of regression | 2.748840 | Akaike info criterion | 4.891466 |
| Sum squared resid | 460.9234 | Schwarz criterion | 4.959502 |
| Log likelihood | -152.0812 | Hannan-Quinn criter. | 4.918225 |
| F-statistic | 52.63470 | Durbin-Watson stat | 1.980911 |
| Prob(F-statistic) | 0.000000 | | |

**Figure C.1.11** Results of checking the residuals of the model for white noise

According to the results of testing Prob. is 0.00, which is less than 0.05, the residuals at the levels are stationary, so they are white noise.

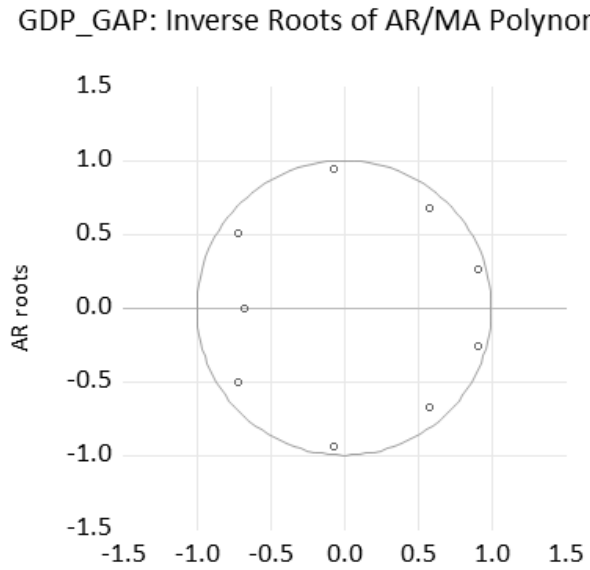



**Figure C.1.12** Graph of the values of the roots of the characteristic polynomial

According to the graph, the roots of the lag polynomial lie in the unit circle.

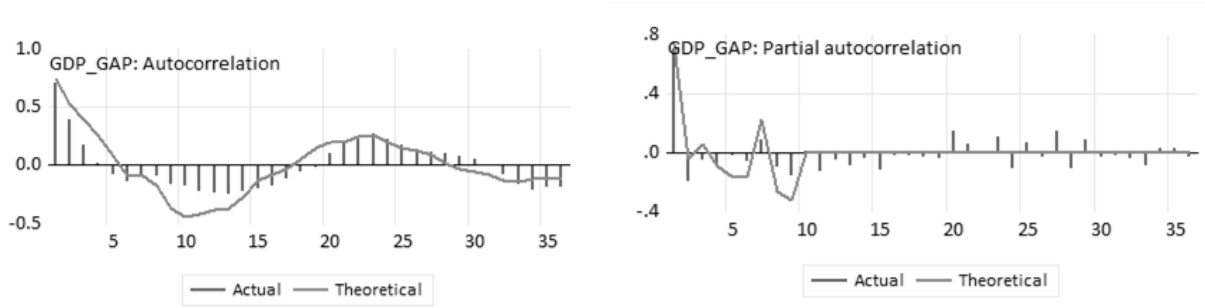



**Figure C.1.13** ACF/PACF graphs of actual and theoretical (calculated) levels of the time series

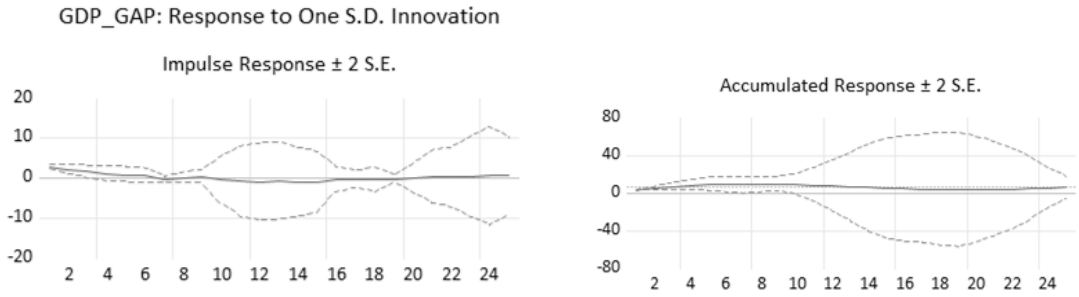



**Figure C.1.14** Impulse function of exchange rate responses to external shocks

The Figure shows damping of the impulse response function, which signalizes about stability of the model.

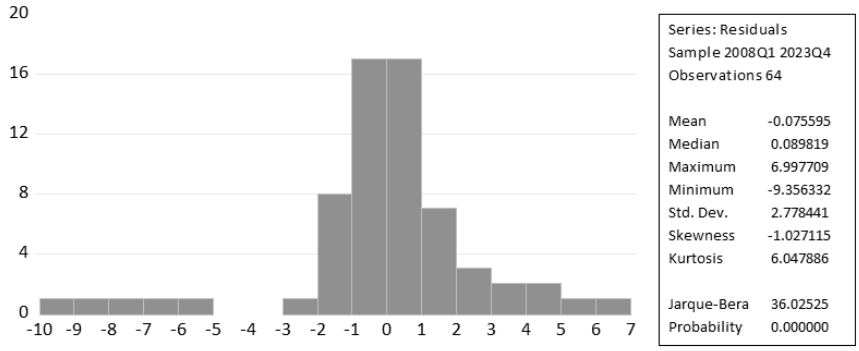



**Figure C.1.15** Descriptive statistics of model residuals.

According to the results of the Zharg-Ber test, the probability of making a mistake when rejecting the hypothesis of a normal distribution of the residuals is 0%, so the residuals are not normally distributed.

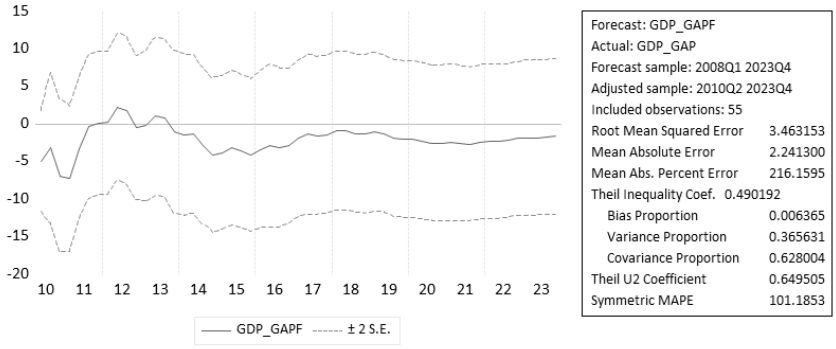



**Figure C.1.16** Forecast

Criteria of predictive quality of the model:

MARE = 3.46% - this indicator is quite low, so this model gives a high forecast accuracy.

MAE = 2.24 – the value is medium in relation to the average value of the model, so this model gives a significant forecast accuracy.

RMSE = 3.46 – this value is also medium in relation to the average value of the model, so this model gives a significant forecast accuracy.

Therefore, this model as a whole has a significant forecast accuracy.

***Annex C.3. VECM model «Exchange rate and Key policy rate"***

**ADF Fisher Unit Root Test on UNTITLED**

Null Hypothesis: Unit root (individual unit root process)
Series: EX_RATE_USD, KEY_RATE
Date: 04/01/24 Time: 16:14
Sample: 2003M02 2024M03
Exogenous variables: Individual effects
Automatic selection of maximum lags
Automatic lag length selection based on SIC: 0 to 1
Total number of observations: 505
Cross-sections included: 2

| Method | Statistic | Prob.** |
|---|---|---|
| ADF - Fisher Chi-square | 4.39696 | 0.3549 |
| ADF - Choi Z-stat | 0.90252 | 0.8166 |

** Probabilities for Fisher tests are computed using an asymptotic Chi -square distribution. All other tests assume asymptotic normality.

Intermediate ADF test results UNTITLED

| Series | Prob. | Lag | Max Lag | Obs |
|---|---|---|---|---|
| EX_RATE_USD | 0.9937 | 0 | 15 | 253 |
| KEY_RATE | 0.1117 | 1 | 15 | 252 |

**Figure C.1.17** The output window of the results of the Dickey-Fuller test of the time series in levels for stationarity

At these levels, the Exchange rate and Key policy rate time series Prob. is more than 0.05, that we cannot reject the null hypothesis regarding the presence of a unit root in the time series. Therefore, the series is non-stationary in levels.

**ADF Fisher Unit Root Test on D(UNTITLED)**

Null Hypothesis: Unit root (individual unit root process)
Series: EX_RATE_USD, KEY_RATE
Date: 04/01/24 Time: 16:20
Sample: 2003M02 2024M03
Exogenous variables: Individual effects
Automatic selection of maximum lags
Automatic lag length selection based on SIC: 0
Total (balanced) observations: 504
Cross-sections included: 2

| Method | Statistic | Prob.** |
|---|---|---|
| ADF - Fisher Chi-square | 215.535 | 0.0000 |
| ADF - Choi Z-stat | -14.2276 | 0.0000 |

** Probabilities for Fisher tests are computed using an asymptotic Chi -square distribution. All other tests assume asymptotic normality.

Intermediate ADF test results D(UNTITLED)

| Series | Prob. | Lag | Max Lag | Obs |
|---|---|---|---|---|
| D(EX_RATE_USD) | 0.0000 | 0 | 15 | 252 |
| D(KEY_RATE) | 0.0000 | 0 | 15 | 252 |

**Figure C.1.18** The results of checking the data group for stationarity according to the Dickey-Fuller test

The obtained results indicate the stationarity of the Exchange rate and Key policy rate in the first differences.

**Johansen Cointegration Test**

Date: 04/01/24 Time: 16:27
Sample (adjusted): 2003M08 2024M03
Included observations: 248 after adjustments
Trend assumption: Linear deterministic trend
Series: EX_RATE_USD KEY_RATE
Lags interval (in first differences): 1 to 5

Unrestricted Cointegration Rank Test (Trace)

| Hypothesized No. of CE(s) | Eigenvalue | Trace Statistic | 0.05 Critical Value | Prob.** |
|---|---|---|---|---|
| None * | 0.084516 | 22.04683 | 15.49471 | 0.0045 |
| At most 1 | 0.000596 | 0.147729 | 3.841465 | 0.7007 |

Trace test indicates 1 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

| Hypothesized No. of CE(s) | Eigenvalue | Max-Eigen Statistic | 0.05 Critical Value | Prob.** |
|---|---|---|---|---|
| None * | 0.084516 | 21.89910 | 14.26460 | 0.0026 |
| At most 1 | 0.000596 | 0.147729 | 3.841465 | 0.7007 |

Max-eigenvalue test indicates 1 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

| Hypothesized No. of CE(s) | Eigenvalue | Max-Eigen Statistic | 0.05 Critical Value | Prob.** |
|---|---|---|---|---|
| None * | 0.084516 | 21.89910 | 14.26460 | 0.0026 |
| At most 1 | 0.000596 | 0.147729 | 3.841465 | 0.7007 |

Max-eigenvalue test indicates 1 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegrating Coefficients (normalized by b'*S11*b=I):

| EX_RATE_USD | KEY_RATE |
|---|---|
| -0.037418 | 0.232518 |
| 0.119200 | -0.099138 |

Unrestricted Adjustment Coefficients (alpha):

| | | |
|---|---|---|
| D(EX_RATE_... | 0.045148 | 0.018283 |
| D(KEY_RATE) | -0.358627 | 0.008492 |

1 Cointegrating Equation(s): Log likelihood -687.3921

Normalized cointegrating coefficients (standard error in parentheses)

| EX_RATE_USD | KEY_RATE |
|---|---|
| 1.000000 | -6.214019 |
| | (1.10017) |

Adjustment coefficients (standard error in parentheses)

| | |
|---|---|
| D(EX_RATE_... | -0.001689 |
| | (0.00186) |
| D(KEY_RATE) | 0.013419 |
| | (0.00300) |

**Figure C.1.19** Johanson's test revealed one cointegrating equation.

VEC Lag Exclusion Wald Tests
Date: 04/01/24 Time: 16:37
Sample (adjusted): 2004M06 2024M03
Included observations: 238 after adjustments

Chi-squared test statistics for lag exclusion:
Numbers in [ ] are p-values

| | D(EX_RATE... | D(KEY_RATE) | Joint |
|---|---|---|---|
| DLag 1 | 9.635695<br>[ 0.0081] | 10.63997<br>[ 0.0049] | 19.53102<br>[ 0.0006] |
| DLag 2 | 1.320067<br>[ 0.5168] | 28.21065<br>[ 0.0000] | 29.54715<br>[ 0.0000] |
| DLag 3 | 1.582913<br>[ 0.4532] | 1.947569<br>[ 0.3777] | 3.402631<br>[ 0.4928] |
| DLag 4 | 1.299011<br>[ 0.5223] | 15.10669<br>[ 0.0005] | 16.20760<br>[ 0.0028] |
| DLag 5 | 4.841512<br>[ 0.0889] | 4.748042<br>[ 0.0931] | 9.596820<br>[ 0.0478] |
| DLag 6 | 6.737996<br>[ 0.0344] | 1.217310<br>[ 0.5441] | 7.885327<br>[ 0.0959] |
| DLag 7 | 1.737738<br>[ 0.4194] | 4.965174<br>[ 0.0835] | 6.507051<br>[ 0.1643] |
| DLag 8 | 1.774145<br>[ 0.4119] | 2.874815<br>[ 0.2375] | 4.591423<br>[ 0.3318] |
| DLag 9 | 7.120632<br>[ 0.0284] | 4.990949<br>[ 0.0825] | 11.69976<br>[ 0.0197] |
| DLag 10 | 0.845783<br>[ 0.6551] | 0.319379<br>[ 0.8524] | 1.177205<br>[ 0.8818] |
| DLag 11 | 0.549395<br>[ 0.7598] | 2.715141<br>[ 0.2573] | 3.176383<br>[ 0.5288] |
| DLag 12 | 4.625030<br>[ 0.0990] | 3.912508<br>[ 0.1414] | 8.279426<br>[ 0.0819] |
| DLag 13 | 3.500228<br>[ 0.1738] | 4.866941<br>[ 0.0877] | 8.247296<br>[ 0.0829] |
| DLag 14 | 1.109003<br>[ 0.5744] | 1.051291<br>[ 0.5912] | 2.080905<br>[ 0.7209] |
| DLag 15 | 0.072041<br>[ 0.9646] | 3.531786<br>[ 0.1710] | 3.645648<br>[ 0.4561] |
| df | 2 | 2 | 4 |

**Figure C.1.20** Results of the test on the possibility of excluding lags from the VECM model

According to the test results, 1, 2, 3, 4 and 9 lags should be included in the model.

VEC Granger Causality/Block Exogeneity Wald Tests
Date: 04/01/24 Time: 16:45
Sample: 2003M02 2024M03
Included observations: 244

Dependent variable: D(EX_RATE_USD)

| Excluded | Chi-sq | df | Prob. |
|---|---|---|---|
| D(KEY_RATE) | 9.956932 | 5 | 0.0465 |
| All | 9.956932 | 5 | 0.0465 |

Dependent variable: D(KEY_RATE)

| Excluded | Chi-sq | df | Prob. |
|---|---|---|---|
| D(EX_RATE_USD) | 47.33753 | 5 | 0.0000 |
| All | 47.33753 | 5 | 0.0000 |

**Figure C.1.21** Results of the Grander Causality test

Based on the conducted analysis, the results of model diagnostics, empirical calculations and logical conclusions, all variables should remain in the endogenous block.

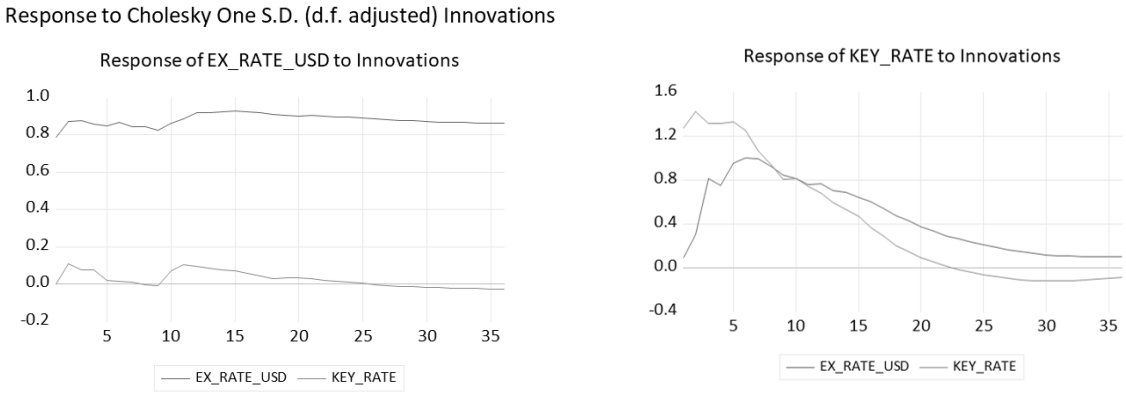



**Figure C.1.22** Impulse response function (Combined graphs).

The graph shows the decreasing (to zero) nature of the impulse response functions, since the shock that occurred over time (increasing the bias period) is leveled off.

ADF Fisher Unit Root Test on UNTITLED

Null Hypothesis: Unit root (individual unit root process)
Series: RESID01, RESID02
Date: 04/01/24 Time: 17:31
Sample: 2003M02 2024M03
Exogenous variables: Individual effects
Automatic selection of maximum lags
Automatic lag length selection based on SIC: 0
Total (balanced) observations: 486
Cross-sections included: 2

| Method | Statistic | Prob.** |
|---|---|---|
| ADF - Fisher Chi-square | 244.525 | 0.0000 |
| ADF - Choi Z-stat | -15.2089 | 0.0000 |

** Probabilities for Fisher tests are computed using an asymptotic Chi -square distribution. All other tests assume asymptotic normality.

Intermediate ADF test results UNTITLED

| Series | Prob. | Lag | Max Lag | Obs |
|---|---|---|---|---|
| RESID01 | 0.0000 | 0 | 14 | 243 |
| RESID02 | 0.0000 | 0 | 14 | 243 |

**Figure C.1.22** The results of checking residuals for white noise.

Therefore, the conducted test indicates the stationarity of the residuals of each individual equation (Prob for RESID is less than 0.05), and also allows us to draw a general conclusion that the residuals of the developed VECM model are white noise (the cumulative Prob is also less than 0, 05).

VEC Residual Normality Tests
Orthogonalization: Cholesky (Lutkepohl)
Null Hypothesis: Residuals are multivariate normal
Date: 04/01/24 Time: 17:33
Sample: 2003M02 2024M03
Included observations: 244

| Component | Skewness | Chi-sq | df | Prob.* |
|---|---|---|---|---|
| 1 | 6.105332 | 1515.853 | 1 | 0.0000 |
| 2 | 6.014508 | 1471.088 | 1 | 0.0000 |
| Joint | | 2986.941 | 2 | 0.0000 |

| Component | Kurtosis | Chi-sq | df | Prob. |
|---|---|---|---|---|
| 1 | 66.14281 | 40534.65 | 1 | 0.0000 |
| 2 | 69.85860 | 45445.74 | 1 | 0.0000 |
| Joint | | 85980.39 | 2 | 0.0000 |

| Component | Jarque-Bera | df | Prob. |
|---|---|---|---|
| 1 | 42050.50 | 2 | 0.0000 |
| 2 | 46916.83 | 2 | 0.0000 |
| Joint | 88967.33 | 4 | 0.0000 |

*Approximate p-values do not account for coefficient estimation

**Figure C.1.23** The results of the test for the normality of the distribution of residuals

Joint Prob is less than 0.05, therefore, the conclusion is that the distribution of residuals is not normal.

VEC Residual Serial Correlation LM Tests
Date: 04/01/24 Time: 17:35
Sample: 2003M02 2024M03
Included observations: 244

Null hypothesis: No serial correlation at lag h

| Lag | LRE* stat | df | Prob. | Rao F-stat | df | Prob. |
|---|---|---|---|---|---|---|
| 1 | 9.393779 | 4 | 0.0520 | 2.367472 | (4, 458.0) | 0.0520 |
| 2 | 4.236222 | 4 | 0.3750 | 1.061640 | (4, 458.0) | 0.3750 |
| 3 | 9.546517 | 4 | 0.0488 | 2.406367 | (4, 458.0) | 0.0488 |
| 4 | 6.226862 | 4 | 0.1828 | 1.563908 | (4, 458.0) | 0.1828 |
| 5 | 9.614754 | 4 | 0.0474 | 2.423748 | (4, 458.0) | 0.0474 |
| 6 | 6.400337 | 4 | 0.1712 | 1.607782 | (4, 458.0) | 0.1712 |
| 7 | 3.402304 | 4 | 0.4929 | 0.851876 | (4, 458.0) | 0.4929 |
| 8 | 4.508123 | 4 | 0.3416 | 1.130116 | (4, 458.0) | 0.3416 |
| 9 | 1.754353 | 4 | 0.7808 | 0.438470 | (4, 458.0) | 0.7808 |
| 10 | 0.715299 | 4 | 0.9494 | 0.178574 | (4, 458.0) | 0.9494 |
| 11 | 1.614207 | 4 | 0.8062 | 0.403381 | (4, 458.0) | 0.8062 |
| 12 | 11.32570 | 4 | 0.0231 | 2.860401 | (4, 458.0) | 0.0231 |

Null hypothesis: No serial correlation at lags 1 to h

| Lag | LRE* stat | df | Prob. | Rao F-stat | df | Prob. |
|---|---|---|---|---|---|---|
| 1 | 9.393779 | 4 | 0.0520 | 2.367472 | (4, 458.0) | 0.0520 |
| 2 | 16.64680 | 8 | 0.0340 | 2.105301 | (8, 454.0) | 0.0340 |
| 3 | 26.15750 | 12 | 0.0102 | 2.219011 | (12, 450.0) | 0.0102 |
| 4 | 32.01044 | 16 | 0.0100 | 2.041000 | (16, 446.0) | 0.0100 |
| 5 | 32.13893 | 20 | 0.0418 | 1.632350 | (20, 442.0) | 0.0419 |
| 6 | 35.01187 | 24 | 0.0682 | 1.480043 | (24, 438.0) | 0.0684 |
| 7 | 38.44634 | 28 | 0.0902 | 1.392162 | (28, 434.0) | 0.0905 |
| 8 | 43.05427 | 32 | 0.0918 | 1.365065 | (32, 430.0) | 0.0921 |
| 9 | 45.94610 | 36 | 0.1239 | 1.293208 | (36, 426.0) | 0.1244 |
| 10 | 46.47810 | 40 | 0.2230 | 1.172597 | (40, 422.0) | 0.2240 |
| 11 | 49.50598 | 44 | 0.2629 | 1.134056 | (44, 418.0) | 0.2642 |
| 12 | 52.48997 | 48 | 0.3042 | 1.100772 | (48, 414.0) | 0.3060 |

*Edgeworth expansion corrected likelihood ratio statistic.

**Figure C.1.24** Results of the serial correlation test of the residuals

The test results show that according to Prob, which for most lags is greater than 0.05, it can be concluded that there is no serial correlation of the residuals.

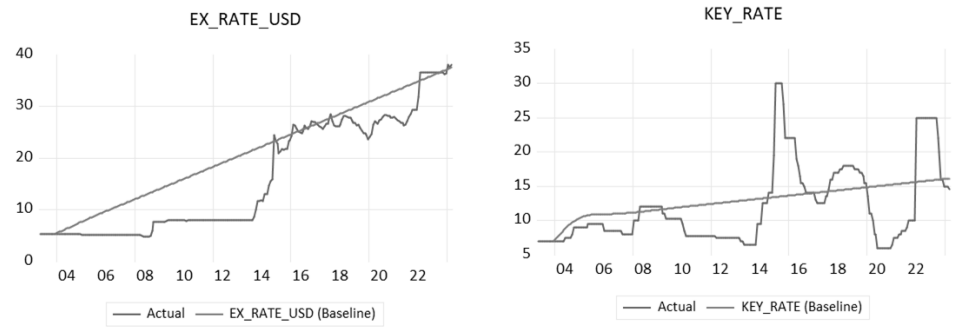



**Figure C.1.25** Graphic display of comparison of actual and forecast values of indicators.

From the analysis of the graphs, we can conclude that since our forecast is long-term and dynamic, over time the forecasted values differ greatly from the historical (actual) values. Therefore, the model begins to reproduce the long-term averaged trend.