A SYSTEM DYNAMIC APPROACH FOR DETERMINATION OF OPTIMAL MONETARY POLICY DURING THE WAR AND POST-WAR PERIOD IN UKRAINE

A SYSTEM DYNAMICS MODELING APPROACH

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Abstract

The primary aim of this thesis is to develop and test a robust model that effectively illustrates the process of inflation targeting in Ukraine during the war. The impact of the full-scale invasion significantly altered the functioning of the inflation-targeting regime, leading to adaptations in the policies pursued by the National Bank of Ukraine (NBU). Initially, due to immense psychological pressure stemming from the invasion, the NBU chose to postpone decisions regarding the key policy rate, recognizing the need for a cautious approach. However, as the conflict persisted, the NBU shifted its strategy and adopted an active interest rate policy to effectively manage inflation expectations. This involved a notable increase in the key policy rate, raising it to 25% per year. The decision to adopt a more proactive approach to interest rates reflected the NBU's commitment to addressing the evolving economic conditions caused by the war and the associated uncertainties. These adjustments in the NBU's policy stance exemplify the institution's adaptability and responsiveness in the face of adverse circumstances. The subsequent analysis and evaluation of the model will provide valuable insights into the effectiveness of these measures in managing inflation and maintaining stability within the Ukrainian economy during this unprecedented wartime context.

The expanded objectives of this research encompass various aspects, including analyzing the current inflation situation and examining the transmission channels of interest rates and inflation expectations. Additionally, the study aims to project inflation under different scenarios based on the duration of the war's conclusion and determine appropriate key policy rate values to control inflation from 2023 to 2025. The research questions revolve around forecasting future inflation values based on different scenarios, understanding the impact of inflation expectations on actual inflation and its driving factors, assessing the need to raise the policy rate to achieve the inflation target, evaluating the responsiveness of deposit and lending interest rates to changes in the key policy rate, and identifying the limitations to achieving the target inflation rate within the specified time frame.

The system dynamics model developed for this research explores the intricacies of the monetary policy in Ukraine during times of war, specifically focusing on the impact of two key transmission channels: inflation expectations and interest rates. This model incorporates scenario analysis that takes into account different potential outcomes depending on when the war eventually comes to an end. By considering various scenarios, the model provides a comprehensive framework for understanding the dynamics of the key policy rate and inflation under different war-ending circumstances.

Table of Contents

Chapter 1: Introduction

The inflation-targeting regime in Ukraine

In many countries, the goal of their central banks is to maintain low, stable inflation rates over the medium term to preserve the purchasing power of their national currencies, and the Ukrainian central bank is no exception. When inflation rises, economic agents' incomes and savings decrease, production costs increase, loans cost more, their servicing costs rise, etc. Moreover, the strong fluctuations in inflation also make attracting long-term investments in the economy difficult. Thus, economic growth is negatively impacted by high inflation and instability (What is price stability...?, NBU).

There was volatility and unpredictable inflation in the Ukrainian economy during the last decades, which reduced confidence in its currency and, consequently, led to high-interest rates on deposits and loans, a high degree of dollarization, as well as an unstable economic environment. As a result, this imbalanced macroeconomic environment resulted from a fixed exchange rate policy (What is price stability...?, NBU). Consequently, the Ukrainian National Bank de facto implemented inflation targeting in 2016, intending to ensure the stability of the monetary unit. The monetary policy has been implemented to reduce inflation rates gradually as well as to achieve the medium-term inflation target of 5% with a range of deviations of 1% (Inflation Targeting Regime, NBU).

The full-scale invasion of russia on Ukraine led to significant changes in the framework of the monetary policy in Ukraine. First of all, the exchange rate of hryvnia to the U.S. dollar was fixed, and the most effective instruments for maintaining macro-financial stability have become FX interventions and capital controls. At the same time, market-based monetary instruments ceased to play an important role in the functioning of the money and foreign exchange markets during the first months of the full-scale war due to the strong psychological shock. As a result, the policy rate has become a complementary tool, and the inflation-targeting regime in Ukraine has been significantly modified (Inflation Report, July 2022).

The NBU returned to active monetary policy at the beginning of June 2022 by raising the key policy rate by 25%. The goal of this resolute step was to secure the households from income and savings losses in the hryvnia, make the hryvnia assets more attractive, and decrease the pressure on the FX market (NBU Raises Key Policy Rate to 25%, 2022). Unfortunately, this step was not very successful due to the significant level of the banking system`s liquidity and uneven distribution of liquidity between the banks (Summary of the Key Policy Rate..., September 2022).

Consequently, the question arises of what could be done to improve the monetary transmission in terms of the modified inflation targeting regime that Ukraine follows during the active phase of the russian-Ukrainian war. Some steps have already been implemented by the NBU, but the results of it are still not visible due to time lags. Respectively, the purpose of this thesis is to determine which instruments could lead to the decrease of inflation in Ukraine with the smallest losses to the GDP and to develop a System Dynamics model that would provide a reliable representation of current inflation targeting regime work via interest rate, and inflation expectations channels, to evaluate the effectiveness of previous and possible decisions and actions in the field of monetary policy, and to build a middle-term forecast of inflation in Ukraine.

Research Objective & Research Questions

The main objective of this research is to develop and test an applicable model structure that could show the inflation-targeting process in Ukraine during the war.

The objectives could be expanded to the following ones:

1. To investigate the current situation with inflation and the interest and inflation expectations` transmission channels;
2. To analyze what the situation with inflation will be according to three different scenarios, depending on when the war ends;
3. To find out what the values of the key policy rate could be set by the NBU to crab inflation in 2023-2025 years.

The research questions:

1. What will be the values of inflation in the following years depending on different scenarios estimating when the full-scale invasion ends – at the end of 2023/2024/2025?
2. How will inflation expectations influence the real values of inflation, and what will drive them?
3. Will it be necessary to increase the policy rate to achieve the target value of inflation?
4. Will the deposit and lending interest rates reflect the changes in the key policy rate?
5. When will inflation achieve its target value of 5%? What are the limitations to achieving the target value of inflation within the following years?

Methodology

System dynamics offer invaluable benefits for depicting the monetary policy of Ukraine. With its ability to capture complex interactions among various economic variables, such as interest rates, inflation, and economic growth, system dynamics provide a dynamic and integrated approach for policymakers to understand the intricate workings of the monetary policy landscape (Forrester, 1961, 1987; Richardson, 2011; Sterman, 2000). In recent years, the number of works representing the work of the Ukrainian economy and monetary policy has grown significantly, but one of the latest ones was the work of Faryna and Dadasova (2015).

One of the key advantages of system dynamics is its ability to model feedback loops, which are common in monetary policy. By explicitly representing these feedback loops, policymakers can gain insights into the time delays and nonlinearities in the system, helping them identify potential unintended consequences of policy actions and develop strategies to mitigate risks. Furthermore, system dynamics take a long-term perspective, allowing policymakers to evaluate the enduring impacts of monetary policy decisions on the economy. This forward-looking approach empowers policymakers in Ukraine to make informed choices that consider both the short-term and long-term implications of different policy options, thereby enabling them to formulate more effective and sustainable monetary policy strategies. In addition, System Dynamics, the econometrics approach was used, as it is used by the NBU – QPM (Quarterly Projection Model), and the big variety of regressions by other researchers (Ніколайчук; Султан, 2000; Лук'яненко, & Насаченко, 2019; Gronicki, 1999; Grui, & Vdovychenko, 2019).

Data Collection

The data used in this model was gathered from the official sources of information – the NBU website in the sections "Macroeconomic Indicators", "Business Surveys", "Statistics of Financial Markets", "External Sector," and the State Statistics Service of Ukraine in the sections "Macroeconomic statistics," "National accounts," and "Labour Market."

Ethics

Since no original data was gathered for this study, ethical considerations regarding the collection, safeguarding, utilization, and dissemination of such data are irrelevant. All information utilized in this undertaking originates from publicly accessible sources, primarily from the official website of the NBU.

Chapter 2: Monetary Policy of Ukraine

Foundation and development of the inflation-targeting regime in Ukraine

The fixed exchange regime was the main tool for keeping inflation quite low for a long period (How does the NBU influence inflation...?, NBU), but the year 2014 became the turning point. Ukraine faced the biggest 21st-century challenges, including the economic crisis, the military conflict in the East, and the annexation of Crimea by Russia. Falling domestic demand and weak external demand caused real GDP to fall by 6.8%. High economic and political uncertainty led to a sharp increase in demand for foreign currency (Економічні підсумки для України, 2015). This, together with the drop in exports, caused a rapid devaluation of the hryvnia. In 2015, IMF came to rescue Ukraine from the crisis, and one of the reforms was the transformation of the National Bank of Ukraine (NBU) and the implementation of the inflation-targeting regime (Press Release, 2015).

In the Monetary Policy Fundamentals for 2015, among its priorities, the NBU emphasized achieving and maintaining price stability in the country. To ensure the price predictability of long-term economic planning and managerial decision-making on long-term economic and social development, it is necessary to maintain low and stable inflation rates (from three to five years). As a medium-term objective, the National Bank of Ukraine aimed to reduce inflation to 5% per year with an acceptable deviation of one percentage point (Monetary Policy Fundamentals, 2015).

In March 2016, the NBU published a Roadmap for the Journey to Inflation Targeting covering the next 12-18 months. It was stated that the price stabilization regime would be implemented by the NBU to ensure inflation control. Towards this objective, the NBU's Monetary Policy Guidelines set inflation targets for the consumer price index as follows: 12 +/- 3 percent annual increase by the end of 2016; 8 +/- 2 percent annual increase by the end of 2017; 6 +/- 2 percent annual increase by end of 2018; and 5 +/- 1 percent annual increase by end of December 2019.

Moreover, it was highlighted that the inflation target, unlike inflation forecasts, which are calculated and therefore subject to revisions (when actual economic developments diverge from forecasts), is unchanging. The central bank would use monetary policy instruments in case of inflation projections deviate from its target.

A journey to inflation targeting has long been underway at the NBU. Before its implementation, the regulator laid the technical groundwork back in 2015. The work in this area has been focused on building macroeconomic models and designing a quarterly forecast cycle. A second stage of reform was carried out by the NBU in the first half of 2015, including modifying the monetary policy decision-

making mechanisms. Starting from the second half of 2015, the regulator was in the middle of the third stage, which is the implementation of inflation targeting. The representatives of NBU also stated that there would be no fiscal dominance and its independence in choosing which monetary policy to use to accomplish the goal of price stability had been secured (NBU Presents a Roadmap, 2016).

The National Bank of Ukraine has chosen the key policy rate as the main tool to influence inflation. It is usually determined regularly, and the decisions could be the following ones: to leave it unchanged or to increase or decrease it (How does the NBU influence inflation...?, NBU). By adjusting its key policy rate, the NBU meets its inflation targets. And as opposed to the current trend of inflation, the regulator bases its decision on the determination of key policy rates for the next 6 weeks on the inflation forecast (About Monetary Policy, NBU).

Moreover, foreign exchange (FX) market interventions are also addressed as an additional instrument of monetary policy in Ukraine, and their goal is to maintain the international reserves at a sufficient level, reduce the volatility of exchange rates, and assist with the transmission of the key policy rate. Also, it is necessary to highlight that FX interventions do not guarantee a specific rate due to the flexibility of the exchange rate in Ukraine. In addition to the instruments listed above, the NBU can use other methods to achieve its goals. They are required reserves of banks, repo and swap transactions, and purchase/sale of government bonds (Monetary Policy Instruments, NBU).

It`s also necessary to mention that the monetary transmission mechanism takes time. It takes 9 to 18 months for a change in the NBU's key policy rate to significantly affect inflation in Ukraine. Consequently, the regulator bases its monetary policy decisions on what is expected to happen in the future, rather than on past events. So, inflation is affected by the key rate through a process called the transmission mechanism of monetary policy (How does the NBU influence inflation...?, NBU). There are several monetary transmission channels, which have been working in Ukraine with more intensification than others (Zholud, Lepushynskyi & Nikolaychuk, 2019). In general, the transmission channel works the following way. Initially, the regulator determines interbank interest rates by changing its key policy rate. Consequently, they affect aggregate demand and inflation, particularly through changes in household and business expectations. This impact is exerted through various channels, such as interest rates, stock markets, and currency markets. Additionally, by implementing an inflation-targeting policy that is both understood and consistent, the regulator can effectively manage expectations. By doing this, the transmission of monetary transmission is enhanced (How does the NBU influence inflation...?, NBU). In Figure 1, we can observe the work of the monetary policy in Ukraine – it provides a summary of the information that was provided before.

The interest rate channel is the first one to be analyzed. It starts with a change in the key policy rate, which affects short-term money market rates, such as the interbank market. Central banks manage bank liquidity to regulate short-term rates. They absorb excess liquidity by selling deposit certificates or government securities, or by conducting reverse repo transactions. If there's a liquidity deficit, they inject funds by providing loans to commercial banks or accepting liquid collateral. Additionally, the NBU may purchase government securities or engage in repo transactions (How does the NBU influence inflation...?, NBU).

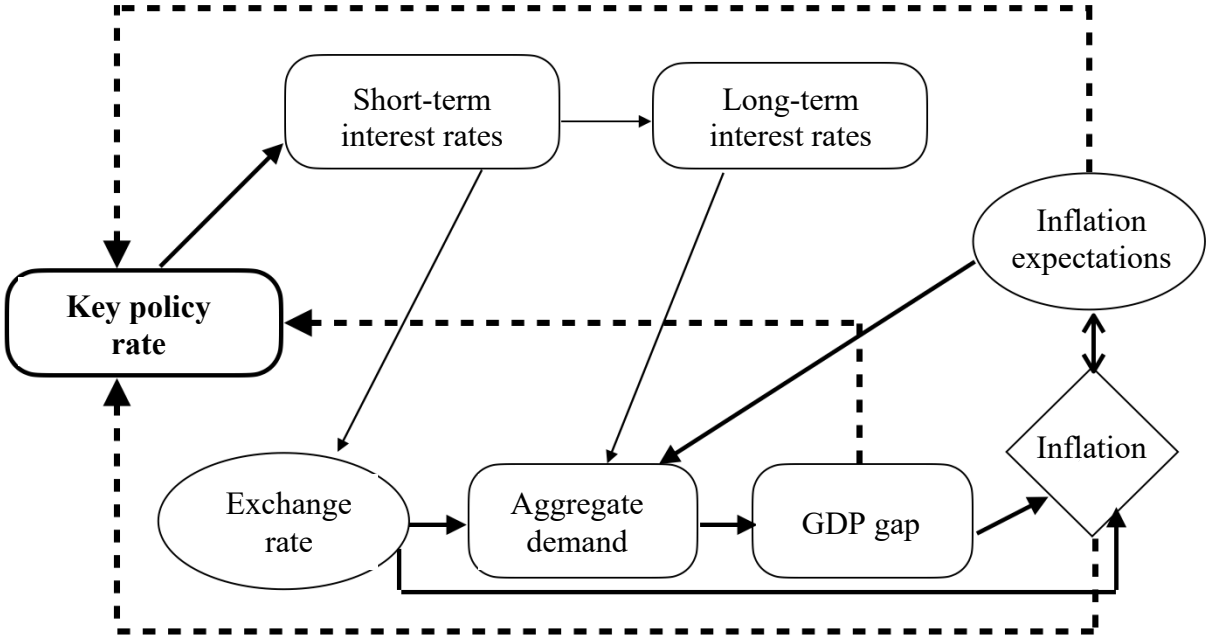

Figure 1: The transmission mechanism of the NBU's monetary policy

The key rate is used by the central bank of Ukraine to communicate its preferred rate level for achieving its monetary policy objectives. To align market rates with the desired level, the bank conducts its transactions based on this key rate. For instance, when there is a liquidity surplus, the NBU sells two-week certificates at the same rate as the key policy rate. The NBU also utilizes standing facilities such as certificates of deposit and overnight loans (1 percentage point below/above the key policy rate) to mitigate market volatility. (How does the NBU influence inflation...?, NBU).

The central bank can easily control short-term interbank rates by not imposing additional limitations on short-term facilities. Commercial banks can transact with the central bank or with each other, keeping the interbank rates close to the key rate set by the central bank. Nevertheless, medium- and long-term interest rates are important in directing funds to where they are needed in the banking system. These rates depend on various factors, including short-term interbank rates, competition within

the banking system, inflation expectations, demand for loans, etc. When the NBU adjusted the short-term rate management system in 2016-2017, which strengthened the relationship between short-term interbank rates and rates on bank loans and deposits, leading to decreased volatility of short-term rates and providing banks with a reliable market indicator of money value (How does the NBU influence inflation...?, NBU).

The change in interest rates on bank loans and deposits affects economic agents' preferences for consumption, investment, and savings. An increase in interest rates promotes savings and reduces investment, leading to a slowdown of inflation and deflation due to a decrease in aggregate demand (Zholud, Lepushynskyi & Nikolaychuk, 2019). This is supported by the experience of developed and developing economies, including the MTM study of the Czech Republic, Poland, and Hungary, which highlights the specifics of transitional economies switching to inflation targeting (Dervas, 2013).

Different methods can be used to evaluate how changes in market interest rates affect aggregate demand components. The National Bank of Poland employs vector autoregression models, and semi-structural and structural models to study this transmission effect (Chmielewski, Kapuściński, Kocięcki, & others), while the Central Bank of Hungary uses companies' balance sheet data (Kátay, & Wolf, 2004). In Ukraine, a range of models, including macro and micro analyses, can be used to evaluate the impact of the monetary transmission mechanism, but the short data sample since the country's transition to inflation targeting poses challenges in modeling (Zholud, Lepushynskyi & Nikolaychuk, 2019).

Moreover, the short-term interest rates affect long-term rates, including yields on government securities that serve as a benchmark for investors to assess the return and risk of other securities. Domestic government bonds have varying maturities and yields, which are plotted on the yield curve to show the relationship between yield and investment term (How does the NBU influence inflation...?, NBU).

The research paper "The Effectiveness of the Monetary Transmission Mechanism in Ukraine since the Transition to Inflation Targeting" found a strong relationship between short-term business loan rates and overnight and key rates, with a weekly pass-through level of 19%. However, market interest rates have a weak impact on aggregate demand and inflation in Ukraine due to factors such as low financial depth and high volatility in interest rates during a long period of high inflation (Zholud, Lepushynskyi & Nikolaychuk, 2019)

Moreover, the paper "The Effectiveness of the Monetary Transmission Mechanism in Ukraine since the Transition to Inflation Targeting" notes that the National Bank of Ukraine handles the short end of the yield curve, while the Finance Ministry handles the DGBs with maturities from six months to several years. Although the government securities market has grown, it remains relatively shallow,

resulting in a significant gap between government security yields and interest rates on individual deposits. So, a further expansion of the DGB market and the resumption of lending, coupled with lower dollarization, can help strengthen the effect of changes in market interest rates on aggregate demand and inflation (Zholud, Lepushynskyi & Nikolaychuk, 2019).

The exchange rate channel is the second monetary transmission channel, allowing borrowing at lower rates in one country and investing in another with higher yields. Rate changes can impact the balance between supply and demand for domestic and foreign bonds, and affect the exchange rate, which in turn can affect inflation and the trade balance (How does the NBU influence inflation...?, NBU). There is a strong correlation between monetary policy decisions and exchange rate trends in Ukraine, and the rate hike cycle in 2017-2018 led to an increase in the key rate and DGB yields, which attracted foreign currency inflows and strengthened the exchange rate (Zholud, Lepushynskyi & Nikolaychuk, 2019).

There is a significant connection between inflation and changes in the value of the Ukrainian hryvnia to the USD due to the country's high levels of openness and dollarization. Significant devaluations lead to a high pass-through of inflation, while mild fluctuations have no significant impact (Faryna, & Simona, 2018). The exchange rate channel also affects balance sheets, as assets and liabilities are mostly held in foreign currencies. Moreover, the hryvnia's real exchange rate strengthens during times of economic growth and weakens during crisis periods. Despite these fluctuations, the impact of exchange rate changes on economic activity in Ukraine is limited due to the offset effect of other channels (Zholud, Lepushynskyi & Nikolaychuk, 2019).

The expectations channel plays a significant role in Ukraine's monetary transmission. The transition to inflation targeting in 2015 has led to a significant decline in inflation expectations, but these remain higher than the declared inflation targets due to low trust in the National Bank of Ukraine (NBU). The use of best communication practices, such as public meetings, press releases, inflation reports, and summaries, has enhanced trust in the NBU's monetary policy. The effectiveness of the monetary transmission mechanism in Ukraine has been examined through the testing of several hypotheses. The results show that inflation expectations are a function of current, backward-looking, and future inflation expectations, but economic agents' predictions are better than naïve forecasts, particularly financial analysts who already have a superior level of understanding of the regulator's goals and monetary policy. Enterprises and households still have weak links to the NBU's inflation target due to the initial low level of trust, the short time of inflation targeting regime work, and considerable inflation shocks in recent years (Zholud, Lepushynskyi & Nikolaychuk, 2019).

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

general, the credit channel theory suggests that tighter monetary policy increases the premium for external financing due to imperfections in the credit market, such as the principal-agent problem and information asymmetry (Bernanke, & Gertler, 1995). The credit channel consists of two components: the lending channel and the balance sheet channel, which operate differently. Recent studies show that the credit channel's contribution to the monetary transmission mechanism in Ukraine is not significant due to institutional factors and a reduction in the corporate sector's dependence on bank lending (Zholud, Lepushynskyi & Nikolaychuk, 2019).

The asset channel is another monetary transmission channel that works poorly in Ukraine. The channel works by increasing the central bank's key rate leading to a decline in asset prices, which affects consumption through the wealth effect and liquidity of households (Mishkin, 1995). However, this channel works best in countries with developed stock and commodity markets, and it has limited capacity in Ukraine due to the underdeveloped stock market and almost non-existent commercial bank activity in mortgage lending. Real estate plays a more significant role in household assets, but the limited capacity of the asset price channel in Ukraine via real estate prices. The channel may be noticeable through foreign currency held by households, where a tighter monetary policy may reduce the real value of household savings in foreign currency, affecting households' long-term consumer and investment decisions (Zholud, Lepushynskyi & Nikolaychuk, 2019).

To sum it up, after the launch of the inflation-targeting regime in 2016, the NBU demonstrated its flourishment of it and the resolution of the banking system crisis. Specifically, according to the research conducted by Ukrainian discoverers, the interest rate, exchange rate, and expectations channels have proven to be effective. However, other channels, such as the credit channel, are still not influential, while the asset price channel remains inchoate. This can be attributed to the underdeveloped financial system, with low stock market development and a negligible role played by long-term investment institutes like pension funds, as well as historical factors such as high and volatile inflation, low trust in the central bank, and structural changes, among others.

The foreign experience of monetary policy during armed conflicts

The goals of monetary policy change during a crisis, with a focus on the additional challenges posed by a military economy. In such an economy, government spending increases, and the role of the state in the economy is heightened. Additionally, the issue of security becomes dominant in economic decisions, and the destruction caused by war limits the economic multiplier effect (Danylyshyn, & Bohdan, 2022).

During World War II, the U.S. Federal Reserve System faced challenges dealing with a surge in federal deficit despite increased tax revenue due to industrial growth. To stabilize financial markets and reduce interest rates, the FRS controlled government bond prices and established maximum yields, resulting in a significant expansion of the monetary base and the FRS's balance sheet. However, inflation still rose despite price and wage controls, and consumer credit controls were imposed. The FRS also used direct controls on consumer credit and increased reserve requirements of commercial banks to curb inflation, but it had only a minor effect on the money supply and the price level. It took six years after the war for monetary policy to regain independence from the Treasury through the Treasury-Federal Reserve Accord (Sances).

For many years, reserve requirements were an important part of US monetary policy, but since the Treasury-Federal Reserve accord, more emphasis was placed on open market operations. Selective credit controls, except on stock exchange securities, were not a permanent part of monetary control. However, the US did not face the same reconstruction or payment difficulties as other countries, and its simple monetary policy techniques combined with budget surpluses facilitated steady economic growth and high employment. Although there had been no direct controls for most postwar years, the US experienced moderate price increases compared to other countries (Patel, 1953).

If we look deeper into the foreign experience of countries who took part in WWII, Belgium returned to economic liberalism after WWII by using orthodox monetary policies, including adjusting the discount rate and controlling the liquidity of the banking system to prevent excessive expansion of bank credit. A monetary purge was also implemented, blocking part of the currency and bank deposits to reduce the money supply. The central bank introduced certified bank acceptances for imports and exports, and different discount rates were applied to different types of bank paper. The discount rate was lowered to boost production and gradually raised as the economy recovered and lowered again during a recession in 1949 (Patel, 1953).

The Netherlands faced latent inflation after WWII with a money supply four times larger than in 1938 and wholesale prices 80% higher than prewar levels in May 1945. To tackle the problem, the government withdrew and blocked all currency and deposit money in September 1945, gradually deblocking old accounts to provide means of payments for current contributions to production. However, this led to the re-emergence of latent inflation in the early postwar years. Control over bank credit was exercised by not allowing banks to give credit to anyone still holding blocked accounts. The discount rate remained at 2.5%, and banks were not subject to reserve requirements. By 1949, the money supply ratio to national income was restored to the 1938 level, and the excess money supply was worked off with the help of rising prices and import surpluses.

Post World War II, Germany experienced significant economic growth since the 1948 currency reform, attributed to a mix of monetary policy and U.S. aid. This resulted in a 20% rise in industrial employment, over double industrial production, and increased real wages with productivity. By 1952, Germany achieved a small balance of payments surplus and a commanding cumulative surplus with EPU. However, despite 1.1 million people remaining unemployed, it is essential to consider the progress made against the backdrop of increased employment and wages, as well as the influx of millions of refugees from Eastern Germany (Patel, 1953).

France faced unique economic challenges after WWII including budget deficits, political instability, and social tensions. To combat inflation, the country implemented an elaborate system of credit controls. However, massive wage and price increases became inevitable as inflationary pressures continued to be generated. In the early 1950s, France made periodic attempts to patch up loopholes in existing credit controls while acknowledging the need to raise the lid on credit in response to inflation.

The United Kingdom's post-WWII monetary policy changes represented a return to monetary orthodoxy compared to other countries. The new policy relied on controlling bank liquidity to restrict bank credit, without using reserve requirements or keeping interest rates low. Short-term government paper interest rates increased to encourage banks to hold short-term government investments. Qualitative credit controls were used along with indirect pressure on banks during refinancing operations. The fear of increasing the cost of government debt was set aside for a flexible monetary policy (Patel, 1953).

During the start of military activities, it is common and effective to fix the exchange rate to stabilize macro-financial conditions. For example, in the summer and autumn of 2008, the Georgian central bank managed to stabilize the foreign exchange market by pegging the exchange rate of the lari to the USD. The National Bank of Georgia has returned to a floating exchange rate regime after devaluing the domestic currency by 16 % and stabilizing the exchange rate at a new level by intervening in the foreign exchange market to achieve these results (Georgia, IMF, 2008). For example, in Israel, since 1985, various forms of pegging the shekel had been used with varying degrees of success, and a floating exchange rate was introduced only in June 2005 (Ötker, & Vávra, 2007)

It is also true that fixing the exchange rate for too long may lead to accumulating macroeconomic imbalances as the effect of stabilizing the exchange rate over time wears off. It is evident from Libya's (in 2016-2020) and Lebanon's (in 2020) negative experiences (UPDATE 1, Reuters, 2020; BANQUE DU LIBAN). Moreover, foreign exchange crises can develop even in peacetime when a rate is fixed for an excessively long time (as in Chile, Mexico, and Thailand) (Morandé, Meigs, & Moreno).

Moreover, we should not forget about war financing and its connection with monetary policy. Among the ways that war can be financed are by raising taxes, borrowing from domestic and foreign

markets, receiving international financial assistance, and borrowing from the banking system. Whenever central banks (CBs) finance the budget deficit on a large scale, hyperinflation, high dollarization, and sometimes the loss of monetary sovereignty has usually resulted. All of it was evidenced after the First World War in such countries as Germany (inflation in October 1923 was 29,500% m-o-m), Austria (129% m-o-m in August 1922), Poland (275% m-o-m in October 1923), etc. as well as, after the Second World War in Japan, Hungary, again Germany, and Austria (Hanke, & Krus, 2013). South Korea was not the exception during the Korean War (213% y-o-y in 1951), and Israel – after the Lebanon War (480% y-o-y in November 1984) (Campbell, & Tullock, 1957; CPI, IMF).

Most countries recovered from wartime crises by abandoning monetization and returning to a looser, independent monetary policy (MP), fiscal consolidation, and market financing. These programs were quite successful in Israel and Croatia (Inflation Report, July 2022). For example, Israel's program reduced annual inflation from 480% to 18% in the mid-1980s through fiscal consolidation (the fiscal deficit was reduced by subsidies decrease, the introduction of new taxes, and the limitation of civil servants), tight monetary policy, and structural reforms (Binyamini, Eckstein, & Flug, 2008). In Croatia, a similar program was introduced in 1993 after annual inflation exceeded 1000% (International Financial Statistics, IMF), and it included measures such as tightening monetary policy, fiscal (the increase of tax revenue, and reduction in state budget expenditures), and structural reforms (a focus had been placed on accelerating privatization and demonopolizing the economy) (Shonfelder, 2005). Both countries limited central bank financing of the government, and with the help of the government and the Central Bank, inflation was brought under control, and inflationary expectations stabilized and contributed to economic growth.

The experience of monetary policy in Ukraine during the full-scale invasion

According to the given information above, Ukraine has not become an exception from other countries, and during the invasion, the NBU pegged the hryvnia to the USD to maintain macro-financial stability and control inflation. FX interventions became the main monetary policy tool (Inflation Report, July 2022), and certain restrictions were imposed to limit foreign exchange demand (see Table 1 in Appendix A) (NBU Raises Key Policy Rate..., 2022).

The NBU postponed decisions regarding the key policy rate due to the psychological pressure caused by the invasion (NBU Postpones Key Policy Rate..., 2022) but raised it to 25% in June 2022. The

NBU focused on ensuring the uninterrupted functioning of the banking system and payments within the economy during this time (NBU Raises Key Policy Rate..., 2022). The interest rate has been kept at the same level for almost a year, and the NBU plans to decrease it gradually only in the 4th quarter of 2023 if the conditions allow them to do it (Summary of Key Policy Rate Discussion, May 2023).

Inflation in Ukraine accelerated due to disruptions in production and logistics, as well as high global energy prices, and was expected to continue increasing (see Figure 2) (Macroeconomic Indicators, NBU). To mitigate these effects, the NBU returned to an active interest rate policy, maintaining the key policy rate at 25% per year (NBU Raises Key Policy Rate..., 2022) and increasing required reserves ratios for banks (NBU Leaves Its Key Policy Rate..., 2023). Starting from January 2023, inflation took a downward course, and it was happening quicker than the NBU projected. If, in January 2023, inflation was equal to 26%, in April it`s already 17,6% (Macroeconomic Indicators, NBU). The primary reasons for the down-trend of inflation were:

- The unforeseen surplus in the availability of food and fuel;
- Enhancement of the hryvnia's position in the cash foreign exchange (FX) market;
- Positive changes in anticipations of inflation;
- The enduring benefits resulting from the liberation of certain regions in Ukraine (NBU January 2023 Inflation Update, February 2023);
- The enhanced condition of the energy industry (NBU February 2023 Inflation Update, March 2023);
- Influence of the base effects from 2022, when inflation underwent rapid acceleration following the commencement of a large-scale invasion (NBU March 2023 Inflation Update, April 2023; NBU April 2023 Inflation Update, May 2023).

Starting from the 24th of February till the middle of July 2022, the exchange rate was pegged to USD (1 USD = 29,25 hryvnia). In July 2022, the NBU devaluated the exchange rate to 36.56 hryvnias per USD (see Figure 3) to improve the competitiveness of domestic production and stimulate export (Summary of Key Policy Rate Discussion..., August 2022). The fixed exchange rate, administrative restrictions, and FX interventions contributed to stabilizing expectations and price dynamics, and inflation is expected to moderate due to tight monetary policy, lower global inflation, and weaker demand (see Figure 2) (NBU Forecast Lower Inflation..., 2023).

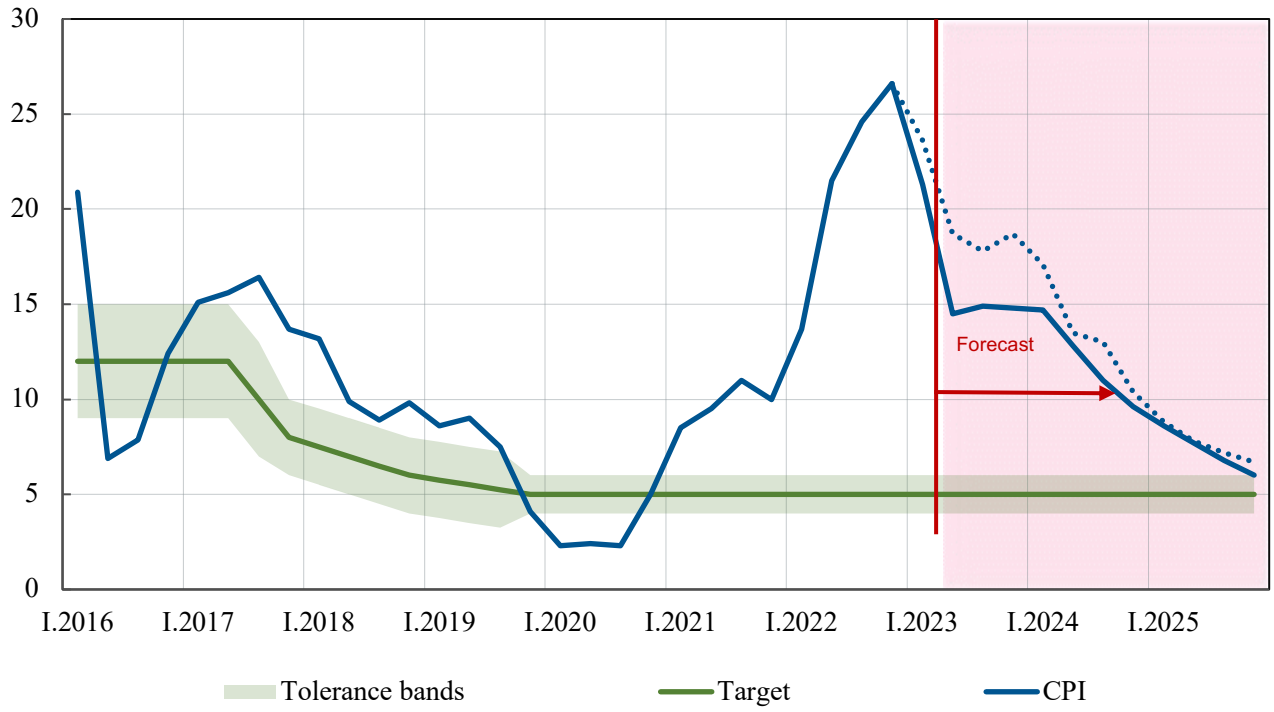

Figure 2: Inflation forecast and inflation targets, % y-o-y, based on the Inflation Report issued in April 2023

However, low yields on hryvnia assets increased the risk of dollarization, and the difference between the cash market exchange rate and the official exchange rate widened, causing negative effects on the economy (NBU Raises Key Policy Rate..., 2022). Starting from March 2023, the cash market exchange rate started narrowing, coming very close in May to the official exchange rate defined by the NBU. The strengthening of the hryvnia was influenced by a combination of factors. One reason was the seasonal activity of farmers getting ready for the spring sowing campaign. Additionally, the actions taken by the NBU, such as refraining from monetizing the budget deficit, boosting the domestic debt market, and improving the pace of financial aid from international partners, played a role. Furthermore, the hryvnia's strength was also influenced by the capacity of individuals to acquire currency through time deposits (Банкіри називають перчинами зміцнення готівкового курсу…, 2023; Курс гривні зміцнюється…, 2023).

Figure 3: The exchange rate of the hryvnia (UAH) to the USD based on the NBU and MinFin data

However, risks to the inflation forecast remain elevated due to security risks. The consequences of putting them into practice could be unfavorable: heightening the strain on the currency exchange rate and global reserves, while also unsettling expectations and jeopardizing the progress made in curbing inflation. At the same time, the representatives of the Monetary Policy Committee consider that the key policy rate could be decreased to 21%, making the 4th quarter of 2023 the most opportune time for the reduction cycle. This choice is motivated by the need to prioritize the easing of specific currency restrictions (Summary of Key Policy Rate Discussion..., May 2023).

Earlier this year, the NBU has taken steps to increase interest rates on hryvnia deposits and tighten reserve requirements (NBU Keeps Enhancing Monetary Transmission..., 2023). Moreover, the regulator has allowed banks to use a wider range of domestic government debt securities to cover up to 50% of their total required reserves to encourage banks to participate in auctions and help revive the domestic debt market (NBU Keeps Taking Measures..., 2023). However, these measures may not be enough to protect hryvnia retail and corporate deposits from inflation, so additional tools are being considered. The MPC also believes that the NBU's measures to stimulate hryvnia term deposits and stabilize the FX

market will lead to easing FX market restrictions that adversely affect business activity (Summary of Key Policy Rate Discussion..., February 2023).

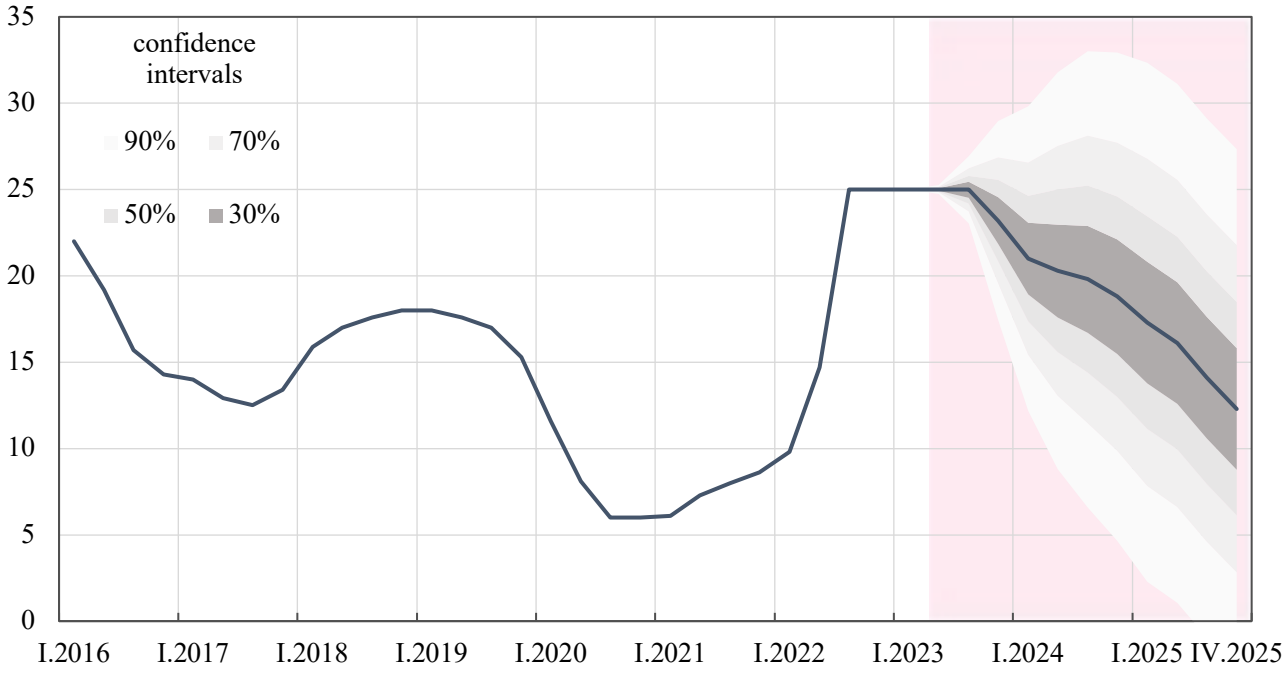

Figure 4: The forecast of the key policy rate, %, based on the Inflation Report issued in April 2023

To sum it up, we looked at how different countries after World War II and other armed conflicts conducted their monetary policy to stabilize financial markets and reduce inflation. The countries used different monetary policy tools such as open market operations, selective credit controls, adjusting discount rates, and controlling bank liquidity. Fixing exchange rates has been also effective in stabilizing macro-financial conditions, but it may also lead to accumulating macroeconomic imbalances over time. Also, we paid attention to how the NBU has been maintaining macro-financial stability and controlling inflation during the active phase of the russian-Ukrainian war, what actions turned out to be successful, and what steps should be implemented to improve the transmission of the key policy rate.

Hypothesis

Our research focuses on examining the potential trajectory of inflation under the current scenario outlined by the NBU (National Bank of Ukraine) and its macro-forecast. We hypothesize that the anticipated decrease in security risks by the end of 2023 will lead to a continued deceleration of inflation. If the security situation improves as expected, there may be a need for the NBU to consider reducing the key policy rate.

The adjustment in the interest rate would aim to stimulate economic expansion and provide support to businesses, fostering a conducive environment for their activities. By investigating the dynamics of inflation and the potential impact of changes in the key policy rate, we seek to assess the effectiveness of monetary policy measures in addressing economic challenges and promoting sustainable growth.

In addition to the scenario where security risks decrease, our research also explores alternative scenarios where the war persists and security risks remain high. In these challenging circumstances, we anticipate that the NBU will adopt a cautious and tight monetary policy stance to address inflationary pressures. However, while maintaining a vigilant approach to inflation control, the NBU may also recognize the importance of supporting economic growth during prolonged periods of conflict.

Therefore, we hypothesize that there could be a consideration for a modest reduction in the key policy rate, aimed at providing stimulus to businesses and households. This adjustment would help them navigate the challenges posed by the ongoing war and sustain economic activity. Our research aims to shed light on the effectiveness of these monetary policy measures in promoting stability and growth in different security scenarios.

Chapter 3: Model Overview

To build a system dynamics model that will depict the work of the inflation-targeting regime, attention was paid to the number of different articles on the official website of the NBU and the research conducted by the leading experts in monetary policy in Ukraine. In addition, certain sectors of the model are based on the research paper of Pervin Dadashova and Oleksandr Faryna (2015).

In general, countries, which conduct the inflation-targeting regime, build the QPM, and the key policy rate is defined by the Taylor rule (Grui, & Vdovychenko, 2019). It is a widely used monetary policy rule that provides a guideline for central banks to determine an appropriate level of short-term interest rates based on macroeconomic indicators. This rule was proposed by economist John B. Taylor in 1993 as a simple and practical way to guide monetary policy decisions. The basis of the Taylor rule rests on the principle that central banks should adjust interest rates in response to changes in economic conditions, particularly inflation, and output. The rule suggests that the central bank should set its target interest rate based on two key factors: inflation and output gaps (Hayes, 2022). In our case, inflation is endogenized variable upon which we build our model, and want to understand how it will be behaving in the future to understand what policies should be implemented to put Ukraine on the path of slow and constant inflation at 5%. At the same time, the output gap is taken as an exogenous one, and it is calculated using the HP filter. The weights of each indicator are based on the regression that is part of the simulation system model.

Figure 5 depicts the influence of inflation on the key policy rate, considering the GDP gap. Inflation is defined by the influence of inflation expectations (Clark, & Davig, 2009; Coibion, & Gorodnichenko, 2015; Afunts, Cato, & Schmidt, 2023). The key policy rate is defined according to Taylor`s rule, which is a guideline used in monetary policy to determine the appropriate interest rate adjustment by central banks. It suggests that the central bank should set its policy rate based on two factors: the inflation gap and the GDP gap. The rule states that when inflation rises above the target, the central bank should raise interest rates, and when the output exceeds its potential, the central bank should lower interest rates. By following Taylor's rule, central banks aim to maintain price stability while promoting economic growth and stability (Twomey, 2022). The regression to define the indicated policy rate was used with the mean of econometrics, and it has a high R^2 and all variables are statistically significant, meaning that p-values are less than 0,1 (see Appendix II). Also, the war shock was included to represent the rapid increase of the key policy rate by 15 p.p. in the middle of 2022 to ensure the financial welfare of local households in hryvnia, enhance the attractiveness of

domestic currency investments, ease pressure on the foreign exchange market, and thus bolster the central bank's capacity to maintain stability in exchange rates and mitigate inflationary pressures during a full-scale invasion (NBU Raises Key Policy Rate..., 2022).

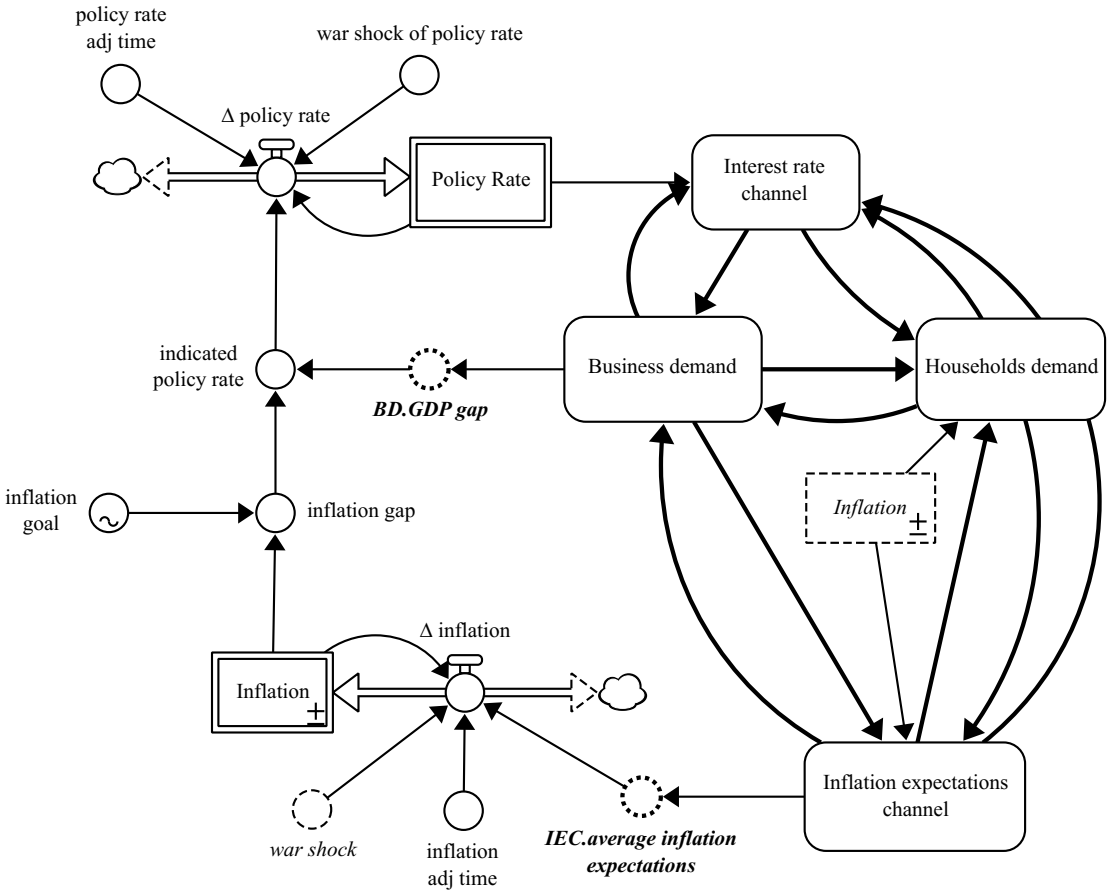

Figure 5. The monetary policy model of Ukraine

Additionally, Figure 5 depicts four sub-models: Interest rate channel, Business demand. Household demand, and Inflation expectations channel. Each of these sectors plays a vital role in transmitting the key policy rate, and we will look at them one by one.

As it was mentioned previously, the key policy rate affects inflation through the interest rate channel (see Figures 5-6). The policy rate affects the interbank interest rate, which is the rate at which banks lend and borrow funds from each other in the interbank market. Typically, the central bank sets its policy rate as a benchmark for short-term interest rates in the economy. When the central bank raises its policy rate, it sends a signal that borrowing costs are increasing, which can influence banks to raise their lending rates in the interbank market. As a result, the interbank interest rate increases,

reflecting the higher cost of borrowing for banks. In the case of Ukraine, the connection between these rates is positive and empirically it takes almost 5 months (0,4 years) to adjust.

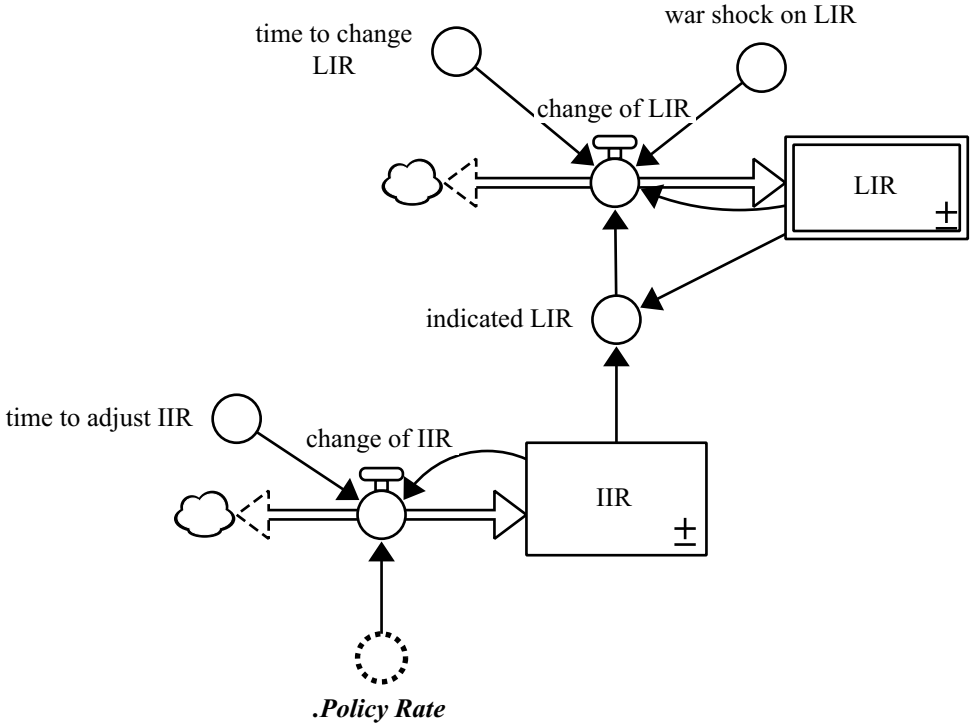

Figure 6: Interest rate channel sub-model. Interbank and Lending Interest rates

Then, the interbank rate affects the lending interest rate that banks set for businesses and consumers to pay on their loans. As banks use the interbank market as a source of short-term funds to meet their reserve requirements or to manage their liquidity needs, the interbank rate serves as a benchmark for banks to determine their lending rates to borrowers, including businesses and consumers. When the interbank rate increases, it becomes more expensive for banks to borrow funds from other banks, which leads to an increase in their overall borrowing costs. As a result, banks may adjust their lending rates to borrowers to reflect the higher cost of borrowing in the interbank market. This can increase loan interest rates that businesses and consumers face when they borrow from banks. Conversely, when the interbank rate decreases, it becomes less expensive for banks to borrow funds from other banks, which can lead to a decrease in their overall borrowing costs. This may result in banks lowering their lending rates to borrowers, leading to a decrease in loan interest rates (How does the NBU influence inflation..., NBU). Empirically, it was found that the time for loan interest rates to adjust to the changes in the interbank interest rate is on average 3 months (0,25 years). The indicated value of LIR was defined with the mean of econometrics, and it has a high R^2, and all variables are statistically

significant, meaning that p-values are less than 0,1 (see Appendix II). Also, the war shock is included to represent how the war influenced banks` decision to secure the risks connected with the conflict.

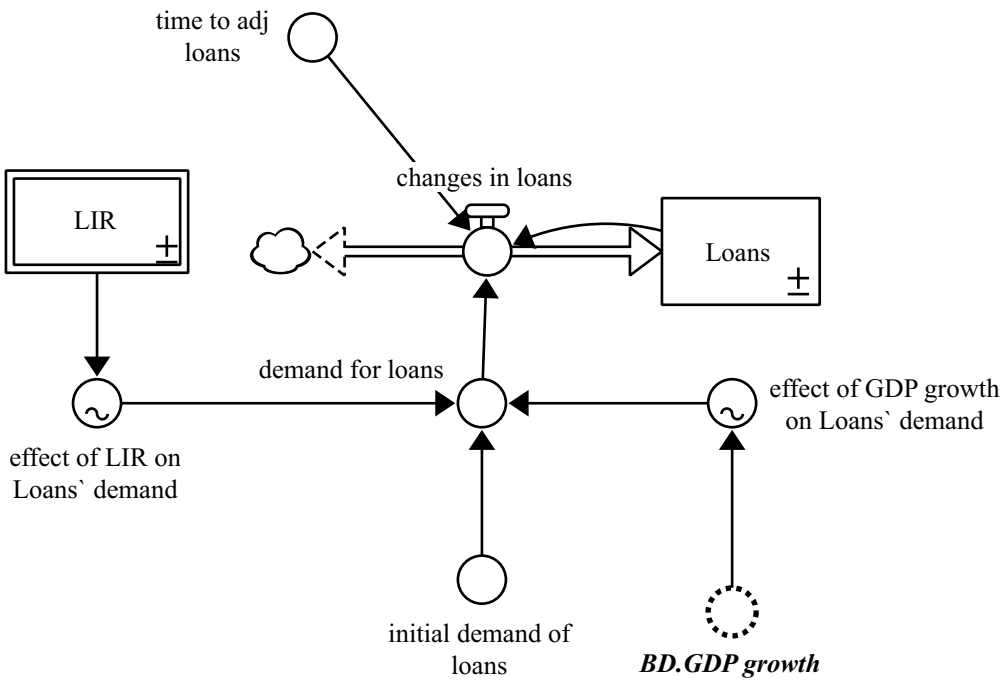

Figure 7: Interest rate channel sub-model. Loans definition

In addition, loans are the main sources for banks to conduct their business, and it is usually determined by the demand on them from the businesses, as they are primarily the economic agents who take loans in Ukraine, and households (their demand depends mostly on the interest rate the banks set). The higher the loan interest rate (LIR), the lower will be demand for loans. These assumptions are based on the hypothesis and the articles devoted to this topic (Gobat; Dijik, Döttling, Lambert, & Beck, 2020; Глущенко, Івахненков, & Демків, 2021). During 2016-2022, the loans have stayed almost at the same level – on average 1 trillion UAH (Наглядова статистика, НБУ).

Also, loans play a vital role in the formation of reserves in the banks (see Figure 8). When a bank makes a loan to a borrower, it creates a new deposit in the borrower's account. This new deposit is considered a liability for the bank, as it represents an obligation to the borrower to repay the loan. However, the loan amount is also considered an asset for the bank, as it represents the amount that the bank expects to receive in principal and interest payments from the borrower. In the process of creating a new deposit through a loan, banks are also required to maintain a certain number of reserves as mandated by the central bank (ОБОВ'ЯЗКОВІ РЕЗЕРВИ, НБУ). In Ukraine, the central bank has its measure of the risk-weighted assets and according to it banks defined what percentage of the loan should

go to reserves. According to our estimations, this fraction was in the range of 30%-50% (Наглядова статистика, НБУ).

Finally, the reserves are formed not only on the loans the banks provide to the customers but also on the deposits (see Figure 8). Banks hold reserves as a percentage of their customers' deposits and current accounts, as required by regulations set by the central bank. These reserves are typically held in the form of cash or deposits with the central bank, and they serve as a buffer to ensure that banks have sufficient funds to meet their obligations, including withdrawals by customers and payment obligations to other banks. When customers deposit money into their accounts with a bank, a portion of those deposits may be held as reserves, as required by regulatory guidelines. In the case of Ukraine, the average reserve ratio was equal to 5% (Обов'язкові резерви, НБУ). It means that banks must hold 5% of their customers' deposits as reserves. The remaining 95% can be used by the bank for various purposes, such as lending to borrowers, investing in securities, or funding other operations.

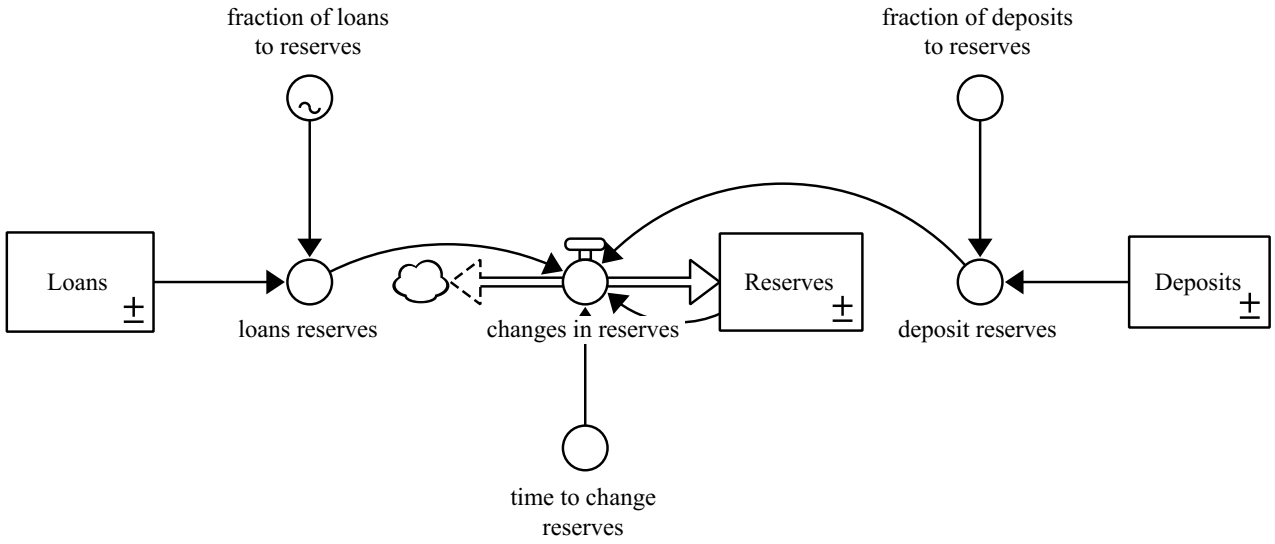

Figure 8: Interest rate channel sub-model. Reserves definition

Another indicator, which is also crucial in our case, is the deposit interest rate. It depends on the lending interest rate and deposit interest rate in the previous period. When the lending interest rate rises, it becomes more expensive for banks to acquire funds. To offset these increased costs, banks may adjust their deposit rates to maintain a balance between their lending and deposit activities and generate income from the spread between the two rates (Kagan, 2021; Landsberg-Kang, & Plosser, 2022; Banton, 2023). The regression to define the indicated deposit rate was used with the mean of econometrics, and it has a

high R^2 and all variables are statistically significant, meaning that p-values are less than 0,1 (see Appendix II).

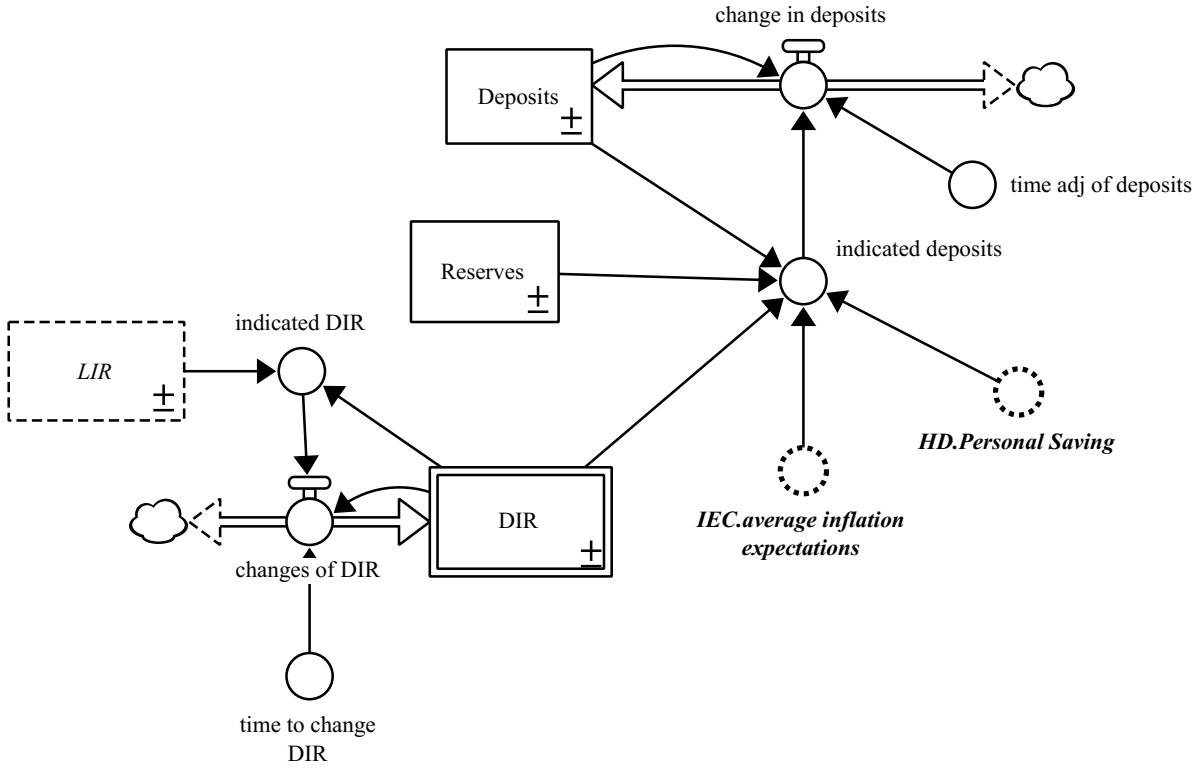

Figure 9: Interest rate channel sub-model. Deposits and their interest rate definition

In our model, the level of deposits is determined by several key factors, including average inflation expectations of economic agents, the deposit interest rate (DIR), reserves, and personal savings. Firstly, the average inflation expectations play a crucial role in shaping individuals' perception of the attractiveness of deposits as a tool for saving money from inflation. When inflation expectations are higher, individuals are more inclined to seek ways to protect the value of their savings against eroding purchasing power. Deposits become particularly appealing in such situations, as they offer a relatively stable and secure means of preserving funds over time (Duca, Kenny, & Reuter, 2018).

Secondly, the deposit interest rate (DIR) directly influences the attractiveness of deposits. A higher DIR tends to incentivize individuals to deposit their money into financial institutions. A more favorable interest rate implies that depositors can earn a higher return on their savings, making deposits a more appealing choice compared to alternative investment options. Conversely, a lower DIR may reduce the attractiveness of deposits and encourage individuals to explore alternative avenues for their savings (Chen, 2022).

Also, reserves play a significant role in influencing the demand for deposits within a banking system. When Central banks impose reserve requirements, they control the amount of money that banks can lend out and influence the overall money supply in the economy. When reserve requirements are increased, banks need to hold more reserves, which reduces the amount of funds available for lending and potentially dampens the demand for deposits (Bajpai, 2022).

Lastly, personal savings also contribute to the level of deposits. The individual propensity to save, influenced by factors such as income, financial goals, and economic conditions, plays a role in determining the overall amount of funds available for deposit. Higher personal savings can lead to increased deposit levels, while lower personal savings may result in reduced deposit volumes (Eule, Kastelein, & Sala, 2022). Therefore, in our model, the combination of average inflation expectations, the deposit interest rate, and personal savings collectively shape the attractiveness and level of deposits. The regression to define the indicated deposit rate was used with the mean of econometrics, and it has a high R^2 and all variables are statistically significant, meaning that p-values are less than 0,1 (see Appendix II).

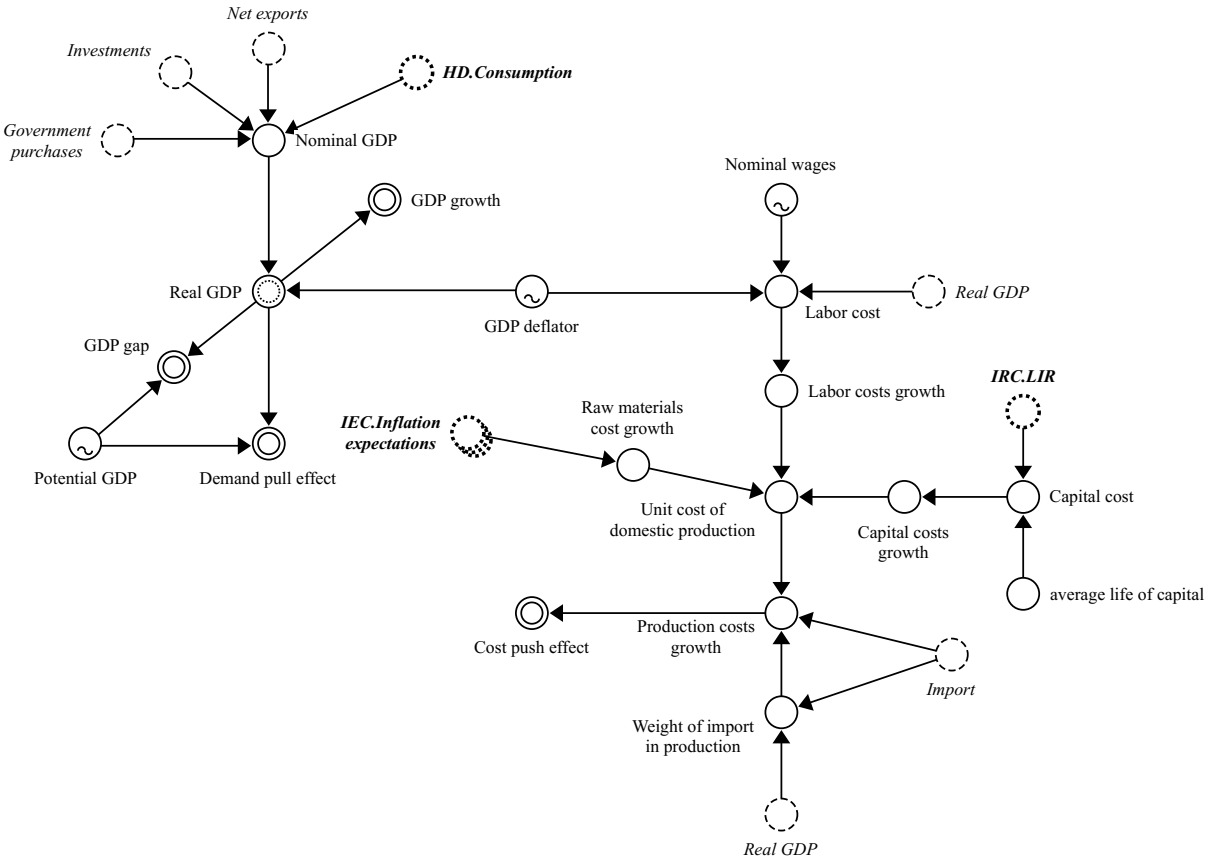

Figure 10: Business demand sub-model

After analyzing the first stage of the interest channel work through the prism of the system dynamics modeling, we are moving to another sub-model – Business demand. Its structure is based on the work of two Ukrainian researchers (Фарина, & Дадашова, 2015). In this sector, the expense associated with capital is established by the proportion of loan interest rates to the average duration of capital, while labor costs are determined by real wages (which are nominal wages adjusted for inflation) and real GDP (which entails adjusting nominal GDP for inflation).

The price level undergoes the influence of two primary factors: the demand-pull effect and the cost-push effect. The demand-pull effect arises from the growth of real GDP within our designated timeframe, whereas the cost-push effect is shaped by alterations in the production cost per unit of output. In the case of domestically produced goods, this effect arises due to changes in raw material costs and fluctuations in the costs of production factors per unit of output (Chen, 2022; Lock, 2022; Kenton, 2022). For imported goods, the cost-push effect manifests in the level of imported inflation, which is weighed against changes in the exchange rate. Essentially, the model assumes that the price level escalation is triggered by a surplus of demand over supply in the market, as well as by an increase in the production cost or purchase price of a unit of output for resale (Фарина, & Дадашова, 2015).

Figure 2.11 depicts the sub-model – Household demand. Its structure is based on the work of two Ukrainian researchers. The way household earnings are distributed plays a vital role in determining how funds are further allocated. Once taxes and social contributions are considered, the remaining disposable income is split between personal savings and consumption. The percentage of income allocated to consumption is influenced by the propensity to consume, which is inversely linked to fluctuations in deposit interest rates adjusted for inflation. Additionally, it is also influenced by the responsiveness of consumption to interest rate changes, referred to as the Interest Rate Elasticity of Consumption. This measure gauges how consumption levels react to variations in interest rates, illustrating how changes in interest rates can impact overall consumption in the economy. A higher elasticity signifies that consumption is more receptive to interest rate shifts, whereas a lower elasticity indicates less sensitivity of consumption to such changes. Consequently, fluctuations in price levels and interest rates are significant factors that affect alterations in consumption levels (Фарина, & Дадашова, 2015).

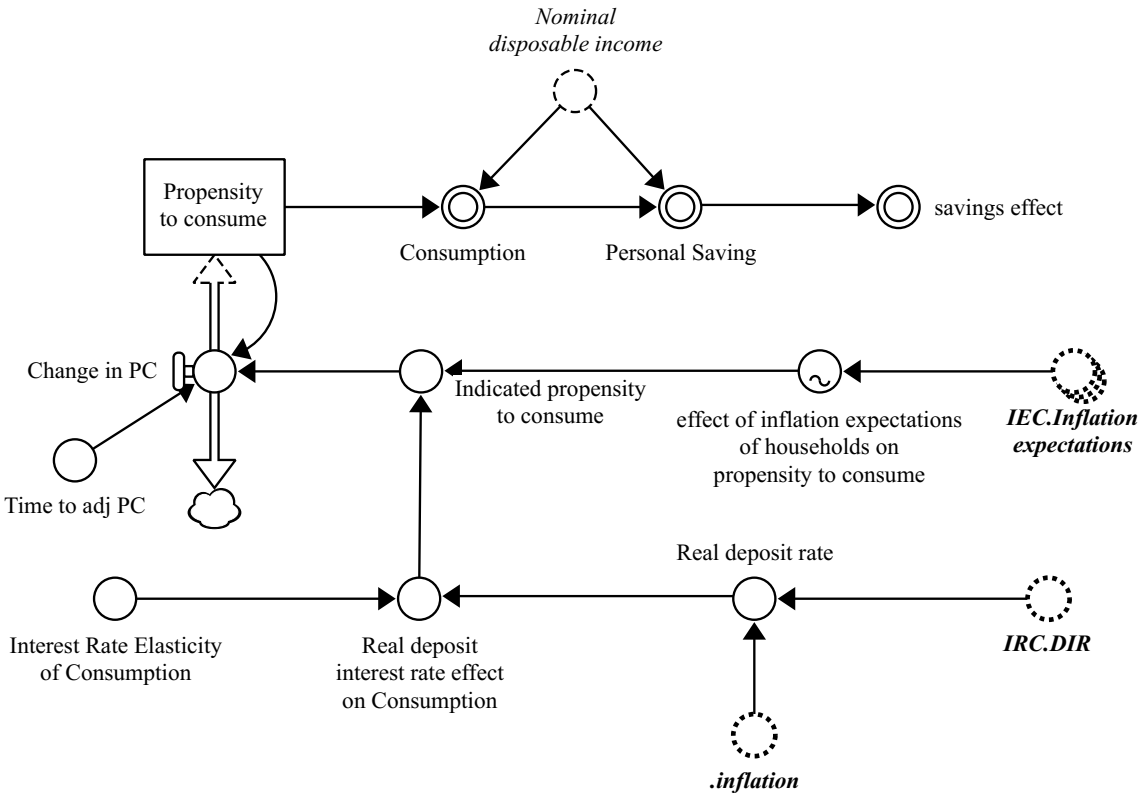

Figure 11: Household demand sub-model

Moreover, the inflation expectations of households regarding the upcoming 12 months are pivotal in shaping the extent of consumption. In the event of expectations for notable inflationary growth, households lean towards higher present spending rather than saving, being aware that the future value of the same goods will incur considerably greater costs (Lee, Powell, & Wessel, 2020). This serves as a primary driver behind Ukrainians expending nearly 99% of their income. Another contributing factor is the magnitude of their salaries and expenses, which fundamentally prohibits them from accumulating savings.

Another monetary transmission channel, which plays a significant role in the framework of the inflation-targeting regime in Ukraine, is inflation expectations (see Figure 12). These expectations by the economic agents are formed by the published forecasts of the NBU, and they are adjusted to the trust of the NBU from households and businesses and the time it takes for economics agents to make decisions (according to the manual calibration, the best time is 3 months or 0,25 year). The higher the deviation between the real values of inflation and the predicted values of the central bank, the lower the trust in this regulator from economic agents is (Christelis, Georgarakos, Jappelli, & Rooij, 2020). Moreover, the inflation expectations of households are affected also by the savings effects, while businesses – cost-push and demand effects.

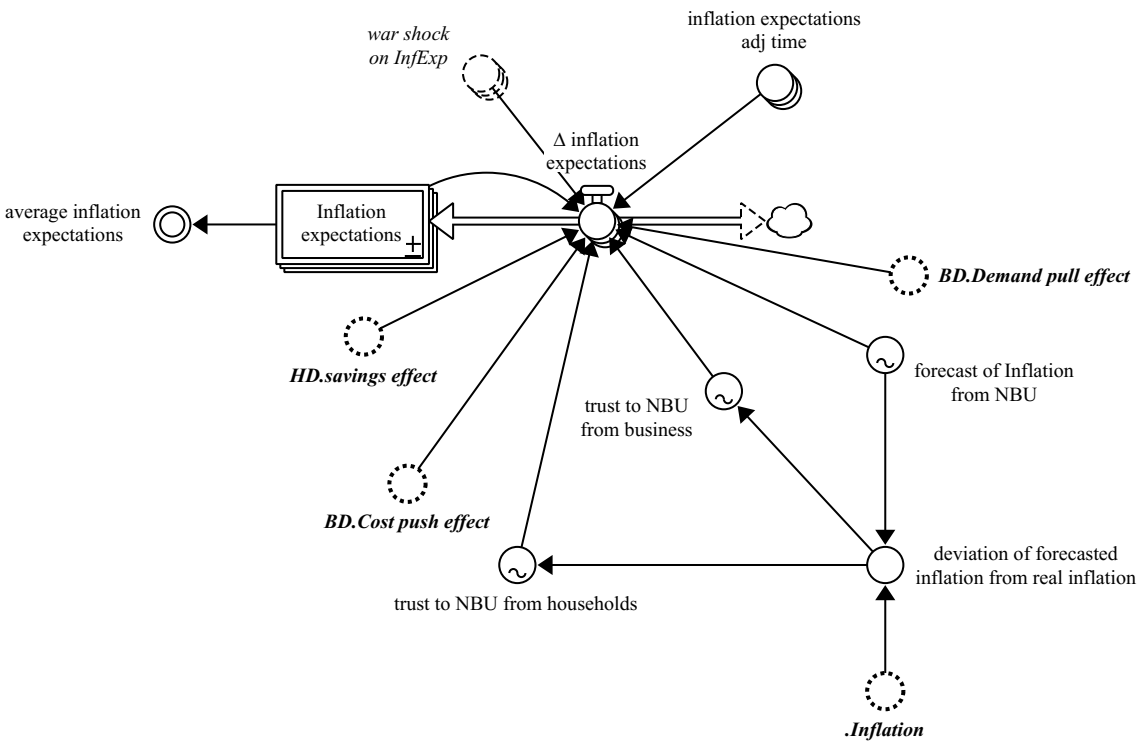

Figure 12: Inflation expectations channel sub-model

The growth of savings can also shape inflation expectations through psychological and confidence factors. When individuals observe a significant increase in savings, they may develop a more positive outlook on their financial well-being and prospects. This improved confidence can influence their expectations regarding future inflation levels. If individuals perceive that their savings are secure and will retain their value over time, they may have lower inflation expectations. Conversely, if individuals are concerned about the erosion of their savings due to inflation, their expectations may become more inflationary (Vellekoop, & Wiederholt, 2017).

Also, we suggest that inflation is influenced by factors such as cost pressures, demand dynamics, and expectations. Price managers are likely to raise prices in response to observed or anticipated increases in unit costs, as well as to output gaps. Moreover, expectations play a crucial role in shaping inflationary trends, as businesses and consumers adjust their behavior based on anticipated price movements. When expectations of future price increases are prevalent, it can lead to a self-fulfilling prophecy, where inflation accelerates due to widespread actions aligned with those expectations. Overall, the hypothesis highlights the complex interplay between cost-push, demand-pull, and expectations in driving inflation.

When the demand push effect is higher than 1, it indicates an overheating economy with higher demand for goods and services than the economy can sustain in the long run. In such a scenario, businesses may anticipate increased demand for their products and services, leading to potential upward pressure on prices. As a result, businesses may revise their inflation expectations upwards, anticipating the need to adjust prices to maintain profitability in the face of heightened demand. If the demand push effect is below 1 (indicating an output gap), businesses may perceive production constraints within the economy. This could be due to factors such as limited resources, bottlenecks in supply chains, or underutilization of productive capacity. In this situation, businesses may have lower expectations of inflation, as they do not perceive significant upward pressure on prices arising from excess demand (Chen, 2022; Lock, 2022). Also, If the production costs increase, businesses may anticipate higher expenses in their production process. As a result, businesses may adjust their inflation expectations upwards, considering the potential need to raise prices to maintain profitability (Kenton, 2022).

According to the research of O.Zholud, V. Lepushynskyi, and S. Nikolaychuk, businesses are more inclined to trust the regulator`s forecasts than households (2019). As a result, the graphical functions were built considering these results. Moreover, this sub-model contains the war shock, and it changes depending on the scenarios we are testing in the model (see Chapter 5). This variable was added due to the full-scale invasion, which caused significant disruptions in the economy, including changes in government spending, resource allocation, production, and trade patterns. These disruptions affect inflationary pressures and, in turn, influence inflation expectations. In the case of households, the inflation expectations for the first time were below the forecasted values of the regulator. It might relate to the pegged exchange rate, which has had a strong impact on inflation expectations (2019). Also, the weaker demand due to the large number of displaced Ukrainians abroad and the shortage of electricity had an impact on the inflation expectations of households. In the case of inflation expectations of business, they reflect the pattern of the NBU`s forecast for 2022. It can be explained due to the devastation of enterprises and infrastructure, the disturbance of manufacturing and distribution networks, the rise in operational expenses for businesses, and the spontaneous surge in demand for specific commodities and services prompted by exaggerated enthusiasm (NBU 2022 Inflation Update, January 2023). To ease the modeling of the inflation expectations of different stakeholders, we take the average values of both businesses and households. Before 2022, their projections for the anticipated inflation were mostly on the same level; so, deriving the average of them does not have any negative impact on the simulations of price levels.

Chapter 4: Analysis of the Simulation Model

In this chapter, we will demonstrate the main loops and describe them more precisely and prove that this model could be used for scenario analysis.

Behavior Dynamics

The main loop, which acts as the driving force for this model, revolves around the intricate relationship between inflation expectations, the key policy rate, other interest rates such as interbank, lending, and deposit rates, as well as the propensity to consume, ultimately leading back to inflation expectations (see Figure 13).

At its core, inflation expectations play a pivotal role in shaping the overall inflationary environment. When individuals and market participants anticipate higher inflation in the future, they adjust their behavior and financial decisions, accordingly, leading to its rise. When inflation rises, it creates a positive inflation gap, meaning that the forecasted inflation deviates from a target value. In that case, the central bank usually responds by increasing the policy rate to dampen inflationary pressures. Conversely, if the inflation gap is negative, central banks may lower the policy rate to stimulate economic growth.

Changes in the key policy rate subsequently affect other interest rates, such as interbank rates, lending rates, and deposit rates. When the policy rate increases, it tends to raise borrowing costs across the financial system, leading to higher interbank interest rates, which, in turn, leads to the increase of lending and later deposit interest rates. On the other hand, a decrease in the policy rate can lead to reduced interest rates, making borrowing more affordable, and deposits less attractive.

The impact of the real deposit interest rate on the propensity to consume is another crucial link in this loop. When the real deposit interest rate is positive, it increases the return on savings in real terms. As a result, saving becomes more attractive to consumers, leading them to allocate a larger portion of their income toward saving rather than consumption. This reduction in consumption can contribute to lower aggregate demand in the economy, potentially leading to a decrease in prices and inflationary pressures. Conversely, the negative value of the real deposit interest rate discourages saving, as individuals find it less attractive to save their money in negative-yield deposits. Increased consumption resulting from a low real deposit interest rate can contribute to elevated aggregate demand, creating the potential for price increases and inflation to occur.

Thus, the interconnectedness between inflation expectations, key policy rates, other interest rates, and the propensity to consume forms a continuous loop that shapes and influences the overall inflationary dynamics and economic conditions.

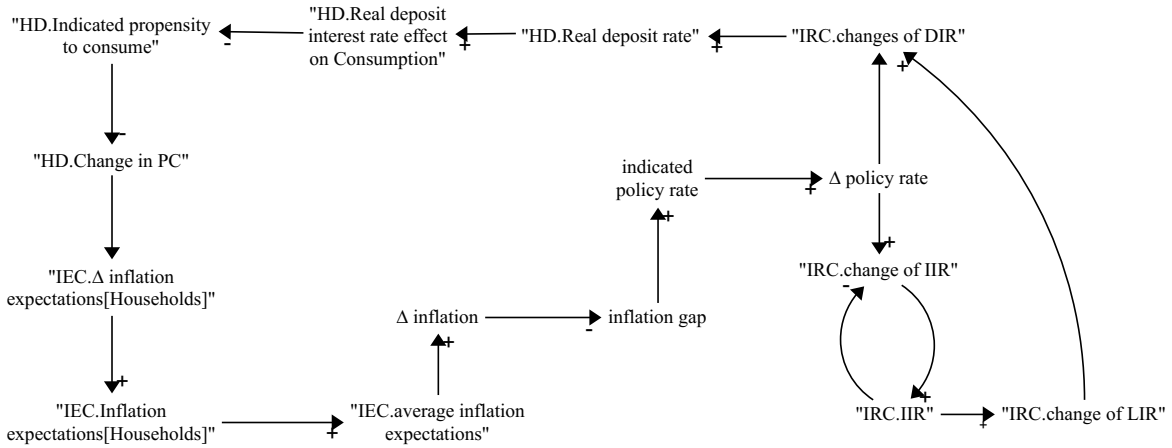

Figure 13: A feedback loop of inflation expectations, policy rates, interest rates, and consumption

Another loop that reinforces and drives this model revolves around the influence of the key policy rate on other interest rates, including interbank rates, lending rates, and deposit rates. These interest rates, in turn, have significant effects on the real deposit interest rate, which plays a crucial role in shaping the propensity to consume, GDP, and the GDP gap, leading back to the key policy rate (see Figure 14).

At the center of this loop is the key policy rate, which is set by central banks to regulate borrowing costs, manage inflation, and influence economic activity. When the key policy rate is adjusted, it has a ripple effect on other interest rates across the financial system. An increase in the key policy rate tends to raise interbank rates, lending rates, and deposit rates, making borrowing more expensive and impacting the overall cost of credit.

The real deposit interest rate, which considers inflation, is a crucial factor influencing the propensity to consume. When the real deposit interest rate is positive, individuals are more inclined to save rather than spend, leading to a decrease in the propensity to consume. Conversely, a negative real deposit interest rate incentivizes spending and can stimulate consumption, potentially boosting economic growth. The propensity to consume, in turn, affects GDP, which is a measure of the total value of goods and services produced within an economy. When consumption increases, it contributes to GDP growth. Conversely, if the propensity to consume decreases, it can have a dampening effect on economic output.

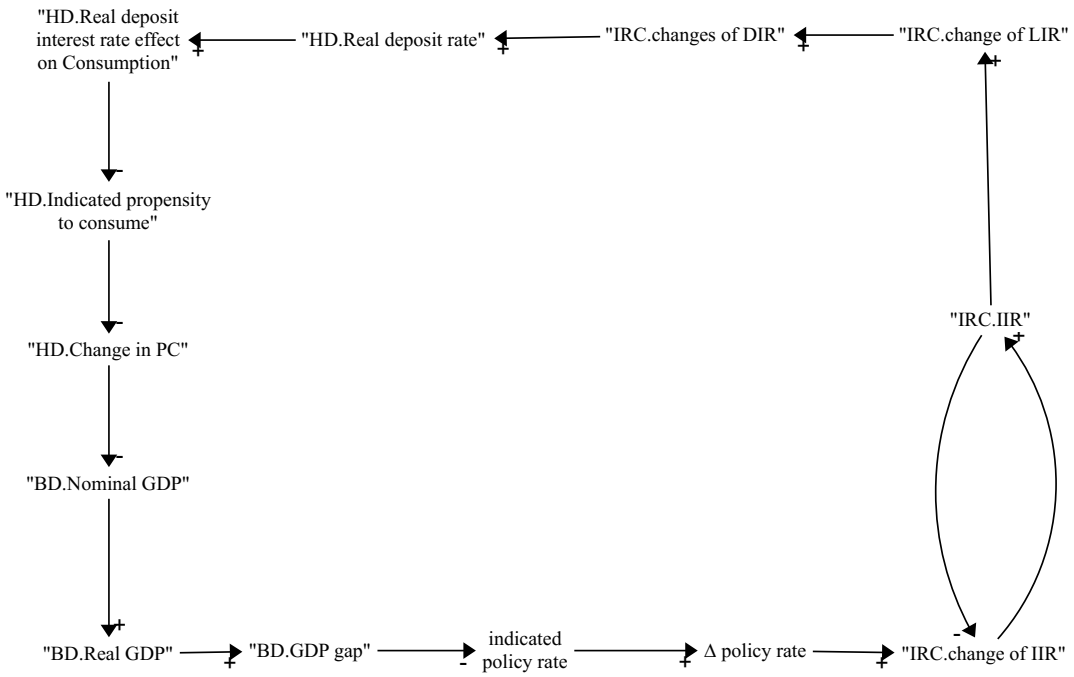

Figure 14: Feedback loop involving the key policy rate, other interest rates, the real deposit interest rate, the propensity to consume, GDP, and the GDP gap

Furthermore, the GDP gap, which represents the difference between actual GDP and potential GDP, is influenced by the level of economic activity. When consumption and GDP are below their potential levels, a negative GDP gap emerges, indicating an underutilization of resources. Conversely, when consumption and GDP exceed their potential levels, a positive GDP gap occurs, indicating potential inflationary pressures. This intricate loop then leads back to the key policy rate. When the GDP gap increases, the central bank may respond by considering a decrease in the key policy rate. This reduction in the interest rate is aimed at stimulating economic activity and promoting growth. By making borrowing cheaper, the central bank encourages businesses and consumers to increase their spending, thereby boosting aggregate demand and potentially reducing the GDP gap and vice versa.

In summary, this loop demonstrates the interplay between the key policy rate, other interest rates, the real deposit interest rate, the propensity to consume, GDP, and the GDP gap. Changes in the key policy rate impact interest rates, which, in turn, influence the real deposit interest rate and consumption patterns. These consumption patterns have ramifications for GDP and the GDP gap, which then inform the central bank's decision regarding the key policy rate, completing the cycle.

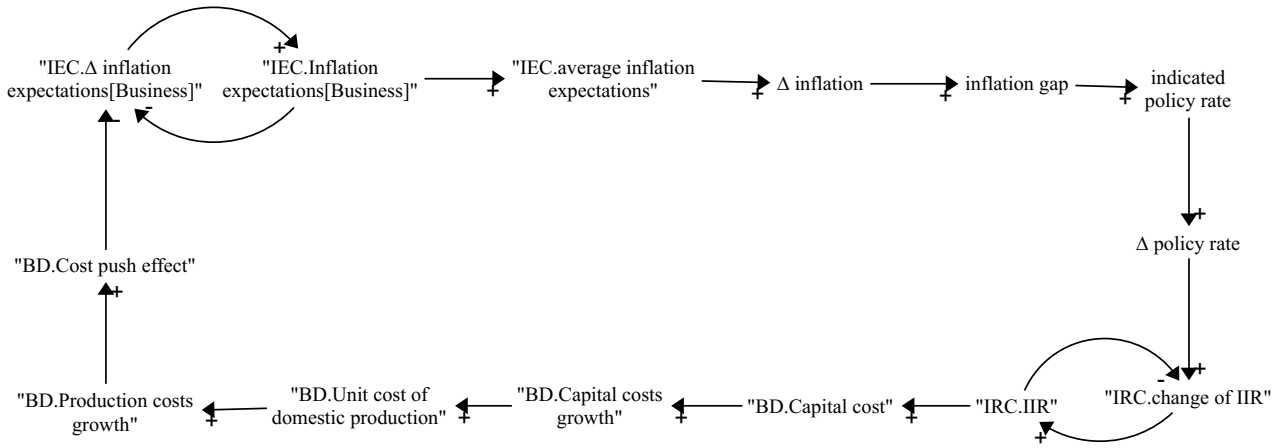

Figure 15: Interest rates loop

Another loop that balances and drives this model involves several interconnected factors (see Figure 15). It begins with the impact of inflation expectations on inflation, which plays a central role in shaping economic dynamics. When inflation expectations rise, it fuels actual inflation as businesses and individuals adjust their behaviors and pricing strategies accordingly. Another key component influenced by inflation expectations is the key policy rate. Central banks, in response to inflation expectations, may adjust the key policy rate to control inflationary pressures. When the positive gap between the target and expected inflation occurs, the central bank increases its policy rate.

Once again, the adjustment of the key policy rate, in turn, has ramifications for other interest rates - interbank, lending, and deposit. When the policy rate increases, it tends to raise borrowing costs across the financial system, impacting the interbank rate positively. The interbank interest rate through the lending interest rate indirectly affects the capital cost for businesses. The higher the lending rate is, the higher cost of borrowing for businesses. As a result, the capital costs for investments and production grow.

The growth in capital costs, in turn, positively influences the unit cost of domestic production - the higher borrowing costs translate into increased expenses related to equipment, facilities, and labor. When the unit cost of domestic production rises, it contributes to overall production cost growth, meaning their increase, which affects the profitability and pricing strategies of businesses. Moreover, production cost growth has a cost-push effect on the inflation expectations of businesses. As production costs increase, businesses may anticipate higher inflation to maintain their profit margins. This feeds back into inflation expectations, creating a cyclical relationship.

In summary, this loop highlights the intricate interplay between inflation expectations, inflation itself, the key policy rate, other interest rates, lending interest rates, capital costs, the unit cost of

domestic production, production cost growth, and the cost-push effect on business inflation expectations. These factors continuously influence and balance one another, shaping the overall economic environment.

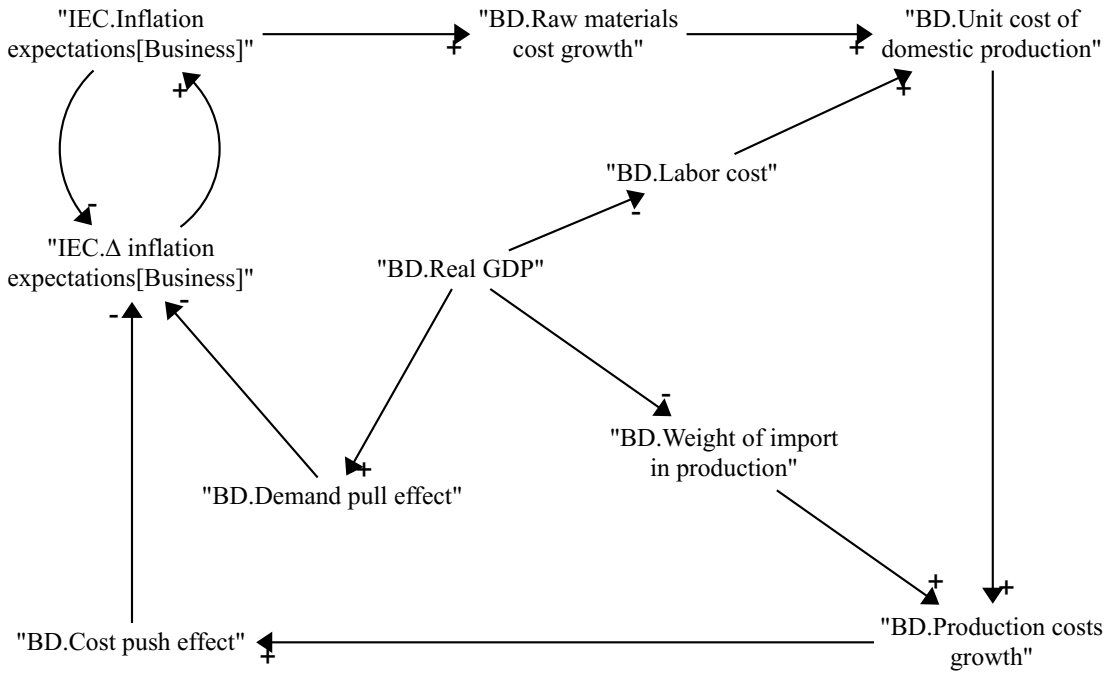

Figure 16: Feedback loop involving the cost and demand-pull effects on inflation expectations of businesses

Another loop that balances and drives this model encompasses several interconnected factors (see Figure 16). It begins with the influence of inflation expectations among businesses on the growth of raw materials costs. As businesses anticipate higher inflation, it leads to the growth in the prices of raw materials they procure for production. The next link in the loop is the unit cost of domestic production, which is affected by both the growth in raw materials costs and labor costs. When raw materials costs increase, it directly impacts the unit cost of domestic production. Similarly, labor costs play a significant role in shaping the overall production costs, making them grow. The growth in production costs, in turn, influences the cost-push effect on the inflation expectations of businesses. If production costs rise, businesses may adjust their pricing strategies, anticipating higher inflation and seeking to maintain profitability. This, in turn, can feed into their inflation expectations.

Another influential factor in the loop is the demand-pull effect, specifically the ratio of real GDP to potential GDP. When real GDP, the actual level of economic output, exceeds potential GDP, it

indicates increased demand and economic expansion. This demand-pull effect influences the inflation expectations of businesses, as higher demand potentially leads to upward price pressures.

In summary, this loop demonstrates the interplay between inflation expectations, raw materials cost growth, the unit cost of domestic production, labor costs, production cost growth, and the demand-pull effect. It highlights how businesses' inflation expectations influence raw materials costs, which further impact the unit cost of production. The growth in production costs, in turn, affects the cost-push effect on inflation expectations, while the demand-pull effect reflects the impact of real GDP on businesses' inflation expectations.

Validation

Validating a system dynamics (SD) model is a dual process that is inherent to its development and involves an iterative, gradual approach to instill trust in the simulation model (Forrester & Senge, 1980). The aim is to establish confidence by demonstrating that both the model's structure and behavior align with existing knowledge of the system being studied (Homer, 2012, p. 282).

We will start with the Theoretical Structure Verification test, as distinguished from the Empirical test, which involves comparing the model's structure with information available in the literature about the system (Barlas, 1996). During the iterative process of developing the model, we diligently carried out such testing by aligning the structural components with pertinent literature, mainly the work of Dadashova and Faryna (2015). This approach has been documented comprehensively, with detailed explanations provided in the relevant sections of this thesis and the accompanying model documentation.

Another test, which we have conducted is the Parameter Verification test, it involves evaluating constant parameters based on knowledge of real systems. This process, discussed by Forrester & Senge (1980), includes Conceptual Correspondence and Numerical Verification. In the monetary policy model of Ukraine, we have conducted detailed conceptual and numerical verification, aligning parameter values with empirical and modeling studies while considering the uncertainties associated with monetary policy-related parameters. However, adaptations were made to fit our adopted model while remaining within the literature's range. Some parameters were defined using Econometrics, and linear regressions, which proved to be adequate and resemble the historical values.

Throughout the development of the model, we carried out the Direct Extreme Conditions Test to evaluate the robustness of each equation when subjected to extreme conditions. A thorough examination was conducted to ensure that the equations exhibit suitable responses to extreme inputs. Also, all variables and parameters are assigned appropriate units of measure, making our simulation model to be

valid (Sterman, 2000). The automatic testing feature in the simulation software we utilized (Stella Architect 3.2.1) conducts this test seamlessly.

In determining the appropriateness of model aggregation and the inclusion of relevant structure, a crucial question revolves around the model's purpose (Forrester & Senge, 1980). In this context, our model aims to provide an endogenous perspective on the key policy rate`s response to inflation and the GDP gap according to different scenarios – when the full-scale invasion is going to end. With this purpose in mind, the boundary of the monetary policy model of Ukraine is deemed adequate, serving as the continuation of the research of the inflation-targeting regime during the war.

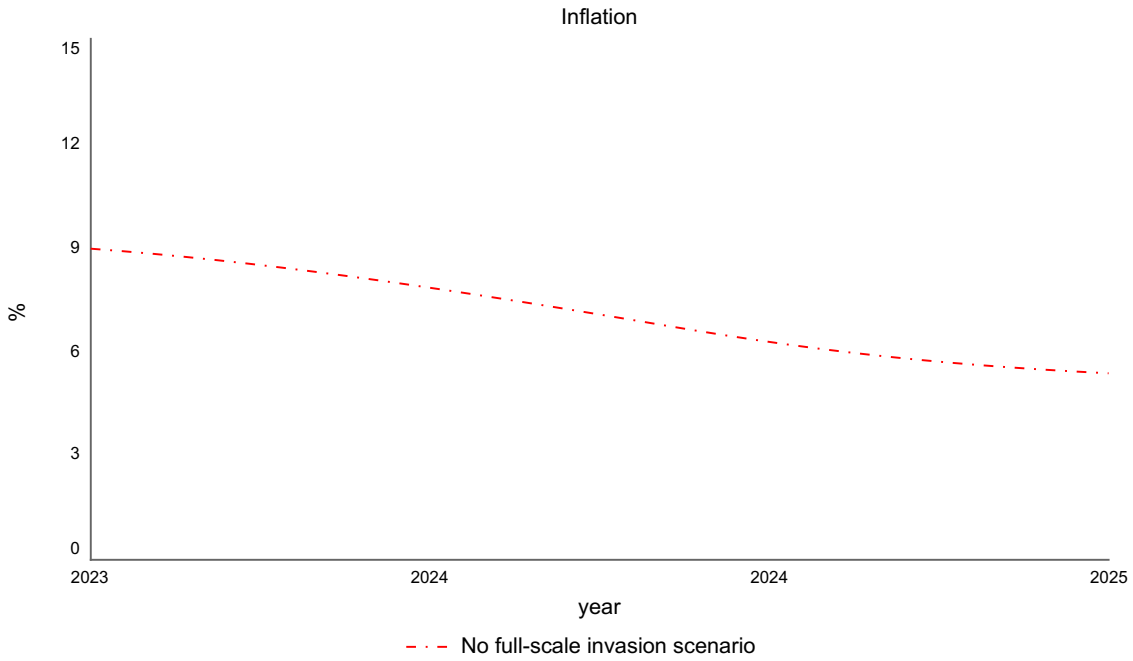

Figure 17. The forecast values of inflation according to the No full-scale invasion scenario

To assess the plausibility of our model's equations under extreme conditions, we employ the Indirect Extreme Conditions test using simulation. A crucial aspect of this evaluation is examining the scenario where no full-scale invasion happened to Ukraine. In such a situation, the expected behavior would entail a decrease in inflation and key policy rate, stimulating economic growth. Confirming this expectation, the graphs depicting this behavior as illustrated in Figures 17-18. The “No full-scale invasion” scenario is based on the macro-forecast, which the NBU presented before the war. According to this scenario, inflation will go down gradually, reaching 5% as of the end of 2025 – the same value the NBU predicted. At the same time, the key policy rate will remain still quite high reaching 12,1% to keep inflation low (Інфляційний звіт, January 2022).

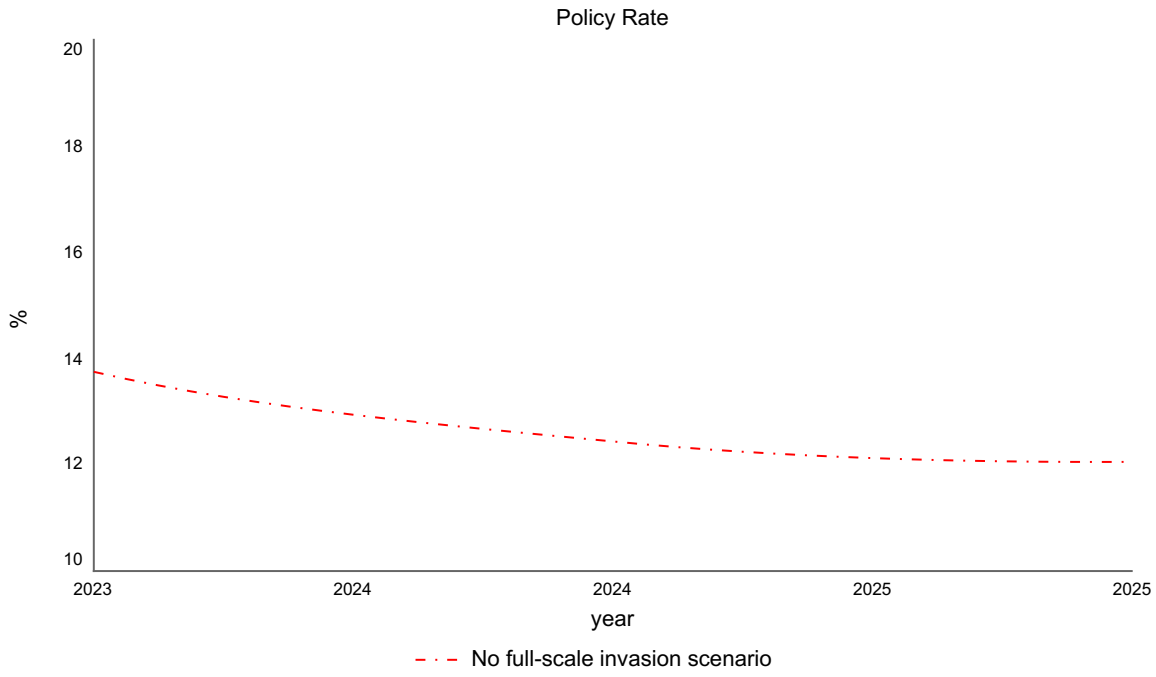

Figure 18. The forecast values of the key policy rate according to the No full-scale invasion scenario

Also, we conducted the sensitivity test (see Appendix III), which assesses the level of sensitivity exhibited by model parameters and compares it to the real system's expected sensitivity to corresponding parameters (Barlas, 1996). In addition to it, the partial model testing to define the most appropriate values of parameters or time adjustment to represent the values of variables as close as it`s possible to the historical values. The last test to which we paid attention is the full model behavior test, which assesses the model's ability to replicate the reference model of behavior and determine its accuracy. These tests prioritize predicting the primary patterns of behavior observed in the real system rather than providing a precise "point-by-point" prediction (Barlas, 1996, pp. 192–193). The key indicators represent the historical values very precisely. Detailed results of these tests are presented in Appendix IV.

Through the validation process, our confidence in the model has grown significantly. We find the structural validity to be notably robust, despite the inherent uncertainties associated with parameter values and the limited data available for parameterization and behavioral validation. Notably, we have observed a lack of sensitivity in many parameters. This validation process has been instrumental in guiding our understanding of the specific values and mechanisms that require further attention and refinement in subsequent iterations of the model.

Chapter 5: Scenario Analysis

In this chapter, we will look at the future, and see how the situation with inflation and what the NBU might do to influence it with the key policy rate according to the persistence of security risks.

Baseline Scenario:

Under this scenario, we assume that the active phase of the full-scale invasion will last till the end of 2023. Already, in 2023, the economy is poised to rebound, with a projected acceleration in the upcoming years driven by a reduction in security vulnerabilities. Furthermore, from 2024 to 2025, the rate of government procurements will experience a deceleration, driven by a reduced necessity for substantial defense expenditures. Simultaneously, investments are expected to accelerate, attributed to the elimination of security risks. In addition to it, there will be a rise in exports, accompanied by a heightened influx of returning Ukrainian citizens from overseas. Nevertheless, due to substantial import requirements for the country's reconstruction, the current account deficit is expected to endure, resulting in an expansion of the net export deficit. This scenario represents the current macro-forecast scenario of the NBU (NBU Expects Inflation to Slow Significantly..., 2023; Summary of Key Policy Rate Discussion, May 2023).

Results

According to the simulations, as of the end of 2023, inflation is expected to decline to 13.3%, followed by a further drop to 12,8% in 2024, and 8,92% in 2025 (see Figure 20). The economy will be booming starting in 2024, and the GDP gap will be narrowing, allowing the NBU to decrease the key policy rate to stimulate business. The outlook considers the expected decline in security vulnerabilities by 2024, as well as the continuous recuperation of transportation systems and manufacturing capacities, and the steadfast execution of monetary measures by the NBU. We expect that the NBU will decrease the key policy rate to 19,5% as of the end of 2023, 13,4% in 2024, and 10,3% in 2025 (see Figure 21). In addition, we expect that the inflation expectations of households will keep quite low in comparison to businesses due to the war shock effect on them.

Alternative Scenario № 1:

Based on this particular scenario, we assume that the period of intense full-scale invasion will extend until the end of 2024. Till this time, the economy will be growing but at a small scale compared to the base case scenario. It relates to businesses' adjustment to the war`s conditions. Meanwhile, there will be a sustained upsurge in government procurements until the culmination of 2024, after which the rate of growth will decelerate in 2025 owing to reduced requirements for defense expenditures. During 2023-2024, the investments are projected to remain relatively stable, experiencing minimal fluctuations, as the security risks will prevail and hinder capital outlays.

Also, with the active phase of the conflict ending at the end of 2024, subsequent years will witness an upsurge in exports and a higher influx of returning Ukrainian citizens. Simultaneously, imports will play a critical role in meeting the demands of households and businesses, resulting in an expansion of the net export deficit, albeit to a lesser extent than the base case scenario in 2024. However, starting in 2025, substantial import requirements for the country's reconstruction will contribute to the persistence of the current account deficit, leading to a further widening of the net export gap at a higher magnitude compared to previous years.

Results

Based on the projected results, inflation is forecasted to decrease to 16,3% by the end of 2023, followed by a further reduction to 13,7% in 2024 and 9,1% in 2025 (see Figure 20). The economy is anticipated to experience a gradual upswing, particularly from 2025 onwards, resulting in a narrower GDP gap. Despite it, the NBU will implement a reduction in the key policy rate, aiming to stimulate business activities. The forecast considers the expected reduction in security vulnerabilities by 2025, as well as the ongoing recovery of transportation systems and manufacturing capacities, supported by the consistent implementation of monetary measures by the NBU. Anticipated NBU actions include reducing the key policy rate to 21,5% by the end of 2023, followed by a further reduction to 17,3% in 2024, and 15,3% in 2025 (see Figure 21). Additionally, it is envisaged that households will maintain relatively modest inflation expectations compared to businesses, primarily influenced by the war shock effect they have experienced.

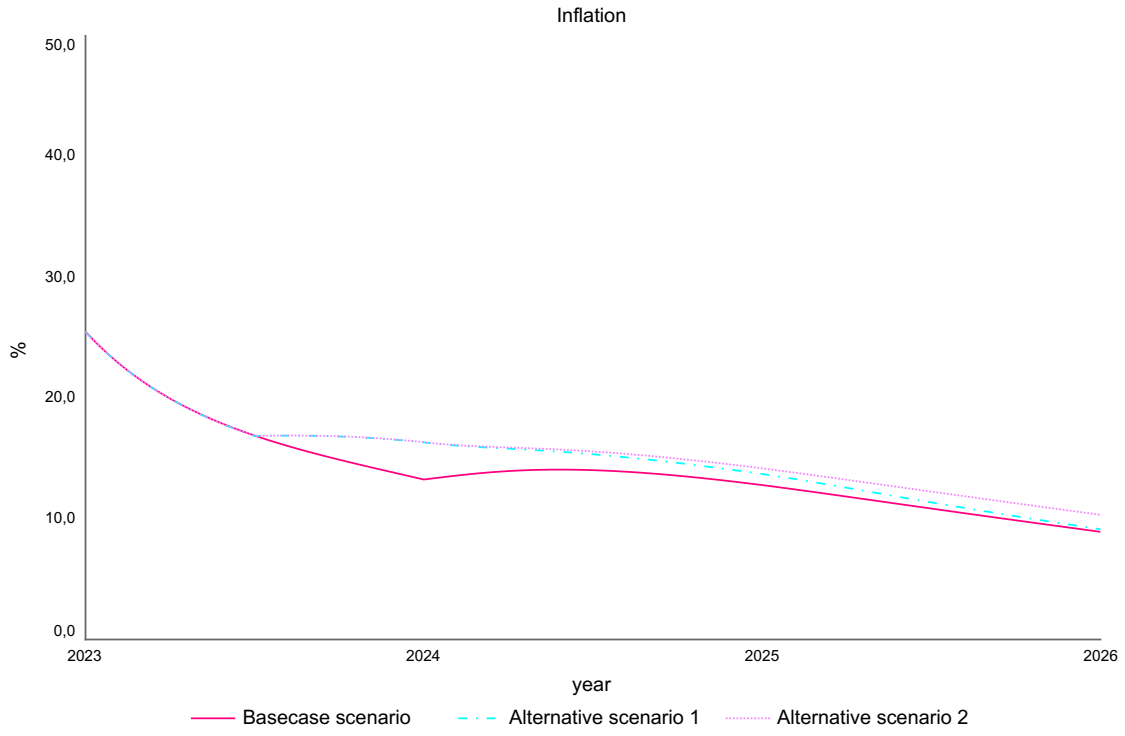

Figure 20: The forecast values of inflation according to different scenarios

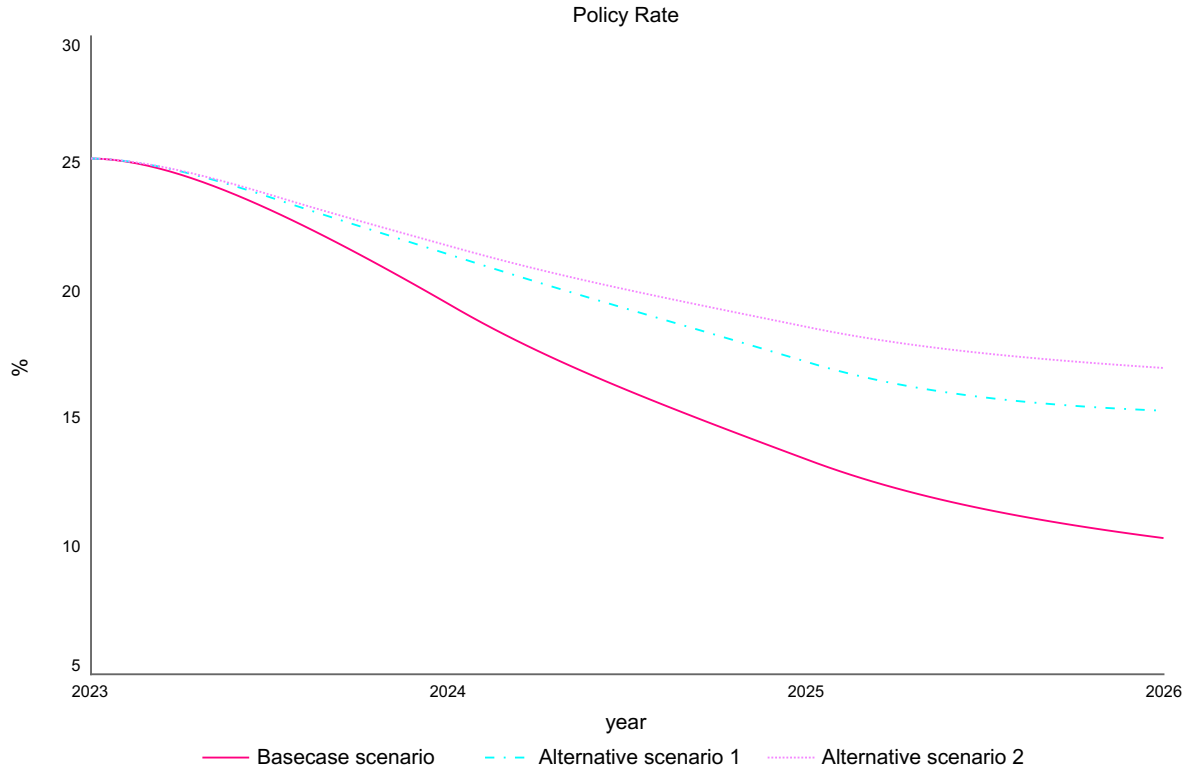

Figure 21: The forecast values of key policy rates according to different scenarios

Alternative Scenario № 2:

In this particular scenario, we assume that the active phase of the comprehensive invasion will extend until the end of 2025. The government purchases will continue to grow significantly till the end of our simulation, as there is a necessity to cover defense and social expenditures. Moreover, till the end of 2025, the significance of imports in meeting the demands of households and businesses will lead to an expansion of the net export deficit. However, the magnitude of this widening will be comparatively higher compared to both the base case and alternative № 1 scenarios throughout 2024-2025. Also, the investments will be growing marginally, as investors are hesitant to invest during times of war due to the high levels of uncertainty, safety concerns, economic instability, regulatory challenges, etc. At the same time, the economy is expected to experience modest growth, albeit on a smaller scale compared to the base case and alternative № 1 scenarios, as businesses adapt to the challenging conditions imposed by the war.

Results

Based on the projected simulations, inflation is set to decrease to 16,3% by the end of 2023, followed by a further decline to 14,2% in 2024 and 10,3% in 2025 (see Figure 20). Subsequently, the economy will be growing very slowly due to hostilities and possible future destructions, resulting in leaving GDP under its potential. Nevertheless, the NBU will decrease the key policy rate to bolster business activities. The prediction considers the projected decline in security risks by 2026, along with the ongoing revival of transportation systems and manufacturing capacities, which are reinforced by the NBU's unwavering commitment to implementing monetary measures. We expect that the NBU will decrease the key policy rate to 21,8% as of the end of 2023, 18,6% in 2024, and 17% in 2025 (see Figure 21). Additionally, it is expected that households will maintain relatively subdued inflation expectations compared to businesses, primarily influenced by the impact of the war shock on their perceptions.

Chapter 6: Discussion

Overview

This thesis aims to enhance our understanding of the full-scale invasion impact on the monetary policy in Ukraine by developing a simulation model that integrates the dynamics of inflation with the behavioral response of the key policy rate. We have looked at how the interest rate and inflation expectations channels work, and whether these transmissions are successful. In addition to it, we discovered what will be happening with inflation, and the Central bank will react to it according to different scenarios, which assume different times of war ending. To the best of our knowledge, this is the first modeling study that specifically addresses the work of the inflation-targeting regime through these two primary transmission channels during the wartimes in Ukraine, and we anticipate that it will contribute to discussions on future policies of the NBU depending on the security circumstances in the country.

Limitations & Further Directions

This model has a lot of limitations, as representing the more precise work of the interest rate formation in the banking system or the inflation expectations might be a separate work, which might be covered in our future works using the methods of System dynamics. In addition, we have presented the simplified form of the monetary policy in Ukraine to make it easier for policymakers to understand, as the primary tool of the inflation targeting regime is still the key policy rate, which influences inflation through different transmission channels. There are some of them, which we have not investigated. It includes the exchange rate, the asset, and the credit channel. In the 1st Chapter, we have explained that even though these channels exist, they don`t play any significant role in the inflation-targeting regime. Another channel, which was left behind in our investigation is the exchange rate channel. The main reason for it is that the exchange rate is currently pegged, and it is very hard to predict what the value of Ukrainian hryvnia is, and there are many indicators, which can influence that. For example, fluctuations in global economic conditions, changes in trade policies, geopolitical tensions, and shifts in investor sentiment can all impact the value of the national currency. But at the same time, the exchange rate is the indicator of economic stability for the economic agents, and they make their inflation forecasts according to the fluctuations in its value compared to other currencies, primarily, the euro and USD. That`s why it was assumed that the exchange rate impact has already been incorporated into the inflation expectations of households and businesses.

Chapter 7: Conclusion

Research Questions

1. What will be the values of inflation in the following years depending on different scenarios estimating when the full-scale invasion ends – at the end of 2023/2024/2025?

According to the simulations under different scenarios, we found out that inflation will go down anyway. The difference is when it`s going to deaccelerate. In the base case scenario, inflation is going down from 13,3% as of the end of 2023 to 8,92% as of the end of 2025. It`s very close to the current forecast of the NBU. The main reasons for such deacceleration are the declination of security risks, recovery of production capacities, and the consistent monetary policy of the Central bank (NBU Expects Inflation to Slow Significantly..., 2023). In other scenarios, the inflation will deaccelerate a little bit slowly, remaining higher for a longer period in 2023-2024 due to the continuation of the full-scale invasion. This will result in a higher GDP gap that will drive inflation expectations, and lower savings making households spend more now.

2. How will inflation expectations influence the real values of inflation, and what will drive them?

We expect that the inflation expectations of businesses will remain closely aligned with the current forecast of the NBU as their expectations are well anchored to the central bank's projections, as indicated by our simulations. However, households' inflation expectations are likely to be more influenced by the shock of the war and the impact on their savings, potentially resulting in higher inflation expectations. It is important to note that the average value of inflation expectations across both businesses and households ultimately serves as a significant driver of overall inflation levels. Additionally, the divergence in inflation expectations between businesses and households can create a complex dynamic in the economy. While businesses may have more stability and confidence in their inflation expectations due to their closer alignment with the NBU's forecast, households' higher inflation expectations could lead to cautious spending behavior and a potential decrease in consumer confidence. This, in turn, can impact overall economic activity and further contribute to inflationary pressures. It highlights the importance of managing and addressing the differing inflation expectations among various economic agents to ensure stability and sustainable economic growth.

3. Will it be necessary to increase the policy rate to achieve the target value of inflation?

Based on our simulations, no increase in the key policy rate is necessary as inflation is expected to decelerate under different scenarios. The focus is on stimulating the economy with varying values of the rate depending on the scenario. In the base case, the rate will gradually decrease from 19,5% to 10,3% by the end of 2025. The NBU aims to promote post-war economic growth by making borrowing more affordable and encouraging investment, expansion, and job creation. Lowering the key policy rate can revitalize the economy, aid in its recovery from the war, and address temporary disruptions in supply chains and increased uncertainty. This proactive approach helps mitigate inflationary pressures and supports price stability, contributing to a more stable economic environment in the post-war period.

In the case of the alternative scenarios, the NBU will decrease the key policy rate more gradually – from 21,5% as of the end of 2023 to 15,3% as of the end of 2025 under the alternative scenario № 1; and from 22% as of the end of 2023 to 17% as of the end of 2025 under the alternative scenario № 2. The NBU will keep a tight monetary policy to counteract the inflationary pressures due to increased government spending. Also, the central bank might do it to help maintain exchange rate stability by attracting foreign investors and preventing excessive currency depreciation. In addition to it, during times of war, there is a higher risk of capital flight as investors seek safer havens for their funds. A tight monetary policy, characterized by higher interest rates, can help retain domestic capital and prevent significant outflows.

At the same time, the simulations show that the key policy rate will still decline slightly. The main reasons for that are a need to support economic activity and promote investment, especially in sectors directly or indirectly affected by the war conflict. A modest reduction in the key policy rate can lower borrowing costs and encourage borrowing for productive purposes. Additionally, war disrupts economic activity, leading to a contraction in output and employment. In such cases, the central bank may opt to decrease interest rates to stimulate aggregate demand and counter recessionary pressures. Finally, lowering interest rates can make it easier for the government to finance war-related expenditures and manage public debt. This can help alleviate the financial burden and facilitate necessary spending during the conflict.

4. Will the deposit and lending interest rates reflect the changes in the key policy rate?

Yes, the deposit and lending interest rates will reflect the changes in the key policy rate, while the lending rate will still be growing quicker than the deposit interest rate. However, a surplus of banking liquidity still poses challenges for the NBU. When there is an excess of liquidity in the banking system, meaning that there is more money available for lending than there is demand for loans, the deposit rates

will not grow as fast as the central bank might expect. To manage the surplus liquidity, the central bank may employ various measures. It could implement open market operations to absorb excess funds from the banking system, adjust reserve requirements to encourage banks to hold higher levels of reserves or engage in other liquidity management operations. These actions are intended to influence the availability and cost of funds for banks, which in turn can impact lending rates.

5. Will inflation achieve its target value of 5% as of the end of the simulation (the end of 2025)? And what are the limitations to achieving the target value of inflation within the following years?

No, inflation will not achieve the target value of the NBU – 5% as of the end of 2025 even under the base case scenario. It might relate to the effects of the full-scale invasion, which might have long-lasting impacts on an economy. Post-war periods often involve rebuilding infrastructure, reestablishing disrupted supply chains, and addressing the socioeconomic consequences of the conflict. These processes can take time and may hinder a quick return to normal economic conditions, potentially leading to persistent inflationary pressures. In other scenarios, the war lasts longer, and the inflation target won`t be achieved, as the war usually results in significant structural changes in an economy, and they create imbalances between demand and supply, leading to inflationary pressures. Also, financing the costs of war and post-war reconstruction can strain government finances and result in increased public debt. If fiscal imbalances persist or if there are challenges in managing government finances effectively, it can create inflationary pressures that impede the achievement of the target inflation rate.

Summary

In conclusion, the main aim of this thesis was achieved, and we built not only adequate and valid to represent the real situation with the inflation, key policy rate, and other indicators but also made forecasts of these indicators under different scenarios. We found out that inflation will decelerate in the following years in the base case scenario due to the decrease in security risks, restoration of production capabilities, and the steadfast monetary policy pursued by the Central Bank. In other scenarios, when the war lasts longer, the NBU will keep a tighter monetary policy to curb the inflation pressure. At the same time, the Central Bank may consider reducing the key policy rate slightly during the war to stimulate economic activity and investment, providing support to businesses and households during a challenging period. Lastly, the NBU will not be able to achieve the inflation target under various scenarios due to persistent inflationary pressures.

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Appendices

Appendix I: Restrictions Imposed on FX Transactions and Capital Movements

Table 1. The currency restrictions in Ukraine since the full-scale invasion

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

Source: Inflation Report, October 2022

Appendix II: Linear Regressions

Table 2. The linear regression for Lending interest rate determination

Regression Statistics	
Multiple R	0.91890182
R Square	0.84438055
Adjusted R Square	0.78213277
Standard Error	1.17176381
Observations	8

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	37.2498478	18.6249239	13.5648297	0.00955344
Residual	5	6.86515215	1.37303043		
Total	7	44.115			

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	17.0641871	3.48312961	4.89909622	0.00447798
IIR	0.41460582	0.07972916	5.20017792	0.00346653
LIR (t-1)	-0.5477605	0.24738784	-2.2141771	0.0776951

Table 3. The linear regression for Deposit interest rate determination

Regression Statistics	
Multiple R	0.94306669
R Square	0.88937477
Adjusted R Square	0.84512468
Standard Error	1.62347469
Observations	8

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	105.947737	52.9738686	20.0988239	0.00407038
Residual	5	13.1783504	2.63567007		
Total	7	119.126088			

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	- 11.70	4.44068067	-2.6344235	0.04628593
DIR (t-1)	0.65	0.13337341	4.8901788	0.00451283
LIR	1.03	0.24461641	4.22371204	0.00829818

Table 4. The linear regression for Key policy rate determination

Regression Statistics	
Multiple R	0.90412551
R Square	0.81744294
Adjusted R Square	0.74442012
Standard Error	3.18593351
Observations	8

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	227.249138	113.624569	11.1943487	0.01423956
Residual	5	50.7508618	10.1501724		
Total	7	278			

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	11.966823	1.53760894	7.78274807	0.0005607
inflation gap	0.31231499	0.12095538	2.58206777	0.04930837
BD.GDP gap	-0.467713	0.20481435	-2.283595	0.07121722

Table 5. The linear regression Indicated deposits determination

Regression Statistics	
Multiple R	0.99896978
R Square	0.99794062
Adjusted R Square	0.99279216
Standard Error	0.01046058
Observations	8

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	5	0.10604969	0.02120994	193.832889	0.00514051
Residual	2	0.00021885	0.00010942		

Total	7	0.10626853

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	11.35	2.8880787	3.93071717	0.05904817
DIR	- 0.01	0.00293655	-4.8305262	0.04028407
Inflation Expectations	- 0.02	0.00459475	-4.5145849	0.0457252
Reserves	- 0.39	0.10613729	-3.6749178	0.06672109
Saving	- 1.11	0.22345087	-4.9617649	0.03830046
Deposits (t-1)	1.47	0.10004933	14.6720348	0.00461324

Appendix III: Full Model Behavior Tests` Results

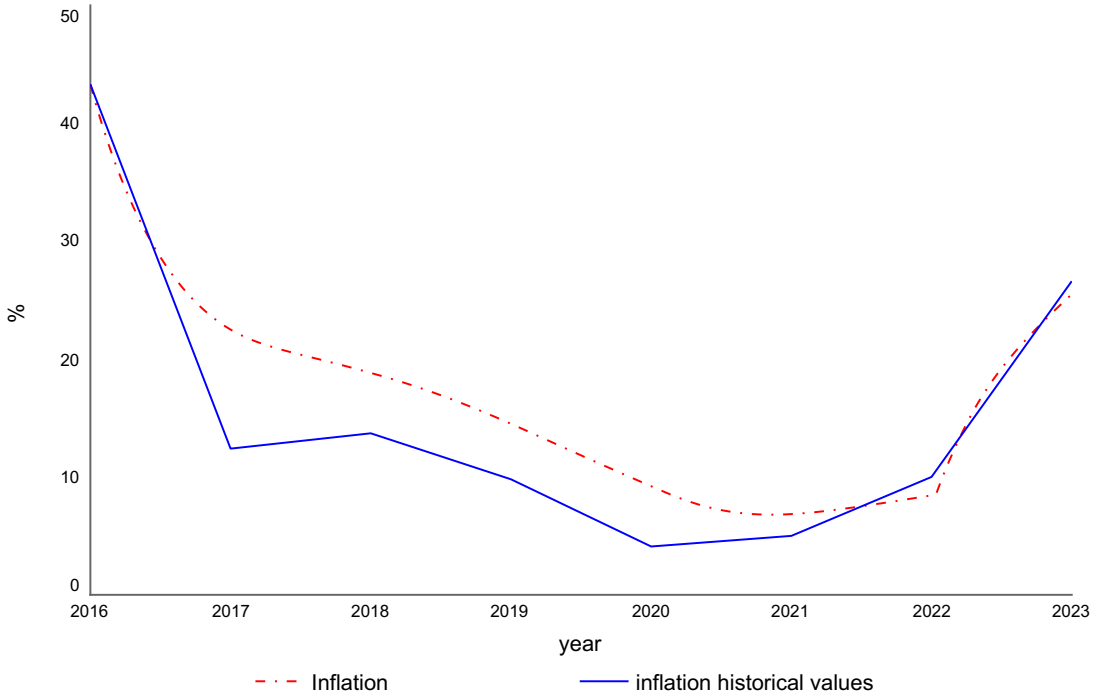

Figure 22: The comparison of historical and simulated values of inflation

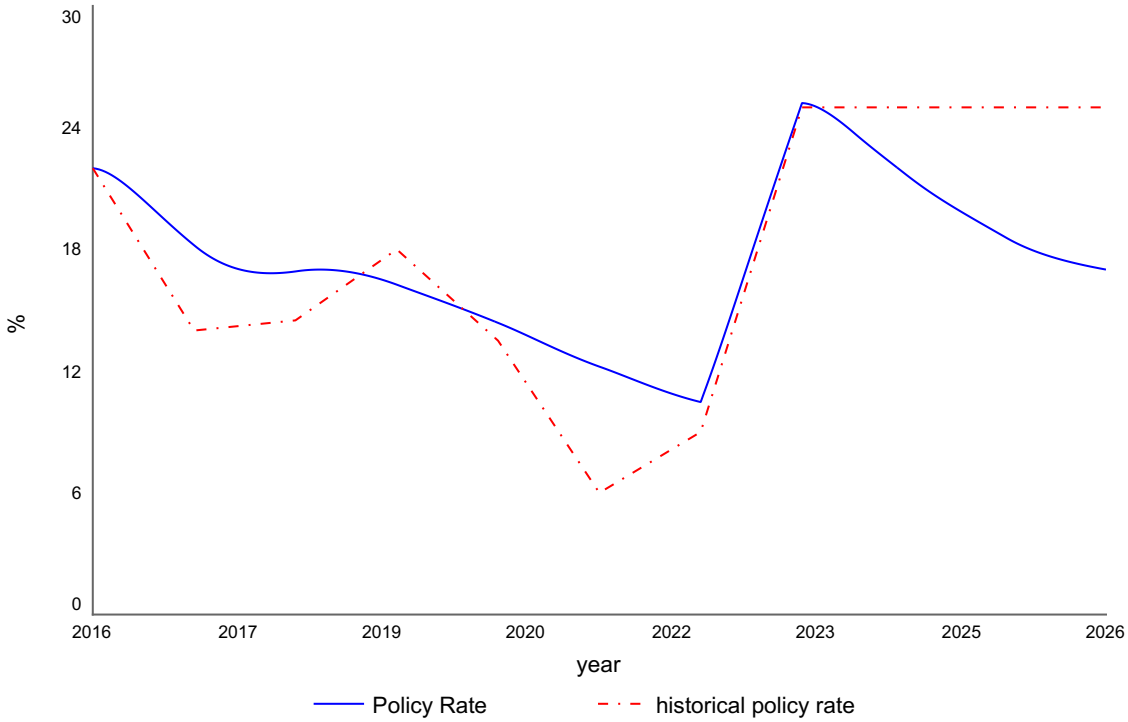

Figure 24: The comparison of historical and simulated values of the key policy rate

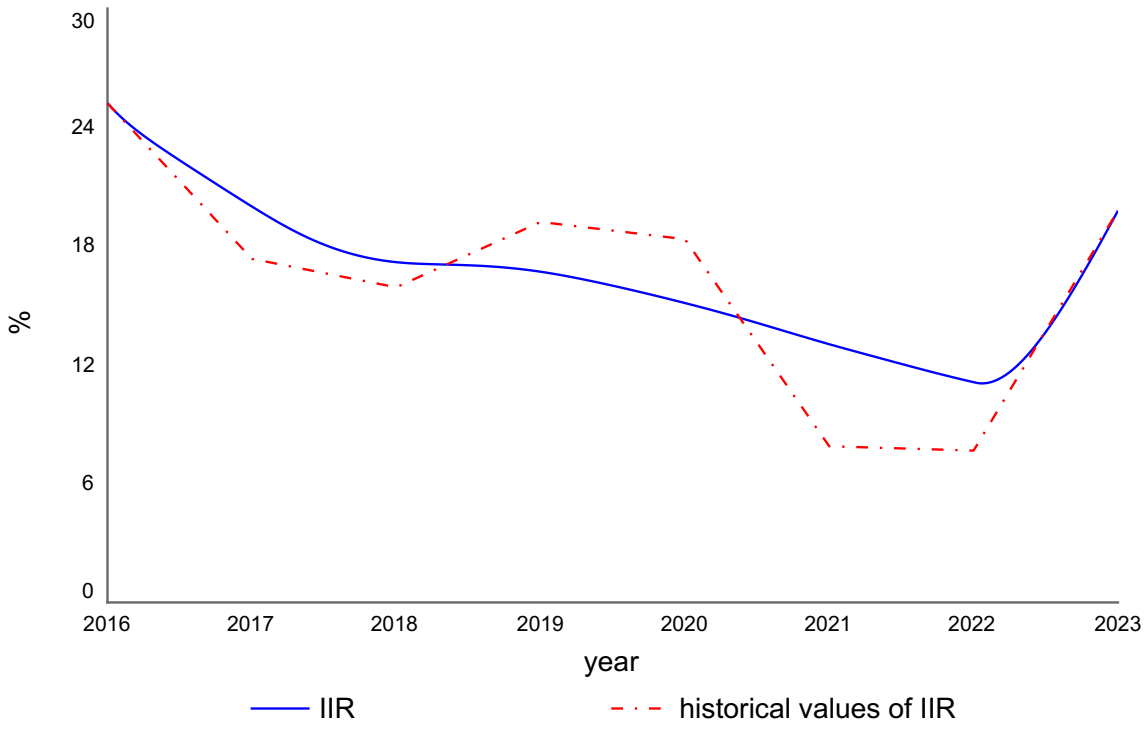

Figure 24: The comparison of historical and simulated values of interbank interest rate (IIR)

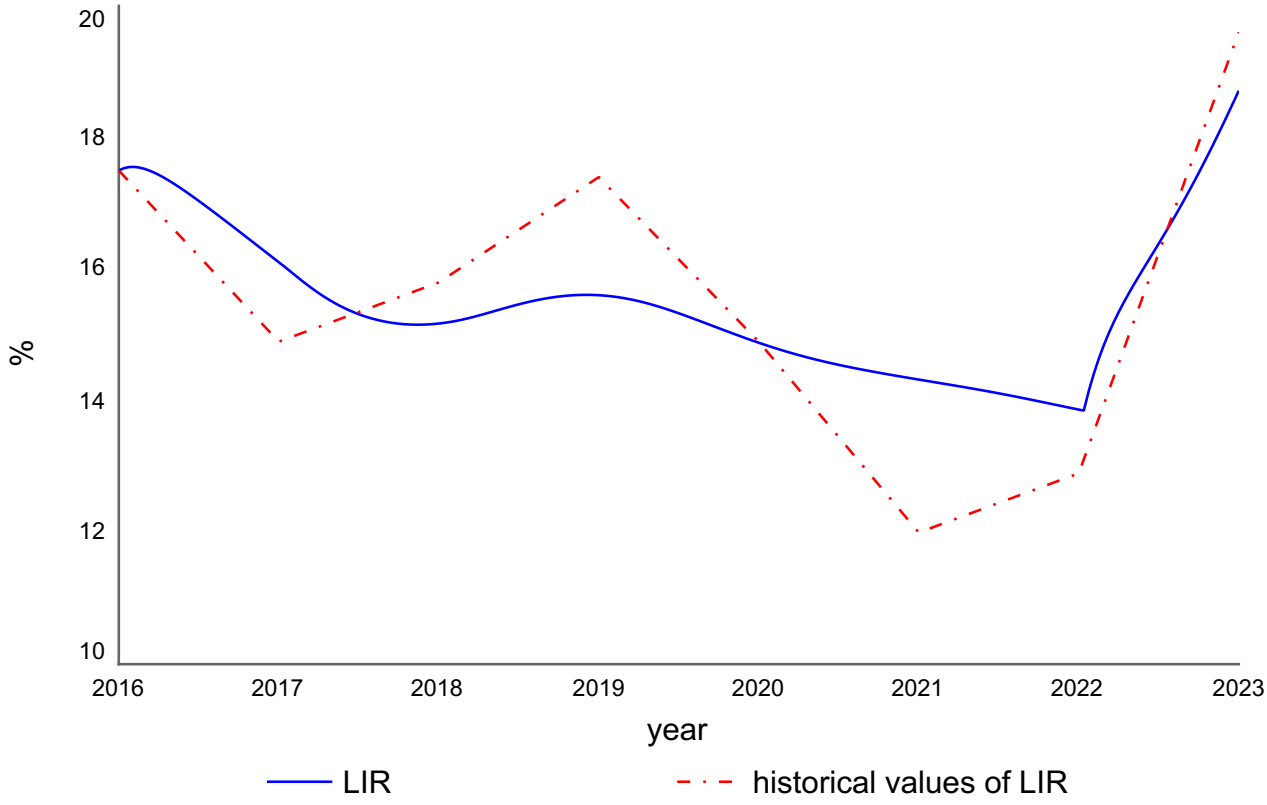

Figure 25: The comparison of historical and simulated values of lending interest rate (LIR)

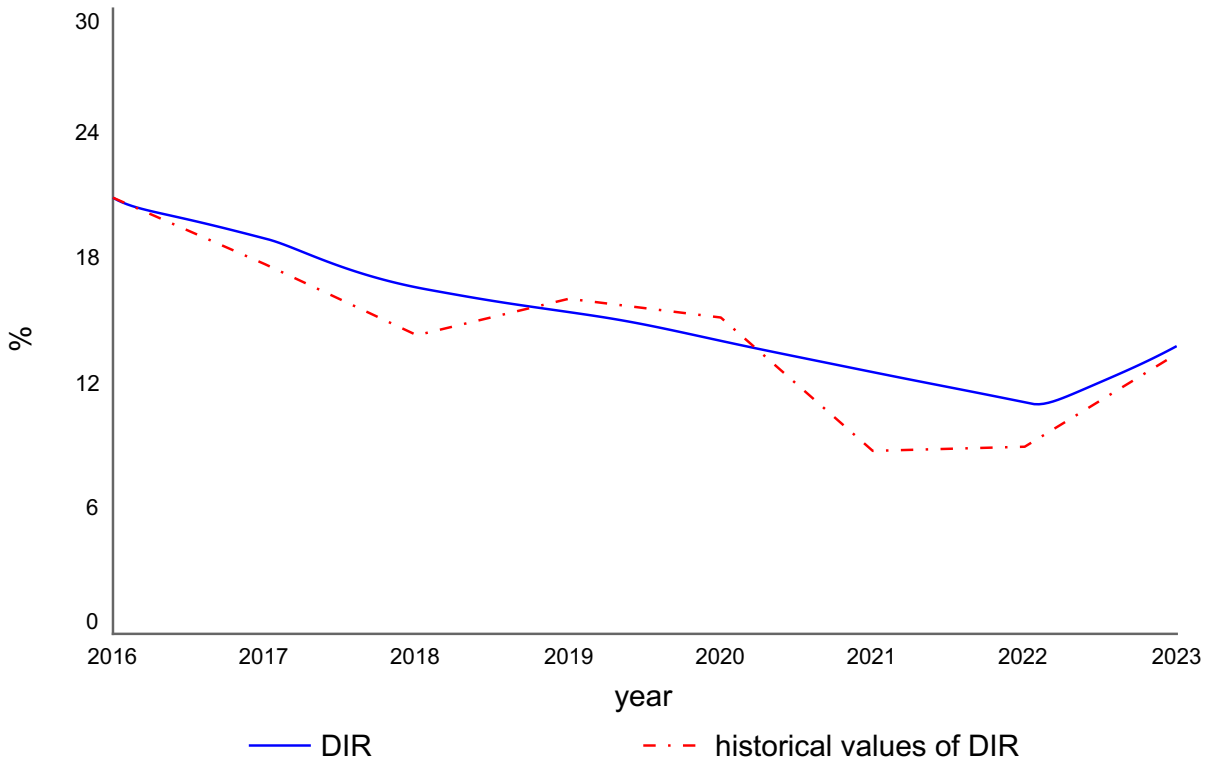

Figure 25: The comparison of historical and simulated values of deposit interest rate (DIR)

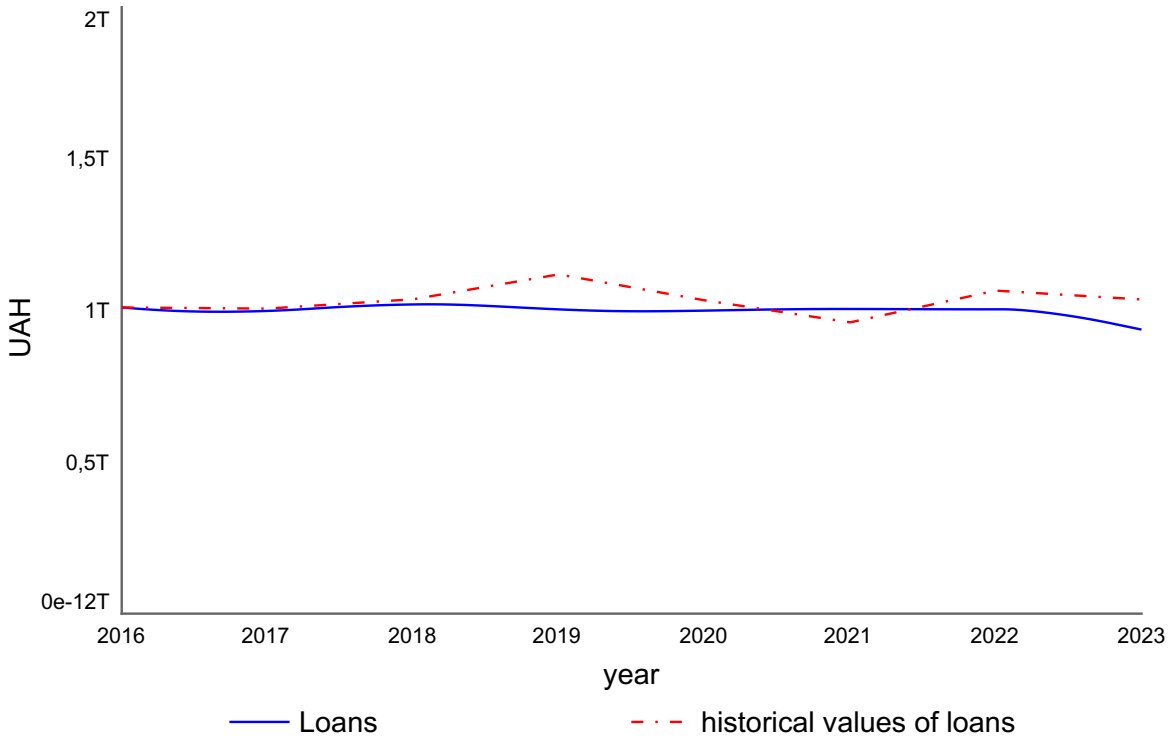

Figure 26: The comparison of historical and simulated values of loans in the banking system of Ukraine

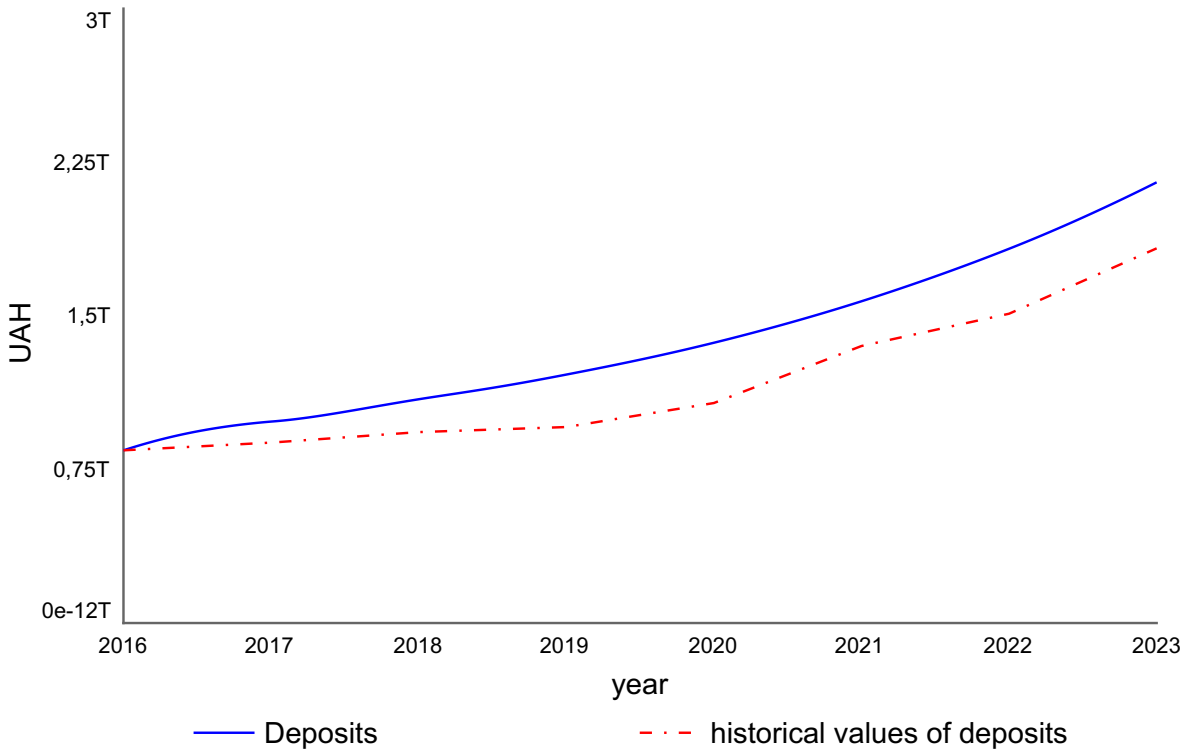

Figure 27: The comparison of historical and simulated values of deposits in the banking system of Ukraine

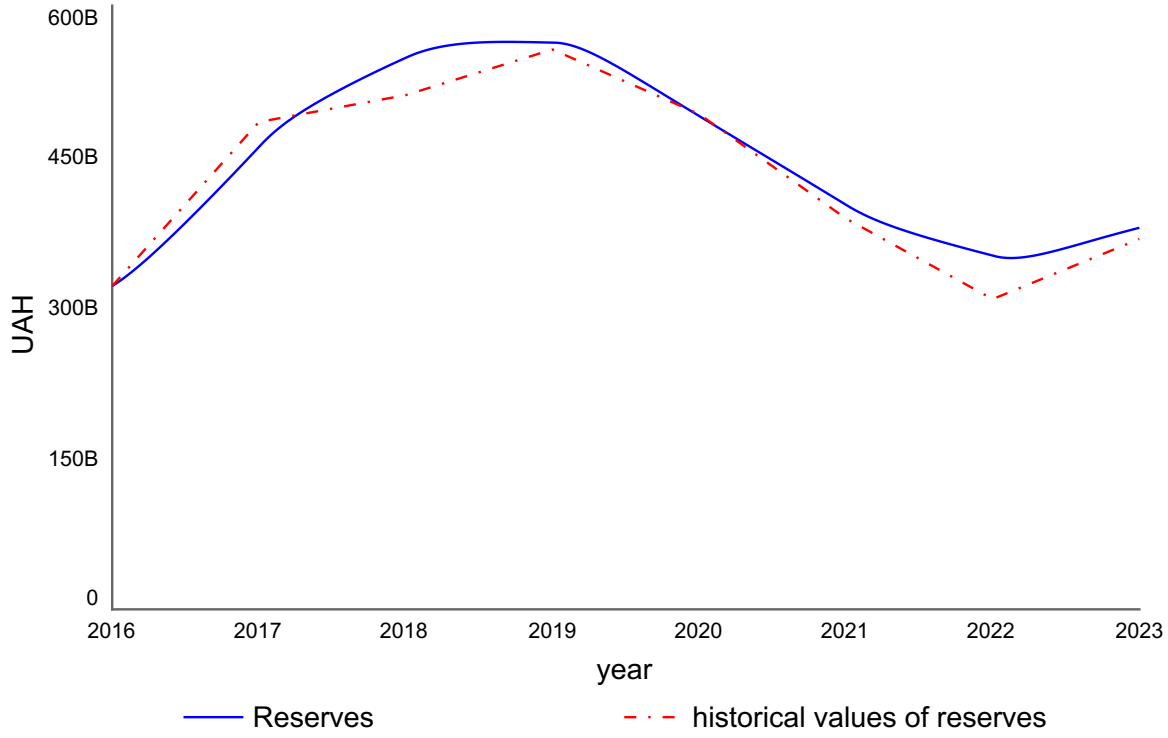

Figure 28: The comparison of historical and simulated values of reserves in the banking system of Ukraine

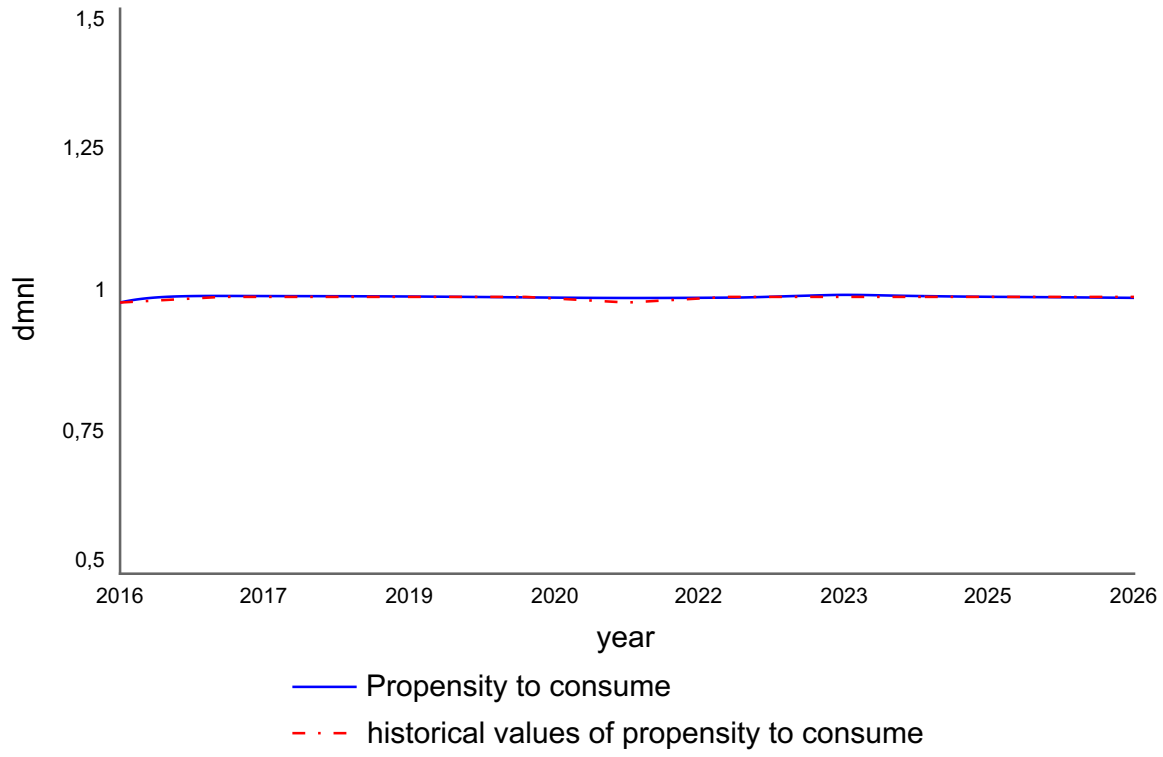

Figure 29: The comparison of historical and simulated values of propensity to consume in Ukraine

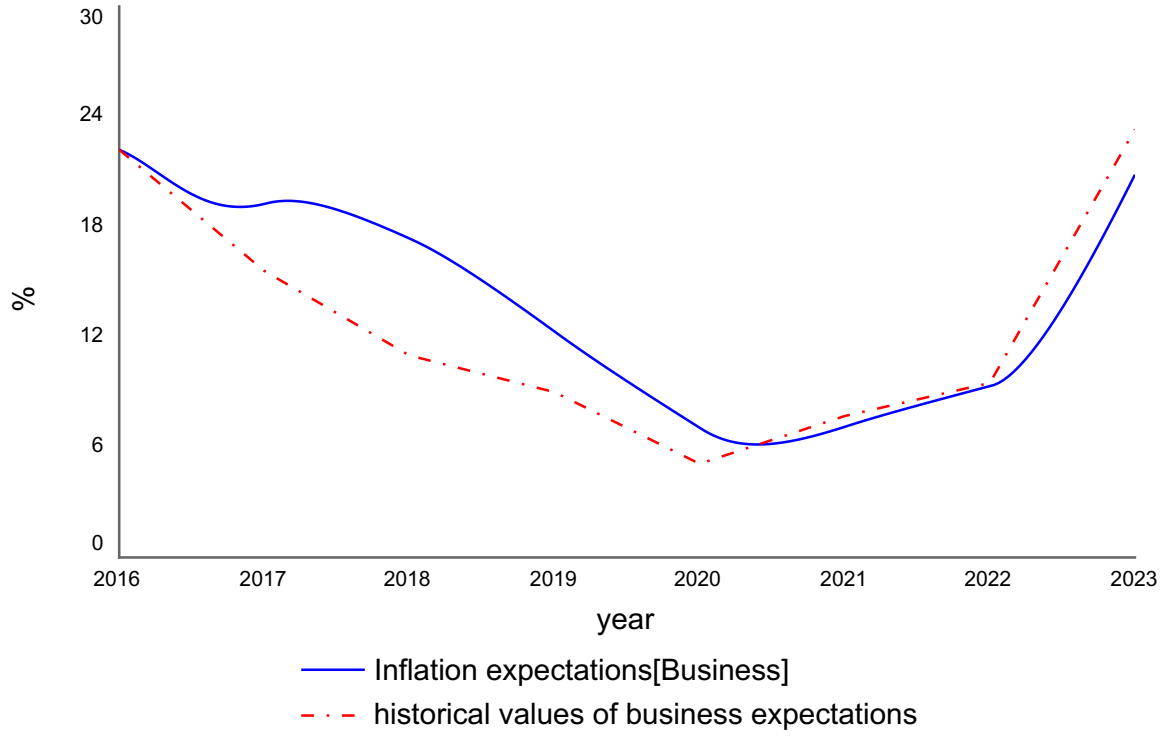

Figure 30: The comparison of historical and simulated values of inflation expectations of businesses in Ukraine

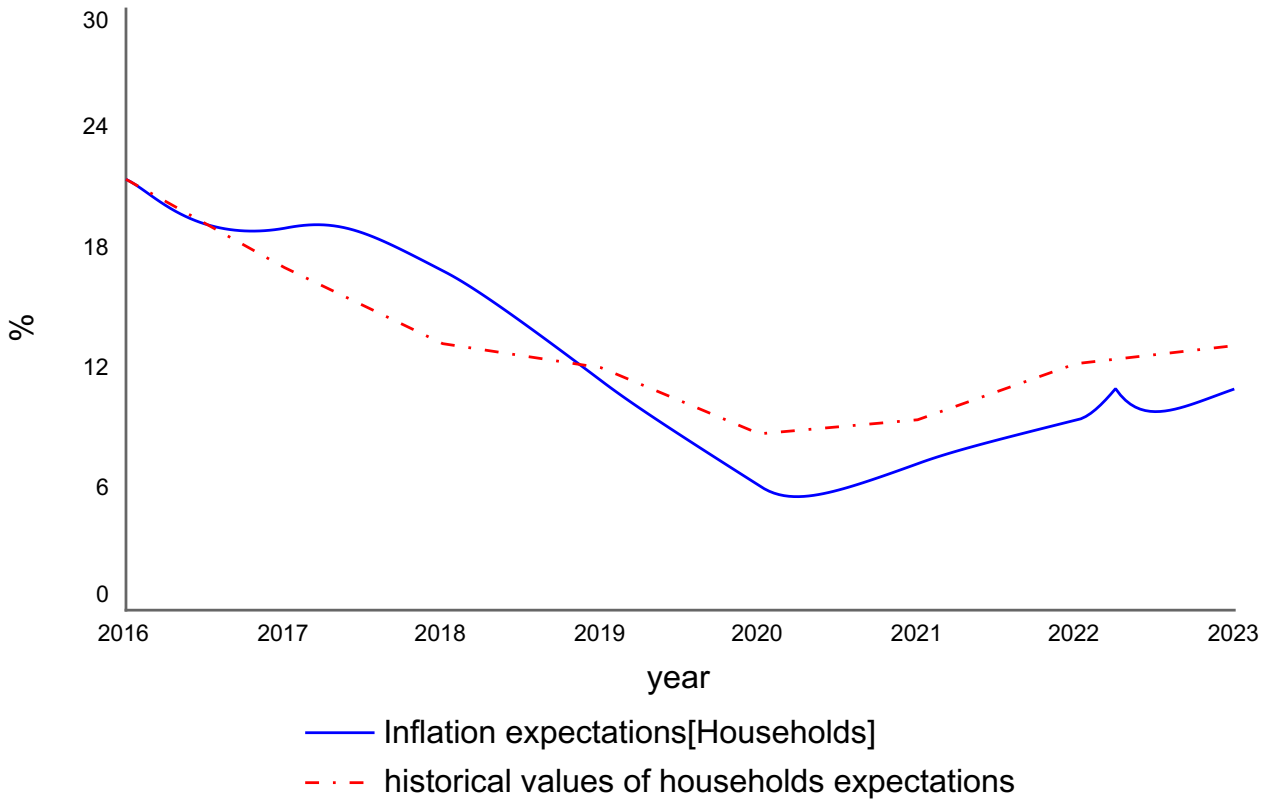

Figure 31: The comparison of historical and simulated values of inflation expectations of households in Ukraine

Appendix IV: Sensitivity Analysis

This evaluation involves identifying parameters that exhibit high sensitivity within the model and assessing whether the real system demonstrates similar sensitivity to those parameters (Barlas, 1996). Through sensitivity testing, we aim not only to validate this model iteration but also to gain valuable insights into the parameters that require further investigation through data collection for precise quantification. Briefly, the parameters in the model are anticipated to display varying levels of inflation and the key policy rate, mostly the time it takes to adjust the inflation, its expectations, and different interest rates from 0,25 to 1 year. Extensive research efforts dedicated to quantifying these parameters underscore their significance, and future versions of the model should align with the latest information regarding their range.

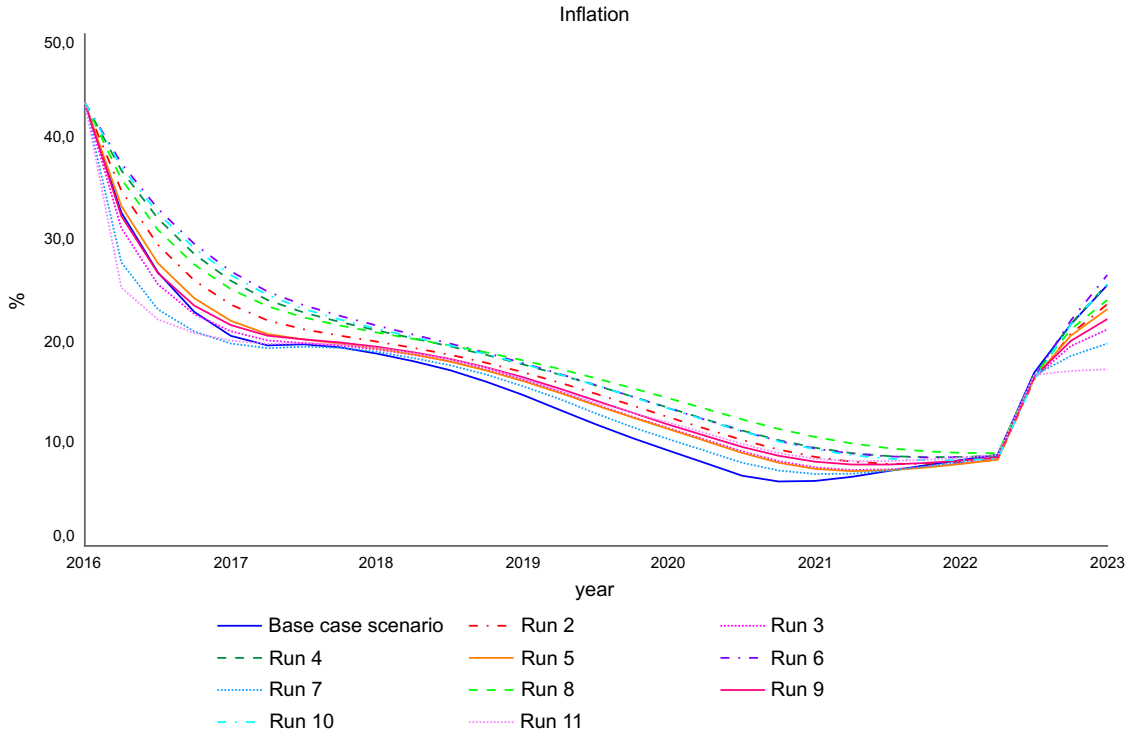

Figure 32: The sensitivity analysis of inflation

Figures 32-39 provide visual evidence of the relationship between the speed of time adjustment and the corresponding changes in inflation values, indicating that a faster time adjustment leads to more rapid shifts in inflation, thereby aligning it with actual historical values. However, it is crucial to note that the disparity between different time adjustments is considerable, underscoring the importance of selecting the most suitable time adjustment parameter to ensure the model's validity.

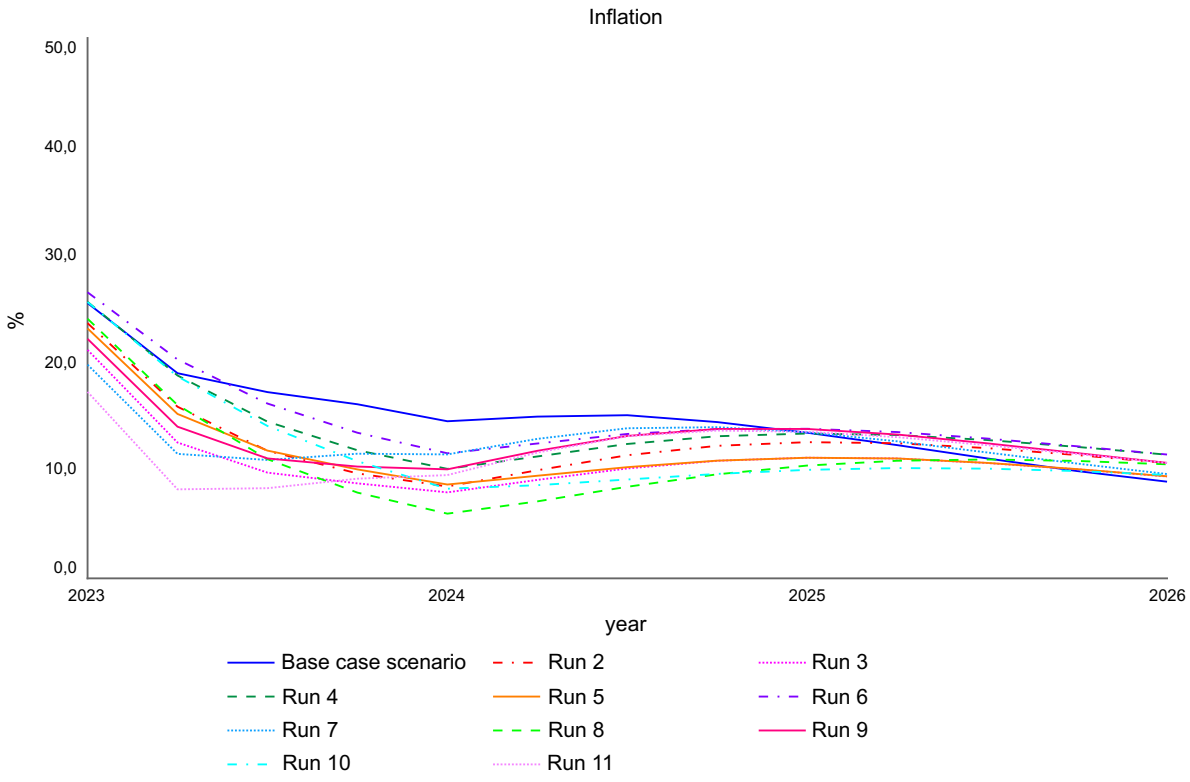

Figure 33: The sensitivity analysis of the forecast inflation under the base case scenario

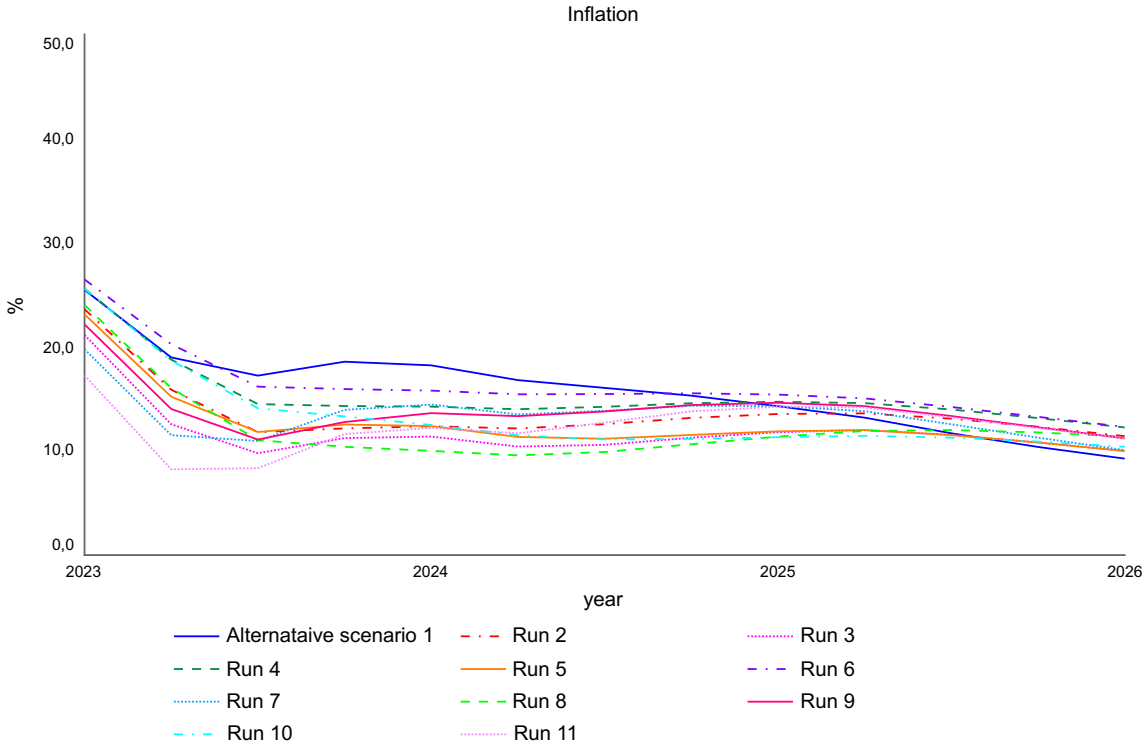

Figure 34: The sensitivity analysis of the forecast inflation under the alternative scenario № 1

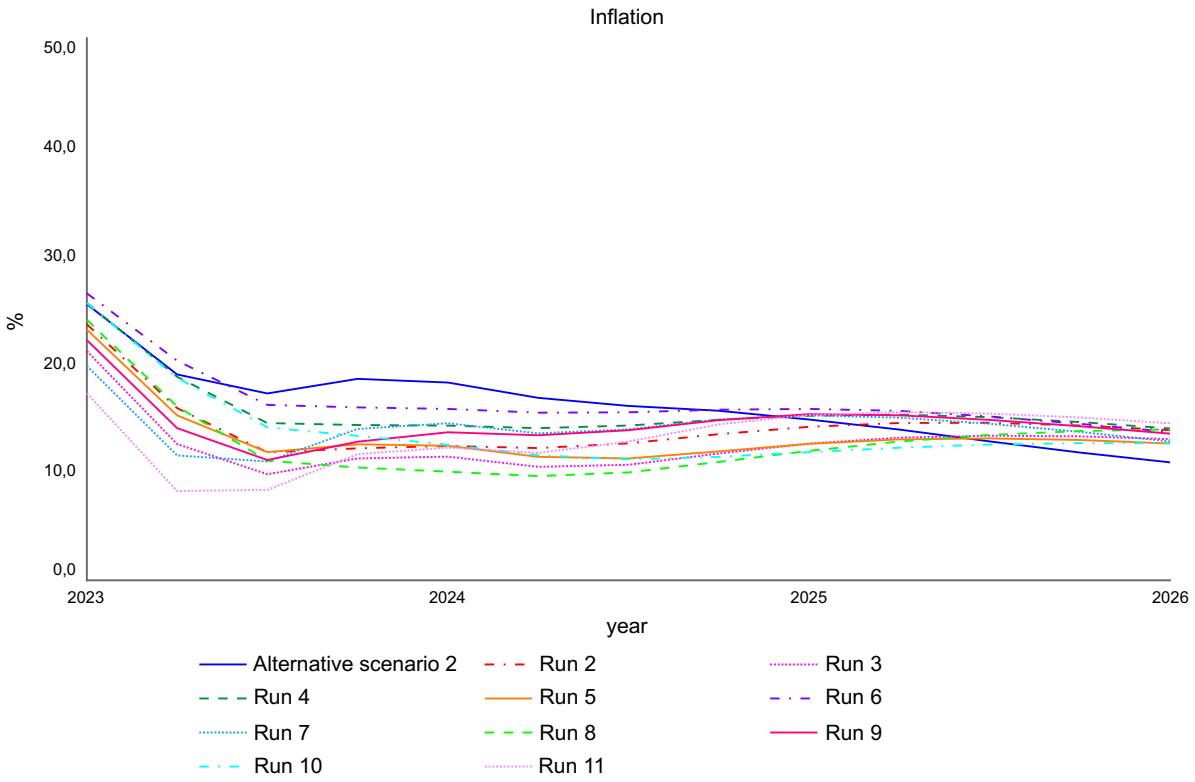

Figure 35: The sensitivity analysis of the forecast inflation under the alternative scenario № 2

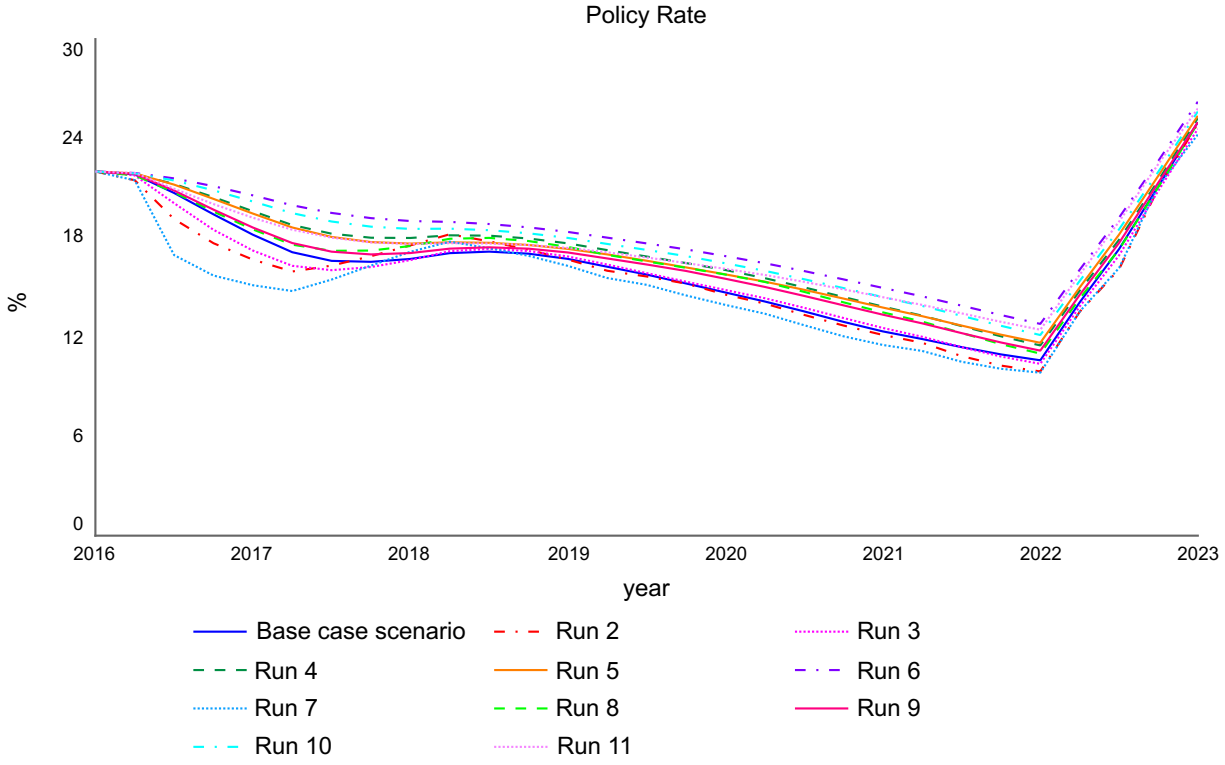

Figure 36: The sensitivity analysis of the key policy rate

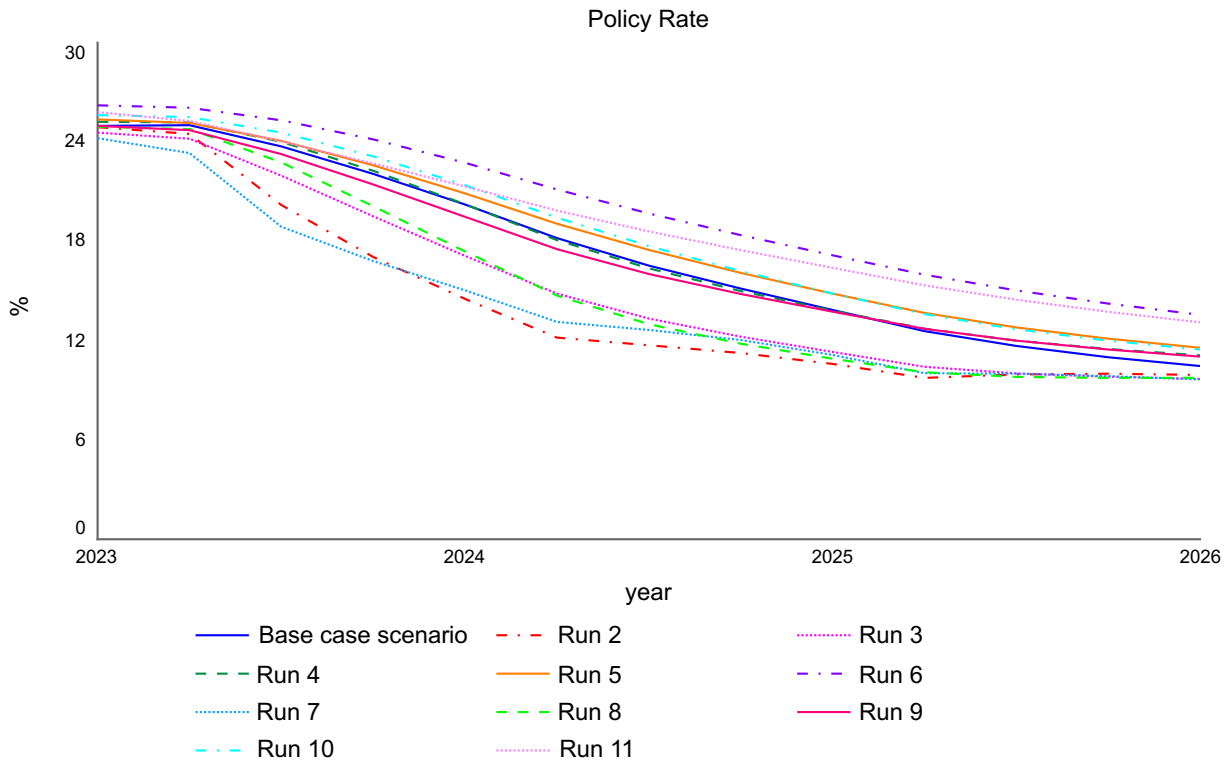

Figure 37: The sensitivity analysis of the key policy rate under the base case scenario

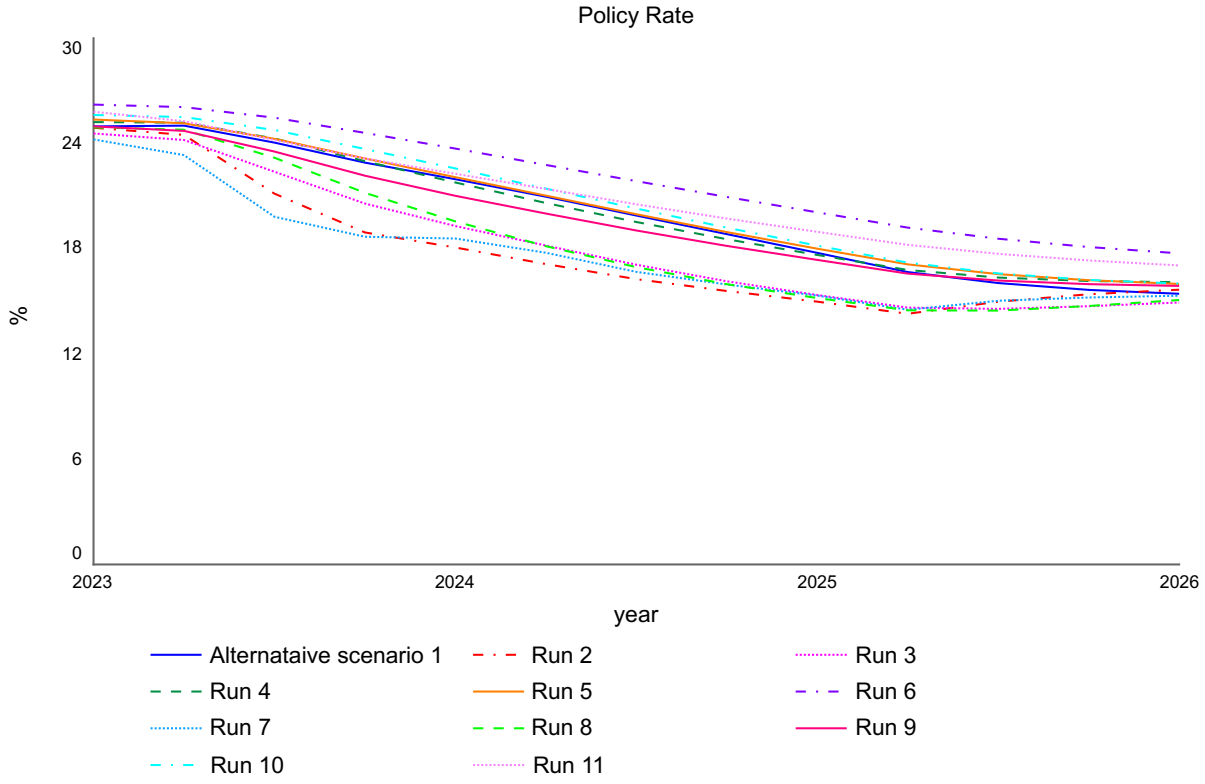

Figure 38: The sensitivity analysis of the key policy rate under the alternative scenario № 1

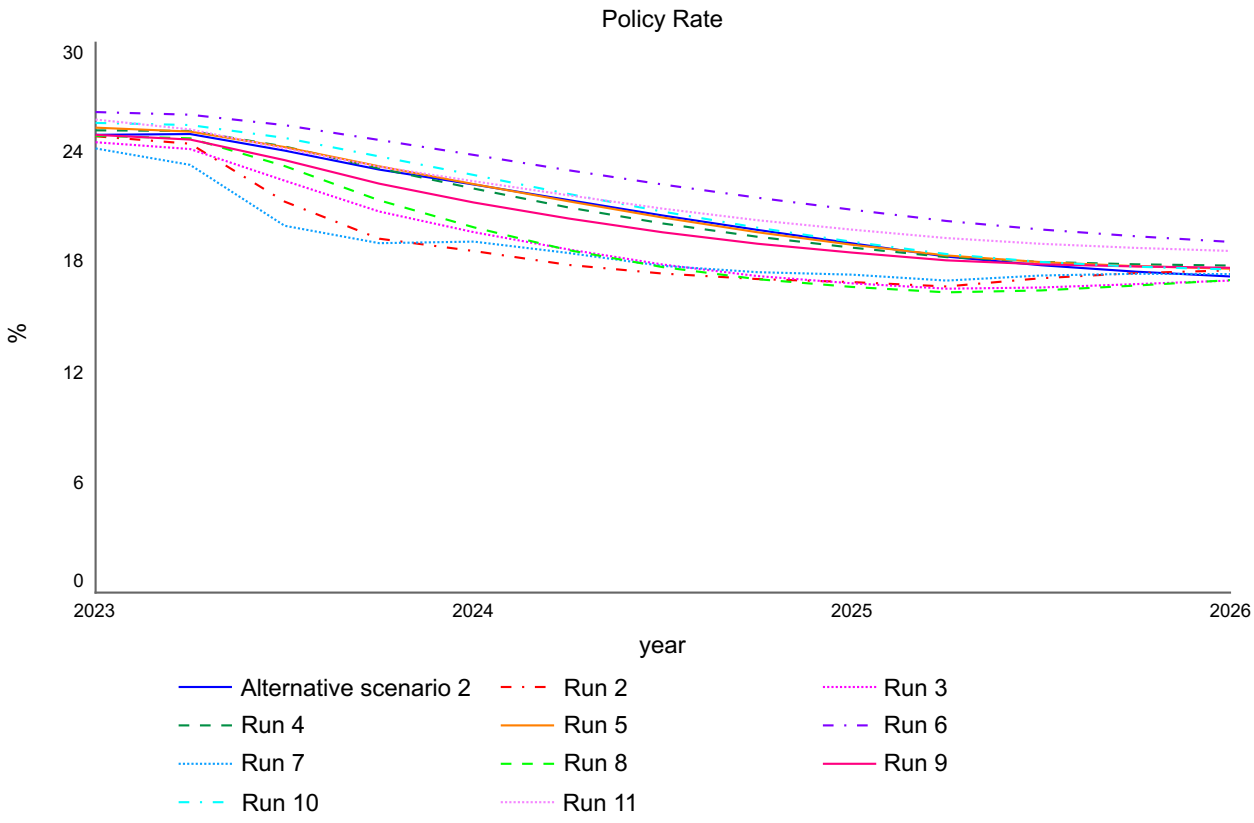

Figure 39: The sensitivity analysis of the key policy rate under the alternative scenario № 2

The observed patterns in the figures highlight the significance of finding an optimal balance in the time adjustment parameter. On one hand, a rapid time adjustment can capture and reflect inflationary dynamics more promptly, allowing the model to closely resemble the actual behavior of inflation. This is particularly valuable in capturing short-term fluctuations and responding to rapid changes in economic conditions. On the other hand, an excessively quick time adjustment may lead to excessive volatility and exaggerated fluctuations in inflation, potentially deviating from the true underlying trends and compromising the model's accuracy.

To enhance the model's validity and ensure a robust representation of inflation dynamics, careful consideration must be given to selecting the most appropriate time adjustment parameter. This decision should involve a thorough analysis of historical data, economic context, and an understanding of the specific dynamics influencing inflation. Striking the right balance will enable the model to accurately capture inflation trends, enhance its predictive capabilities, and provide valuable insights for policymakers and researchers alike.

Appendix V: Model Documentation

{ The model has 144 (153) variables (array expansion in parens).
In root model and 4 additional modules with 5 sectors.
Stocks: 10 (11) Flows: 10 (11) Converters: 124 (131)
Constants: 19 (20) Equations: 115 (122) Graphics: 37 (37)
There are also 25 expanded macro variables. }

Top-Level Model:
Inflation(t) = Inflation(t - dt) + (Δ_inflation) * dt
INIT Inflation = 43,3
UNITS: %
DOCUMENT: Inflation refers to the general increase in prices of goods and services in an economy over some time, resulting in a decrease in the purchasing power of money.

It is a percentage value, and the initial value is taken from the website of the NBU, where they publish their statistics.
Policy_Rate(t) = Policy_Rate(t - dt) + (Δ_policy_rate) * dt {NON-NEGATIVE}
INIT Policy_Rate = historical_policy_rate
UNITS: %
DOCUMENT: The key policy rate, also known as the benchmark interest rate or the policy interest rate, is the interest rate set by a central bank as a tool to influence the economy and achieve monetary policy objectives. It serves as a reference rate for the interest rates in an economy and influences borrowing costs for banks, businesses, and individuals.

Δ_inflation = ((IEC.average_inflation_expectations-Inflation)/inflation_adj_time)+war_shock
UNITS: %/year
DOCUMENT: The change in inflation refers to the difference between inflation expectations and inflation. It represents the magnitude of the adjustment or movement in inflation over a given period. Also, it includes the war shock.
Δ_policy_rate = ((indicated_policy_rate-Policy_Rate)/policy_rate_adj_time)+war_shock_of_policy_rate

UNITS: %/year

DOCUMENT: The change in the key policy rate refers to the difference between the indicated and real policy rates. It represents the magnitude of the adjustment or movement in the key policy rate over a given period. Also, it includes the war shock.

Alternative_scenario_1 = 0

UNITS: dmnl

DOCUMENT: Alternative scenario №1 is a variable, which equals 0 or 1. If it`s 1 then, then the monetary policy goes according to the alternative scenario №1 and vice versa.

In this scenario, we assume that the war lasts till the end of 2024, and after this time the economy recovers from wartime, leading to the growth of investments, and income, a decrease in government expenditures, and a widening of the next export for the country`s reconstruction. Before that time all indicators grow marginally compared to their values in 2022.

Alternative_scenario_2 = 0

UNITS: dmnl

DOCUMENT: Alternative scenario №2 is a variable, which equals 0 or 1. If it`s 1 then, then the monetary policy goes according to the alternative scenario №2 and vice versa.

In this scenario, we assume that the war lasts till the end of 2025. During 2023-2025, the economy will be growing very slowly, and all other indicators also grow marginally, except government expenditures, which will be growing significantly due to the persistence of security risks.

Base_case_scenario = 1

UNITS: dmnl

DOCUMENT: The base case scenario is a variable, which equals 0 or 1. If it`s 1 then, then the monetary policy goes according to the base case scenario and vice versa.

In this scenario, we assume that the war lasts till the end of 2023, and after this time the economy recovers from wartime, leading to the growth of investments, income, a decrease in government expenditures, and a widening of the next export for the country`s reconstruction.

historical_policy_rate = GRAPH(TIME)

Points: (2014,000, 6,5), (2015,000, 14,0), (2016,000, 22,0), (2017,000, 14,0), (2018,000, 14,5), (2019,000, 18,0), (2020,000, 13,5), (2021,000, 6,0), (2022,000, 9,0), (2023,000, 25,0)

UNITS: %

DOCUMENT: This variable represents the historical values of the key policy rate, and data is taken from the official website of the NBU.

indicated_policy_rate = 11,97+0,31*inflation_gap-0,47*BD.GDP_gap

UNITS: %

DOCUMENT: The indicated policy rate is an estimated level for the policy rate based on Taylor`s rule.

It is a linear regression and consists of the inflation gap and the GDP gap.

inflation_adj_time = 0,5

UNITS: year

DOCUMENT: Inflation adjustment time refers to the time it is necessary for the economy to react to the new value of inflation.

In our case, it`s 0,5 years or 6 months. This value was derived from the manual calibration.

inflation_gap = Inflation-inflation_goal

UNITS: %

DOCUMENT: The inflation gap is the difference between the real inflation values and the inflation goal. This indicator serves as one of the components of Taylor`s rule for the definition of the key policy rate.

inflation_goal = GRAPH(TIME)

Points: (2016,000, 12,0), (2017,000, 8,0), (2018,000, 6,0), (2019,000, 5,0), (2020,000, 5,0), (2021,000, 5,0), (2022,000, 5,0), (2023,000, 5,0)

UNITS: %

DOCUMENT: An inflation goal, also known as an inflation target, is a monetary policy objective set by a central bank or monetary authority to guide their efforts in managing and controlling inflation within an economy. The inflation goal represents the desired level of inflation that the central bank aims to achieve or maintain over a specified time frame.

It is an exogenous variable, and it is set by the NBU.

inflation_historical_values = GRAPH(TIME)

Points: (2014,000, 0,5), (2015,000, 24,9), (2016,000, 43,3), (2017,000, 12,4), (2018,000, 13,7), (2019,000, 9,8), (2020,000, 4,1), (2021,000, 5,0), (2022,000, 10,0), (2023,000, 26,6)

UNITS: %

DOCUMENT: This variable represents the historical values of inflation, and data is taken from the official website of the NBU.

policy_rate_adj_time = 0,75

UNITS: Year

DOCUMENT: The key policy rate adjustment time refers to the time the central bank must react to the changes in output and inflation gaps and establish a new level of the policy rate.

In our case, it`s 0,75 years or 9 months. This value was derived from the manual calibration.

war_shock = IF Base_case_scenario = 1 THEN "war_shock_(base_case_scenario)" ELSE IF Alternative_scenario_1 = 1 THEN "war_shock_(alternative_scenario_1)" ELSE IF Alternative_scenario_2 = 1 THEN "war_shock_(alternative_scenario_2)"ELSE "war_shock_(base_case_scenario)"

UNITS: %/year

DOCUMENT: This variable represents the changes in inflation that are not covered in this model, and the value depends on different scenarios.

"war_shock_(alternative_scenario_1)" = IF TIME > 2022 AND TIME < 2023 THEN 30 ELSE IF TIME >=2023 AND TIME < 2023,5 THEN -10 ELSE 0

UNITS: %/year

"war_shock_(alternative_scenario_2)" = IF TIME > 2022 AND TIME < 2023 THEN 30 ELSE IF TIME >=2023 AND TIME < 2023,5 THEN -10 ELSE 0

UNITS: %/year

"war_shock_(base_case_scenario)" = IF TIME > 2022 AND TIME < 2023 THEN 30 ELSE IF TIME >=2023 AND TIME < 2024 THEN -10 ELSE 0

UNITS: %/year

DOCUMENT: This variable represents the rapid increase in inflation that is not covered in our model. The value for the period 2022-2023 was calibrated manually to represent as closely the value of inflation to real data. During one year, the inflation accelerated due to the outcomes of russia's full-scale invasion, which destroyed businesses and infrastructure, disruptions in production and supply chains, rising production costs for companies, and a surge in demand for specific goods and services driven by hype. Furthermore, Ukraine faced additional price pressures due to the global acceleration of inflation, as numerous countries recorded multi-year highs in inflation rates during the previous year.

According to the base case scenario, the war lasts till the end of 2023, and the inflation decelerates more significantly in 2023 due to tight monetary conditions, the downward trend in global inflation, and the continued subdued domestic demand. It is based on the current macro-forecast of the NBU.

war_shock_of_policy_rate = IF TIME >= 2022 AND TIME < 2023 THEN 15 ELSE 0

UNITS: %/year

DOCUMENT: This variable represents the rapid increase of the key policy rate by 15 p.p. in the middle of 2022 to safeguard the financial well-being of households in the local currency, increase the appeal of domestic currency investments, alleviate strain on the foreign exchange market, and thereby strengthen the ability of the central bank to uphold exchange rate stability and curb inflationary pressures amid a conflict.

BD:

Alternative_scenario_1 = 0

UNITS: dmnl

DOCUMENT: Alternative scenario №1 is a variable, which equals 0 or 1. If it`s 1 then, then the monetary policy goes according to the alternative scenario №1 and vice versa.

In this scenario, we assume that the war lasts till the end of 2024, and after this time the economy recovers from wartime, leading to the growth of investments, and income, a decrease in government expenditures, and a widening of the next export for the country`s reconstruction. Before that time all indicators grow marginally compared to their values in 2022.

Alternative_scenario_2 = 0

UNITS: dmnl

DOCUMENT: Alternative scenario №2 is a variable, which equals 0 or 1. If it`s 1 then, then the monetary policy goes according to the alternative scenario №2 and vice versa.

In this scenario, we assume that the war lasts till the end of 2025. During 2023-2025, the economy will be growing very slowly, and all other indicators also grow marginally, except government expenditures, which will be growing significantly due to the persistence of security risks.

average_life_of_capital = 10

UNITS: year

DOCUMENT: The average life of capital, also known as the average economic life or the average age of capital, refers to the expected duration or lifespan of productive capital assets in an economy. It represents the average length of time that capital assets, such as machinery, equipment, buildings, or infrastructure, are expected to remain in service and contribute to production before being replaced or becoming obsolete.

In our case, it`s 10 years, and this value is based on  Faryna and Dadashova`s book "Концептуальні підходи до побудови макромоделі економіки України методами системної динаміки."

Base_case_scenario = 1

UNITS: dmnl

DOCUMENT: The base case scenario is a variable, which equals 0 or 1. If it`s 1 then, then the monetary policy goes according to the base case scenario and vice versa.

In this scenario, we assume that war lasts till the end of 2023, and after this time the economy recovers from wartime, leading to the growth of investments, and income, a decrease in government expenditures, and a widening of the next export for the country`s reconstruction.

Capital_cost = SMTH1(IRC.LIR; 1)/average_life_of_capital

UNITS: %/year

DOCUMENT: The ratio represents the relationship between the cost of borrowing (as indicated by the loan interest rate) and the average lifespan of capital assets. It can be viewed as an indicator of the potential profitability or financial viability of utilizing borrowed funds to invest in long-term capital assets.

Capital_costs_growth = SMTH1(Capital_cost/HISTORY(Capital_cost; TIME-0,25); 1)

UNITS: dmnl

DOCUMENT: Capital costs growth refers to the increase in the expenses associated with obtaining and maintaining capital assets over time. It represents the growth or change in the costs within the last 3 months.

The equation is based on the book "Концептуальні підходи до побудови макромоделі економіки України методами системної динаміки" by Faryna and Dadashova.

Cost_push_effect = SMTH1(Production_costs_growth; 1)

UNITS: dmnl

DOCUMENT: The cost-push effect refers to a phenomenon where an increase in production costs leads to a subsequent increase in the prices of goods and services. It`s calculated as a smoothed function of the variable "Production costs growth," and the equation is based on the book "Концептуальні підходи до побудови макромоделі економіки України методами системної динаміки" by Faryna and Dadashova.

Demand_pull_effect = (Real_GDP/Potential_GDP)

UNITS: dmnl

DOCUMENT: The relationship between real GDP and potential GDP offers insights into inflationary or deflationary pressures within an economy.

When real GDP exceeds potential GDP, it suggests that the economy is operating above its long-term capacity, and demand is outpacing supply. This can create inflationary pressures in the economy. When there is excess demand for goods and services, producers may increase prices to take advantage of the strong demand. As a result, the CPI may rise due to the upward pressure on prices.

Conversely, when real GDP is below potential GDP, it indicates that there is underutilized capacity in the economy. This situation may lead to deflationary pressures or lower inflation rates. With excess supply relative to demand, producers may lower prices to stimulate consumption and reduce inventories. This can result in a decrease in the CPI, reflecting falling prices.

GDP_deflator = GRAPH(TIME)

Points: (2016,00, 38,9), (2017,00, 17,1), (2018,00, 22,1), (2019,00, 15,4), (2020,00, 8,2), (2021,00, 10,3), (2022,00, 25,1), (2023,00, 34,3), (2024,00, 22,9), (2025,00, 13,4), (2026,00, 8,7) {GF EXTRAPOLATED}

UNITS: dmnl

DOCUMENT: The GDP deflator refers to changes in the prices of goods and services that affect the level of the country's gross domestic product (GDP). The GDP deflator is an indicator that reflects changes in the overall price level over a given period compared to a base period. The change in the GDP deflator indicates the inflation or deflation rates in the economy.

If the GDP deflator increases, it means that the overall price level is increasing at a faster rate than the GDP. This can indicate inflation, where the cost of goods and services rises. On the other hand, if the GDP deflator decreases, it means that the overall price level is decreasing at a faster rate than the GDP. This can indicate deflation, where the cost of goods and services decreases.

Changes in the GDP deflator are an important economic indicator used to measure changes in the real output of a country, accounting for the impact of inflation or deflation. They are a key factor in assessing the state of the economy and determining necessary policy measures to ensure sustainable economic growth.

It`s an exogenous variable, and it`s given from the values given by the State Statistics Service of Ukraine, and the forecast values are based on the macro-forecast of the NBU.

GDP_gap = ((Real_GDP-Potential_GDP)/Potential_GDP)*100

UNITS: %

DOCUMENT: The GDP gap, also known as the output gap, is a measure that quantifies the difference between actual Gross Domestic Product (GDP) and potential GDP within an economy. It represents the shortfall or excess in economic output relative to its maximum potential level.

GDP_growth = Nominal_GDP/HISTORY(Nominal_GDP; TIME-1)

UNITS: dmnl

DOCUMENT: GDP growth, or economic growth, refers to the increase in the value of Gross Domestic Product (GDP) over a specific period, typically measured on an annual basis. It represents the expansion or contraction of an economy's total output of goods and services.

It is calculated by comparing the current GDP to the GDP of the previous year.

Government_purchases = IF Base_case_scenario = 1 THEN "Government_purchases_(base_case)" ELSE IF Alternative_scenario_1 = 1 THEN "Government_purchases_(alternative_scenario_1)" ELSE IF Alternative_scenario_2 = 1 THEN "Government_purchases_(alternative_scenario_2)" ELSE "Government_purchases_(base_case)"

UNITS: UAH/year

DOCUMENT: Government purchases refer to the expenditures made by the government in acquiring goods and services to fulfill its functions and provide public goods and services to its citizens. These purchases typically involve transactions between the government and private businesses or individuals.

This variable is an external one, and the values are given by the State Statistics Service of Ukraine, and the forecast values are based on the assumptions of different scenarios.

"Government_purchases_(alternative_scenario_1)" = GRAPH(TIME)

Points: (2016,00, 392103000000,0), (2017,00, 462626000000,0), (2018,00, 640486000000,0), (2019,00, 770514000000,0), (2020,00, 786780000000,0), (2021,00, 854817000000,0), (2022,00, 1016423000000,0), (2023,00, 1984794000000,0), (2024,00, 2360025914157,1), (2025,00, 2363942125255,0), (2026,00, 1943461366518,7) {GF EXTRAPOLATED}

UNITS: UAH/year

DOCUMENT: In the alternative scenario №1, we assume that the active phase of the war ends at the end of 2024, and the government purchases will continue to grow significantly till the end of 2024, and this speed decreases in 2025 due to less demand in defense spending.

"Government_purchases_(alternative_scenario_2)" = GRAPH(TIME)

Points: (2016,00, 392103000000,0), (2017,00, 462626000000,0), (2018,00, 640486000000,0), (2019,00, 770514000000,0), (2020,00, 786780000000,0), (2021,00, 854817000000,0), (2022,00, 1016423000000,0), (2023,00, 1984794000000,0), (2024,00, 2372072520867,0), (2025,00, 2462439713808,0), (2026,00, 2526463146366,0) {GF EXTRAPOLATED}

UNITS: UAH/year

DOCUMENT: In the alternative scenario №2, we assume that the active phase of the war ends at the end of 2025, and the government purchases will continue to grow significantly till the end of our simulation.

"Government_purchases_(base_case)" = GRAPH(TIME)

Points: (2016,00, 392103000000,0), (2017,00, 462626000000,0), (2018,00, 640486000000,0), (2019,00, 770514000000,0), (2020,00, 786780000000,0), (2021,00, 854817000000,0), (2022,00, 1016423000000,0), (2023,00, 1984794000000,0), (2024,00, 2156429564424,6), (2025,00, 1969951771046,0), (2026,00, 1871454182493,3) {GF EXTRAPOLATED}

UNITS: UAH/year

DOCUMENT: In the base case scenario, we assume that the active phase of the war ends at the end of 2023, and the government purchases will be growing more slowly, as the need for significant defense spending will decrease.

Import = IF Base_case_scenario = 1 THEN "Import_(base_case)" ELSE IF Alternative_scenario_1 = 1 THEN "Import_(alternative_scenario_1)"ELSE IF Alternative_scenario_2 = 1 THEN "Import_(alternative_scenario_2)" ELSE "Import_(base_case)"

UNITS: UAH/year

DOCUMENT: Imports refer to goods and services purchased by a country from foreign sources and brought into the domestic economy. When a country buys products or services from another country, those purchases are considered imports.

This variable is external, and the values are given by the State Statistics Service of Ukraine, and the forecast values are based on the assumptions of different scenarios.

"Import_(alternative_scenario_1)" = GRAPH(TIME)

Points: (2016,00, 1097854000000,0), (2017,00, 1341115000000,0), (2018,00, 1662128000000,0), (2019,00, 1919862000000,0), (2020,00, 1959945000000,0), (2021,00, 1702946000000,0), (2022,00, 2289881000000,0), (2023,00, 2712325000000,0), (2024,00, 3526022500000,0), (2025,00, 4760130375000,0), (2026,00, 6188169487500,0) {GF EXTRAPOLATED}

UNITS: UAH/year

DOCUMENT: In the alternative scenario №1, we assume that the active phase of the war ends at the end of 2024, and, starting from 2025, import needs will significantly grow due to the reconstruction of the country. But in 2023-2024, the level of imports still be high to cover supply businesses and households with goods they cannot get due to partly economic destruction.

"Import_(alternative_scenario_2)" = GRAPH(TIME)

Points: (2016,00, 1097854000000,0), (2017,00, 1341115000000,0), (2018,00, 1662128000000,0), (2019,00, 1919862000000,0), (2020,00, 1959945000000,0), (2021,00, 1702946000000,0), (2022,00, 2289881000000,0), (2023,00, 2712325000000,0), (2024,00, 3729446875000,0), (2025,00, 5068657343750,0), (2026,00, 6335821679688,0) {GF EXTRAPOLATED}

UNITS: UAH/year

DOCUMENT: In the alternative scenario №2, we assume that the active phase of the war ends at the end of 2025, and till the end of our simulation imports still be high to cover supply businesses and households with goods they cannot get due to partly economy destruction, but not such big as it could have been according to other two scenarios.

"Import_(base_case)" = GRAPH(TIME)

Points: (2016,00, 1097854000000,0), (2017,00, 1341115000000,0), (2018,00, 1662128000000,0), (2019,00, 1919862000000,0), (2020,00, 1959945000000,0), (2021,00, 1702946000000,0), (2022,00, 2289881000000,0), (2023,00, 2712325000000,0), (2024,00, 3390406250000,0), (2025,00, 4407528125000,0), (2026,00, 5509410156250,0) {GF EXTRAPOLATED}

UNITS: UAH/year

DOCUMENT: In the base case scenario, we assume that the active phase of the war ends at the end of 2023, and, starting from 2024, import needs will significantly grow due to the reconstruction of the country.

Investments = IF Base_case_scenario = 1 THEN "Investments_(base_case)" ELSE IF Alternative_scenario_1 = 1 THEN "Investments_(alternative_scenario_1)" ELSE IF Alternative_scenario_2 = 1 THEN "Investments_(alternative_scenario_2)" ELSE "Investments_(base_case)"

UNITS: UAH/year

DOCUMENT: Investments refer to the allocation of financial resources with the expectation of generating future income, growth, or value. In the context of personal finance or business, investments typically involve the purchase or acquisition of assets to earn a return on the invested capital.

This variable is an external one, and the values are given by the State Statistics Service of Ukraine, and the forecast values are based on the assumptions of different scenarios.

"Investments_(alternative_scenario_1)" = GRAPH(TIME)

Points: (2016,00, 270895000000,0), (2017,00, 212591000000,0), (2018,00, 316841000000,0), (2019,00, 518201000000,0), (2020,00, 595194000000,0), (2021,00, 661801000000,0), (2022,00, 788599000000,0), (2023,00, 654629000000,0), (2024,00, 599236398658,0), (2025,00, 690924104550,2), (2026,00, 889232368989,2) {GF EXTRAPOLATED}

UNITS: UAH/year

DOCUMENT: In the alternative scenario №1, we assume that the active phase of the war ends at the end of 2024, and, starting from 2025, the investments will be growing at a higher pace due to the security risks` abolishment. In the period of 2024, it will stay almost in the same range.

"Investments_(alternative_scenario_2)" = GRAPH(TIME)

Points: (2016,00, 270895000000,0), (2017,00, 212591000000,0), (2018,00, 316841000000,0), (2019,00, 518201000000,0), (2020,00, 595194000000,0), (2021,00, 661801000000,0), (2022,00, 788599000000,0), (2023,00, 654629000000,0), (2024,00, 562675464590,0), (2025,00, 579415378812,0), (2026,00, 660202188761,0) {GF EXTRAPOLATED}

UNITS: UAH/year

DOCUMENT: In the alternative scenario №2, we assume that the active phase of the war ends at the end of 2025, and till the end of the simulation they will grow marginally based on 2022 data values.

"Investments_(base_case)" = GRAPH(TIME)

Points: (2016,00, 270895000000,0), (2017,00, 212591000000,0), (2018,00, 316841000000,0), (2019,00, 518201000000,0), (2020,00, 595194000000,0), (2021,00, 661801000000,0), (2022,00, 788599000000,0), (2023,00, 654629000000,0), (2024,00, 661971134811,7), (2025,00, 851408275095,0), (2026,00, 1070367615929,3) {GF EXTRAPOLATED}

UNITS: UAH/year

DOCUMENT: In the base case scenario, we assume that the active phase of the war ends at the end of 2023, and, starting from 2024, the investments will be growing at a higher pace due to the security risks` abolishment.

Labor_cost = (Nominal_wages/(1+GDP_deflator/100))/Real_GDP

UNITS: dmnl

DOCUMENT: The labor cost indicator, which is measured as a ratio of real wages to real GDP, is used to analyze labor's share of the overall economy or to assess wage growth relative to economic output.

This ratio can provide insights into the relative compensation of workers compared to the overall economic output. A higher ratio indicates that wages are growing at a faster pace than the economy, suggesting potentially higher labor costs for businesses. Conversely, a lower ratio suggests that wage growth is slower relative to economic output, indicating potentially lower labor costs.

Labor_costs_growth = Labor_cost/HISTORY(Labor_cost; TIME-0,25)

UNITS: dmnl

DOCUMENT: Labor cost growth refers to the rate at which labor costs increase or decrease over a specific period. It represents the growth or change in the costs within the last 3 months.

The equation is based on the book "Концептуальні підходи до побудови макромоделі економіки України методами системної динаміки" by Faryna and Dadashova.

"Net_export_(Alternative_scenario_1)" = GRAPH(TIME)

Points: (2016,00, -51926000000,0), (2017,00, -165162000000,0), (2018,00, -229438000000,0), (2019,00, -310497000000,0), (2020,00, -320079000000,0), (2021,00, -63886000000,0), (2022,00, -72021000000,0), (2023,00, -871762000000,0), (2024,00, -617118750000,0), (2025,00, -503934600000,0), (2026,00, -366065700000,0) {GF EXTRAPOLATED}

UNITS: UAH/year

DOCUMENT: In the alternative scenario №1, we assume that the active phase of the war ends at the end of 2024, and, starting from 2025, exports will increase, and Ukrainians will return more actively from abroad. At the same time, imports will play a crucial role in supplying households and businesses, so the net export will be widening too, but at a lower degree than in the base case scenario during 2024.

But, starting in 2025, significant import needs for the reconstruction of the country will cause the current account deficit to persist. That`s why the net export will be widening at a higher value than in previous years.

"Net_export_(Alternative_scenario_2)" = GRAPH(TIME)

Points: (2016,00, -51926000000,0), (2017,00, -165162000000,0), (2018,00, -229438000000,0), (2019,00, -310497000000,0), (2020,00, -320079000000,0), (2021,00, -63886000000,0), (2022,00, -72021000000,0), (2023,00, -871762000000,0), (2024,00, -765227250000,0), (2025,00, -620227200000,0), (2026,00, -506860200000,0) {GF EXTRAPOLATED}

UNITS: UAH/year

DOCUMENT: In the alternative scenario №2, we assume that the active phase of the war ends at the end of 2025. Till this time, imports will play a crucial role in supplying households and businesses, so

the net export will be widening too, but at a higher degree than in the base case and alternative № 1 scenario during 2024-2025.

"Net_export_(base_case)" = GRAPH(TIME)

Points: (2016,00, -51926000000,0), (2017,00, -165162000000,0), (2018,00, -229438000000,0), (2019,00, -310497000000,0), (2020,00, -320079000000,0), (2021,00, -63886000000,0), (2022,00, -72021000000,0), (2023,00, -871762000000,0), (2024,00, -493695000000,0), (2025,00, -387642000000,0), (2026,00, -281589000000,0) {GF EXTRAPOLATED}

UNITS: UAH/year

DOCUMENT: In the base case scenario, we assume that the active phase of the war ends at the end of 2023, and, starting from 2024, exports will increase, and Ukrainians will return more actively from abroad. However, significant import needs for the reconstruction of the country will cause the current account deficit to persist. That`s why the net export will be widening.

Net_exports = IF Base_case_scenario = 1 THEN "Net_export_(base_case)"ELSE IF Alternative_scenario_1 = 1 THEN "Net_export_(Alternative_scenario_1)" ELSE IF Alternative_scenario_2 = 1 THEN "Net_export_(Alternative_scenario_2)" ELSE "Net_export_(base_case)"

UNITS: UAH/year

DOCUMENT: Net export, also known as the trade balance or trade surplus/deficit, refers to the difference between the value of a country's exports and the value of its imports over a given period, typically a year. It is a component of a country's balance of payments, which measures all financial transactions between residents of that country and the rest of the world.

This variable is external and the values are given by the State Statistics Service of Ukraine, and the forecast values are based on the assumptions of a different scenario.

Nominal_GDP = Government_purchases+Investments+Net_exports+HD.Consumption

UNITS: UAH/year

DOCUMENT: Nominal GDP (Gross Domestic Product) is a measure of the total value of all goods and services produced within a country's borders during a specific period, typically a year. It represents the current market prices of final goods and services without adjusting for inflation.

To calculate nominal GDP, the total value of goods and services produced in different sectors of the economy is summed. This includes consumer spending, business investment, government expenditures, and net export.

Nominal_wages = GRAPH(TIME)

Points: (2014,000, 294602599673,0), (2015,000, 352611373861,0), (2016,000, 422042375438,0), (2017,000, 505144700000,0), (2018,000, 673865800000,0), (2019,000, 838321100000,0), (2020,000, 963428000000,0), (2021,000, 1048837600000,0), (2022,000, 1225656900000,0), (2023,000, 1371440719170,0) {GF EXTRAPOLATED}

UNITS: UAH/year

DOCUMENT: Nominal wages refer to the wages stated in current hryvnia amounts, without considering inflation or changes in purchasing power over time. They represent the actual hryvnia amount received by all employees for their work in Ukraine.

This variable is external, and the values are given by the State Statistics Service of Ukraine, and the forecast values are extrapolated.

Potential_GDP = GRAPH(TIME)

Points: (2016,00, 1,42832307098e+12), (2017,00, 2052909336810,0), (2018,00, 2701854248622,3), (2019,00, 3546477645577,6), (2020,00, 4335138555476,7), (2021,00, 4721985225206,5), (2022,00, 4450153995506,9), (2023,00, 3838291230012,1), (2024,00, 4645147885022,0), (2025,00, 5456445475014,3), (2026,00, 6487025581420,0) {GF EXTRAPOLATED}

UNITS: UAH/year

DOCUMENT: Potential GDP, also known as full-employment GDP or trend GDP, refers to the level of economic output an economy can sustain over the long term when all its resources, including labor and capital, are fully utilized without generating inflationary pressures. It represents the economy's maximum sustainable level of production.

It`s calculated using the Hodrick-Prescott (HP) filter, which estimates the potential GDP by separating the cyclical component from the overall GDP series. The HP filter uses a mathematical approach to decompose the data into a trend component and a cyclical component. It takes into account the average data of real GDP according to different scenarios.

Production_costs_growth = (1-Weight_of_import_in_production)*Unit_cost_of_domestic_production + Weight_of_import_in_production*(Import/HISTORY(Import; TIME-1))

UNITS: dmnl

DOCUMENT: Production costs growth refers to the change or increase in the costs of producing goods or services over a specific period.

The equation appears to calculate the production costs growth by considering two components: the unit cost of domestic production and the import component.

The first part of the equation represents the cost of domestic production. It calculates the product of the unit cost of domestic production and the complement of the weight of import in production. The weight of imports in production refers to the proportion of imported inputs used in the production process. By subtracting this weight from 1, we get the weight of domestic production. Multiplying it by the unit cost of domestic production gives us the cost of domestically produced components.

The second part of the equation represents the cost of imported components. It calculates the product of the weight of import in production and the ratio of current import to the historical import at the previous period. This is a way to account for the change in import costs over time.

By adding the cost of domestic production and the cost of imported components, the equation provides an estimate of the overall production costs growth. The equation is based on the book "Концептуальні підходи до побудови макромоделі економіки України методами системної динаміки" by Faryna and Dadashova.

Raw_materials_cost_growth = SMTH1(IEC.Inflation_expectations[Business]/HISTORY(IEC.Inflation_expectations[Business]; TIME-0,25); 1)

UNITS: dmnl

DOCUMENT: Raw materials cost growth refers to the rate at which the costs of raw materials used in production increase or decrease over a specific period (in our case, it`s 3 months).

It`s defined as a smooth function, and we compare how the prices will go up according to the inflation expectations of the business sector.

Real_GDP = Nominal_GDP*(1-(GDP_deflator/100))

UNITS: UAH/Year

DOCUMENT: Real GDP refers to the inflation-adjusted measure of a country's gross domestic product (GDP). Real GDP accounts for changes in the price level by adjusting the nominal GDP using the GDP deflator.

The equation calculates the real GDP by multiplying the nominal GDP by a factor that reflects the difference between 100% and the GDP deflator expressed as a decimal. The GDP deflator represents the average price level of all goods and services produced in an economy relative to a base year.

Real GDP provides a more accurate representation of the economic output of a country over time by removing the influence of price changes. It allows for meaningful comparisons of economic growth and productivity across different periods, facilitating the analysis of long-term trends and economic performance.

Unit_cost_of_domestic_production = SMTH1(Labor_costs_growth*Raw_materials_cost_growth*Capital_costs_growth; 1)

UNITS: dmnl

DOCUMENT: The unit cost of domestic production refers to the cost incurred to produce a single unit of a product or service within a domestic market or country.

It is calculated as a smoothed product of labor, raw materials, and capital cost growth. The equation is based on the book "Концептуальні підходи до побудови макромоделі економіки України методами системної динаміки" by Faryna and Dadashova.

Weight_of_import_in_production = (Import)/Real_GDP

UNITS: dmnl

DOCUMENT: The weight of imports in production, also known as the import-to-GDP ratio, is a measure that quantifies the share of imports of the real Gross Domestic Product (GDP) of a country. It represents the extent to which imports contribute to the overall production and economic output of a nation.

HD:

Propensity_to_consume(t) = Propensity_to_consume(t - dt) + (- Change_in_PC) * dt {NON-NEGATIVE}

INIT Propensity_to_consume = historical_values_of_propensity_to_consume

UNITS: dmnl

DOCUMENT: The propensity to consume is a measure that quantifies the inclination of households or individuals to spend their disposable income on goods and services rather than saving them. It represents the proportion of income that is allocated to consumption.

The propensity to consume is expressed as a decimal between 0 and 1. A propensity to consume of 0 indicates that all income is saved, while a propensity to consume of 1 indicates that all income is spent on consumption.

The initial value of propensity to consume is equal to 0,98, and it was defined as a fraction of consumption to income based on data provided by the State Statistics Service of Ukraine.

Change_in_PC = (Propensity_to_consume-Indicated_propensity_to_consume)/Time_to_adj_PC

UNITS: dmnl/year

DOCUMENT: The change in propensity to consume refers to a shift or alteration in the willingness and ability of individuals or households to spend a larger or smaller proportion of their income on consumption goods and services. It is a concept commonly discussed in the field of macroeconomics, particularly within the framework of Keynesian economics.

A change in propensity to consume is defined as the difference between the indicated and current values of propensity to consume adjusted to the time to change the value of propensity to consume.

Consumption = Nominal_disposable_income*Propensity_to_consume

UNITS: UAH/year

DOCUMENT: Consumption refers to the expenditure or spending by individuals, households on goods and services. It represents the demand side of the economy and is a vital component of measuring economic activity and determining aggregate demand.

Consumption is a key indicator of economic growth and is defined as a product of the nominal disposable income and the propensity to consume.

effect_of_inflation_expectations_of_households_on_propensity_to_consume = GRAPH(IEC.Inflation_expectations[Households])

Points: (5,00, 0,95), (7,00, 0,9506), (9,00, 0,9522), (11,00, 0,9558), (13,00, 0,9634), (15,00, 0,975), (17,00, 0,9866), (19,00, 0,9942), (21,00, 0,9978), (23,00, 0,9994), (25,00, 1)

UNITS: dmnl

DOCUMENT: Inflation expectations of households have an impact on their propensity to consume, which refers to the likelihood or willingness of households to spend money on goods and services.

If households anticipate high inflation in the future, they may expect their income to lose purchasing power. As a result, they might choose to increase their current consumption and spend more on goods and services before prices rise further. This behavior is known as "precautionary spending." On the other

hand, if households expect low inflation or deflation, they may be more inclined to save their income, anticipating that prices will be lower in the future.

Also, inflation expectations impact consumer confidence. If households are confident that inflation will remain low and stable, they may feel more secure about their financial situation and be more willing to spend. On the other hand, if households have concerns about rising inflation, it can erode their confidence in the economy, leading to reduced spending and a higher propensity to save.

In our case, this effect is presented as an s-shaped growth graph, and it`s based on.

historical_values_of_propensity_to_consume = GRAPH(TIME)

Points: (2014,000, 0,92), (2015,000, 0,98), (2016,000, 0,98), (2017,000, 0,99), (2018,000, 0,99), (2019,000, 0,99), (2020,000, 0,99), (2021,000, 0,98), (2022,000, 0,99), (2023,000, 0,99)

UNITS: dmnl

DOCUMENT: This variable represents the historical values of business expectations, and data is taken from the official website of the State Statistical Service of Ukraine.

Indicated_propensity_to_consume = 0,98^(effect_of_inflation_expectations_of_households_on_propensity_to_consume*Real_deposit_interest_rate_effect_on_Consumption)

UNITS: dmnl

DOCUMENT: Indicated propensity to consume refers to the estimated or predicted level of household consumption. It is a measure used to gauge the inclination of households to spend their income on goods and services.

The indicated propensity to consume is often used in macroeconomic analysis and forecasting to understand consumer behavior and its impact on economic growth. It helps economists and policymakers make predictions about future consumption levels, which in turn affects overall economic activity, employment, and investment decisions.

In our case, this indicator is estimated as a function of the initial value of propensity to consume in the power of the product of the real deposit interest rate effect on consumption and the effect of inflation expectations of households on the propensity to consume. This equation is based on the book "Концептуальні підходи до побудови макромоделі економіки України методами системної динаміки" by Dadashova and Faryna.

Interest_Rate_Elasticity_of_Consumption = -0,5

UNITS: dmnl

DOCUMENT: The real deposit interest rate elasticity of consumption is a measure of how sensitive consumer spending is to changes in the real interest rate earned on deposits. It measures the percentage change in consumer spending that results from a one percent change in the real deposit interest rate. A higher real deposit interest rate elasticity of consumption means that consumers are more sensitive to changes in the real interest rate earned on deposits and are more likely to adjust their spending habits in response to changes in the real deposit interest rate. This concept is important for policymakers and economists to understand when making decisions about monetary policy and interest rate adjustments, as it can help them predict how changes in the real deposit interest rate will affect consumer spending and overall economic activity.

In our case this value is equal to -0,5. It`s based on the book of Faryna and Dadashova "Концептуальні підходи до побудови макромоделі економіки України методами системної динаміки."

Nominal_disposable_income = IF BD.Base_case_scenario = 1 THEN "Nominal_disposable_income_(base_case)" ELSE IF BD.Alternative_scenario_1 = 1 THEN "Nominal_disposable_income_(alternative_1)" ELSE IF BD.Alternative_scenario_2 = 1 THEN "Nominal_disposable_income_(alternative_2)" ELSE "Nominal_disposable_income_(base_case)"

UNITS: UAH/year

DOCUMENT: Nominal disposable income refers to the total amount of income that individuals or households have available for spending and saving after accounting for taxes and other deductions. It represents the income received before adjusting for inflation or changes in purchasing power.

It`s an external variable, and the values are given by the State Statistics Service of Ukraine, and the forecast values are based on the assumptions of different scenarios.

"Nominal_disposable_income_(alternative_1)" = GRAPH(TIME)

Points: (2016,00, 1772016000000,0), (2017,00, 2051331000000,0), (2018,00, 2652082000000,0), (2019,00, 3248730000000,0), (2020,00, 3744060000000,0), (2021,00, 4045191000000,0), (2022,00, 4698611000000,0), (2023,00, 3289027700000,0), (2024,00, 3375508479480,0), (2025,00, 3866567187785,6), (2026,00, 4438156619939,7) {GF EXTRAPOLATED}

UNITS: UAH/year

DOCUMENT: In the alternative case scenario №1, we assume that the active phase of the war ends at the end of 2024, and the nominal disposable income will decline a little bit and will resume its growth in 2025. The forecast values are made according to previous growth and the author`s hypothesis.

"Nominal_disposable_income_(alternative_2)" = GRAPH(TIME)

Points: (2016,00, 1772016000000,0), (2017,00, 2051331000000,0), (2018,00, 2652082000000,0), (2019,00, 3248730000000,0), (2020,00, 3744060000000,0), (2021,00, 4045191000000,0), (2022,00, 4698611000000,0), (2023,00, 3289027700000,0), (2024,00, 3453479085000,0), (2025,00, 3695222620950,0), (2026,00, 4064744883045,0) {GF EXTRAPOLATED}

UNITS: UAH/year

DOCUMENT: In the alternative scenario №2, we assume that the active phase of the war ends at the end of 2025, and the nominal disposable income will be declining gradually during this timeline. The forecast values are made according to previous growth and the author`s hypothesis.

"Nominal_disposable_income_(base_case)" = GRAPH(TIME)

Points: (2016,00, 1772016000000,0), (2017,00, 2051331000000,0), (2018,00, 2652082000000,0), (2019,00, 3248730000000,0), (2020,00, 3744060000000,0), (2021,00, 4045191000000,0), (2022,00, 4698611000000,0), (2023,00, 3289027700000,0), (2024,00, 3875508479480,0), (2025,00, 4566567187785,6), (2026,00, 5138156619939,7) {GF EXTRAPOLATED}

UNITS: UAH/year

DOCUMENT: In the base case scenario, we assume that the active phase of the war ends at the end of 2023, and the nominal disposable income will be growing steadily. The forecast values are made according to previous growth and the author`s hypothesis.

Personal_Saving = Nominal_disposable_income-Consumption

UNITS: UAH/year

DOCUMENT: Personal saving, also known as personal savings or household savings, refers to the portion of disposable income that individuals or households set aside or save for future use instead of spending it on immediate consumption. It represents the difference between nominal disposable income and consumption.

Real_deposit_interest_rate_effect_on_Consumption = (((Real_deposit_rate-INIT(Real_deposit_rate))//INIT(Real_deposit_rate))*Interest_Rate_Elasticity_of_Consumption)

UNITS: dmnl

DOCUMENT: The indicator "Real deposit interest rate effect on consumption" measures the impact of changes in the real deposit interest rate on consumer spending.

It considers the difference between the current real deposit interest rate and the initial (baseline) real deposit interest rate. This difference is divided by the initial real deposit interest rate to capture the relative change. The result is then multiplied by the parameter known as the Interest Rate Elasticity of Consumption, which represents the sensitivity of consumer spending to changes in interest rates.

The indicator helps quantify how variations in the real deposit interest rate can influence consumer behavior and consumption patterns. The lower the value is, the higher level of savings encouragement is, potentially leading to a decrease in consumption and the other way around.

The equation is based on the book "Концептуальні підходи до побудови макромоделі економіки України методами системної динаміки" by Dadashova and Faryna.

Real_deposit_rate = IRC.DIR-.Inflation

UNITS: %

DOCUMENT: The real deposit rate is the interest rate earned on a deposit after adjusting for inflation. It is the rate of return on an investment after accounting for the effects of inflation. In other words, it is the rate at which the purchasing power of the deposit increases over time.

savings_effect = Personal_Saving/HISTORY(Personal_Saving; TIME-1)

UNITS: dmnl

DOCUMENT: The effect of household savings on inflation has both inflationary and deflationary effects on an economy.

1) Inflationary Effect: When households save a smaller proportion of their income and spend more, it increases the aggregate demand for goods and services. This increased demand can potentially lead to an increase in prices, known as inflation. When households have a lower savings rate and are actively participating in consumption, it puts upward pressure on prices, especially if the production capacity of the economy is limited. Higher consumer spending can stimulate economic growth, but if it exceeds the productive capacity, it can contribute to inflationary pressures.

2) Deflationary Effect: On the other hand, if households save a larger proportion of their income and spend less, it can have a deflationary effect on the economy. When savings increase, it reduces the immediate spending on consumption goods and services, leading to a decrease in aggregate demand. This demand reduction can put downward pressure on prices, potentially resulting in deflation or a decrease in the overall price level. Deflation can have negative implications for the economy, such as discouraging spending, increasing the real burden of debt, and causing a slowdown in economic activity.

In our case, this effect is the relative change in savings in comparison to its value one year before.

Time_to_adj_PC = 0,5

UNITS: year

DOCUMENT: Time to adjust propensity to consume refers to the period it takes for households or individuals to adapt and modify their consumption behavior in response to changes in their income or other economic factors. It represents the adjustment process of households aligning their spending patterns with their changing financial circumstances.

The time to adjust propensity to consume is equal to half of the year (6 months) or 0,5 years.

It`s based on the book of Faryna and Dadashova "Концептуальні підходи до побудови макромоделі економіки України методами системної динаміки."

IEC:

Inflation_expectations[Households](t) = Inflation_expectations[Households](t - dt) + (Δ_inflation_expectations[Households]) * dt

INIT Inflation_expectations[Households] = historical_values_of_households_expectations

UNITS: %

DOCUMENT: Inflation expectations of households refer to the anticipated rate of inflation that households expect to occur in the future. These expectations can be influenced by a variety of factors, including past inflation rates, current economic conditions, and expectations for future economic growth. Inflation expectations are important because they can affect consumer behavior, such as spending and saving habits, and can also influence the decisions of policymakers and central banks when setting monetary policy. Surveys and other data sources are often used to measure inflation expectations of households, as they can provide valuable insights into how consumers perceive the economy and how they are likely to respond to changes in economic conditions.

Inflation expectations of businesses refer to the anticipated future changes in the overall price level of goods and services. It represents the expectations or predictions of businesses regarding the rate at which prices will increase or decrease in the future. Businesses closely monitor inflation expectations as they can impact their decision-making processes, such as pricing strategies, investment plans, wage negotiations, and overall economic outlook. These expectations are influenced by factors such as economic indicators, market conditions, government policies, and supply and demand dynamics. Tracking inflation expectations is important for businesses to make informed decisions and manage their operations effectively in an inflationary environment.

Inflation_expectations[Business](t) = Inflation_expectations[Business](t - dt) + (Δ_inflation_expectations[Business]) * dt

INIT Inflation_expectations[Business] = historical_values_of_business_expectations

UNITS: %

DOCUMENT: Inflation expectations of households refer to the anticipated rate of inflation that households expect to occur in the future. These expectations can be influenced by a variety of factors, including past inflation rates, current economic conditions, and expectations for future economic growth. Inflation expectations are important because they can affect consumer behavior, such as spending and saving habits, and can also influence the decisions of policymakers and central banks when setting monetary policy. Surveys and other data sources are often used to measure inflation expectations of households, as they can provide valuable insights into how consumers perceive the economy and how they are likely to respond to changes in economic conditions.

Inflation expectations of businesses refer to the anticipated future changes in the overall price level of goods and services. It represents the expectations or predictions of businesses regarding the rate at which prices will increase or decrease in the future. Businesses closely monitor inflation expectations as they can impact their decision-making processes, such as pricing strategies, investment plans, wage negotiations, and overall economic outlook. These expectations are influenced by factors such as economic indicators, market conditions, government policies, and supply and demand dynamics. Tracking inflation expectations is important for businesses to make informed decisions and manage their operations effectively in an inflationary environment.

Δ_inflation_expectations[Households] = ((trust_to_NBU_from_households*(forecast_of_Inflation_from_NBU-Inflation_expectations[Households])*HD.savings_effect)/inflation_expectations_adj_time[Households])+war_shock_on_InfExp[Households]

UNITS: %/year

DOCUMENT: The change in inflation expectations refers to the shift in the anticipated level of future inflation. The equation includes the indicated inflation expectations, which are adjusted to the time it takes for households and businesses to update their expectations. Also, the war shock effect captures the additional impact of the war on inflation expectations.

Indicated inflation expectations of households and businesses refer to the anticipated or projected levels of inflation as perceived by individuals and companies.

For households, indicated inflation expectations represent their anticipated future changes in prices and the cost of living. They take into account the inflation forecast published by the NBU: it`s represented as the difference between the inflation forecast and the real value of inflation and adjusted to their trust in the regulator and saving effect.

Indicated inflation expectations of businesses reflect their outlook on future price levels and the impact on their operations. They take into account the inflation forecast published by the NBU: it`s represented as the difference between the inflation forecast and the real value of inflation and adjusted to their trust in the regulator and saving demand and cost-push effects.

Δ_inflation_expectations[Business] = ((trust_to_NBU_from_business*(forecast_of_Inflation_from_NBU-Inflation_expectations[Business])*BD.Cost_push_effect*BD.Demand_pull_effect)/inflation_expectations_adj_time[Business])+war_shock_on_InfExp[Business]

UNITS: %/year

DOCUMENT: The change in inflation expectations refers to the shift in the anticipated level of future inflation. The equation includes the indicated inflation expectations, which are adjusted to the time it takes for households and businesses to update their expectations. Also, the war shock effect captures the additional impact of the war on inflation expectations.

Indicated inflation expectations of households and businesses refer to the anticipated or projected levels of inflation as perceived by individuals and companies.

For households, indicated inflation expectations represent their anticipated future changes in prices and the cost of living. They take into account the inflation forecast published by the NBU: it`s represented as the difference between the inflation forecast and the real value of inflation and adjusted to their trust in the regulator and saving effect.

Indicated inflation expectations of businesses reflect their outlook on future price levels and the impact on their operations. They take into account the inflation forecast published by the NBU: it`s represented as the difference between the inflation forecast and the real value of inflation and adjusted to their trust in the regulator and saving demand and cost-push effects.

average_inflation_expectations = Inflation_expectations[Business]*0,5+Inflation_expectations[Households]*0,5

UNITS: %

DOCUMENT: Average inflation expectations refer to the aggregated or combined expectations of inflation held by businesses and households within an economy. It is a measure of the anticipated rate of inflation over a specific period (in our case 1 year).

The equation takes the average of two sets of inflation expectations - households and businesses - by assigning equal weight to each group. The weights of 0.5 for both businesses and households imply that each group contributes equally to the calculation of the average inflation expectations.

deviation_of_forecasted_inflation_from_real_inflation = .Inflation-forecast_of_Inflation_from_NBU

UNITS: %

DOCUMENT: The deviation of forecasted inflation from real inflation represents the difference between the actual inflation rate (.inflation) and the predicted or forecasted inflation rate (forecast_of_Inflation_from_NBU). It measures the extent to which the forecasted inflation diverges from the actual observed inflation.

By subtracting the forecasted inflation from the actual inflation, the equation quantifies the difference between the two measures. A positive deviation indicates that the actual inflation is higher than the forecasted value, suggesting an overestimation of inflation in the forecast. Conversely, a negative deviation indicates that the actual inflation is lower than the forecasted value, suggesting an underestimation of inflation in the forecast.

Analyzing the deviation of forecasted inflation from real inflation helps evaluate the accuracy and reliability of inflation forecasts. It provides insights into the performance of forecasting models or institutions in predicting future inflation trends. Deviations can be used to assess the effectiveness of monetary policy, guide adjustments in forecasting methodologies, and improve economic decision-making based on more accurate inflation expectations.

forecast_of_Inflation_from_NBU = GRAPH(TIME)

Points: (2016,00, 15,0), (2017,00, 20,0), (2018,00, 16,0), (2019,00, 10,0), (2020,00, 5,0), (2021,00, 8,0), (2022,00, 10,0), (2023,00, 26,6), (2024,00, 14,8), (2025,00, 9,6), (2026,00, 6,0)

UNITS: %

DOCUMENT: The forecast of inflation from the National Bank of Ukraine (NBU) refers to the projected or anticipated inflation rate provided by the central bank of Ukraine. The NBU releases regular forecasts that estimate the expected inflation trajectory over a specific period, typically covering the upcoming months or years.

The NBU's forecast of inflation is based on a thorough analysis of various economic indicators, including but not limited to GDP growth, monetary aggregates, fiscal policy, exchange rates, external factors, and domestic price pressures. The central bank considers both domestic and international factors that may influence inflation dynamics in Ukraine.

It`s an external variable, and the data is taken from Inflation reports published on the official website of the NBU.

historical_values_of_business_expectations = GRAPH(TIME)

Points: (2016,000, 22,2), (2017,000, 15,6), (2018,000, 11,0), (2019,000, 9,0), (2020,000, 5,1), (2021,000, 7,7), (2022,000, 9,5), (2023,000, 23,3)

UNITS: %

DOCUMENT: This variable represents the historical values of business expectations, and data is taken from the official website of the NBU.

historical_values_of_households_expectations = GRAPH(TIME)

Points: (2016,000, 21,5), (2017,000, 17,1), (2018,000, 13,3), (2019,000, 12,1), (2020,000, 8,8), (2021,000, 9,5), (2022,000, 12,3), (2023,000, 13,2)

UNITS: %

DOCUMENT: This variable represents the historical values of households` expectations, and data is taken from the official website of the NBU.

inflation_expectations_adj_time[Economic_agents] = 0,25

UNITS: year

DOCUMENT: Inflation expectations adjustment time refers to the period it takes for individuals and businesses to update their expectations of future inflation in response to new information or changes in economic conditions. The adjustment time is 3 months, and it`s defined by manual testing, so it will be able to represent the historical data the most precisely.

trust_to_NBU_from_business = GRAPH(deviation_of_forecasted_inflation_from_real_inflation)

Points: (-10,00, 1,0000), (-8,33333333333, 0,9419), (-6,66666666667, 0,8862), (-5,00, 0,8327), (-3,33333333333, 0,7814), (-1,66666666667, 0,7322), (0,00, 0,6851), (1,66666666667, 0,6398),

(3,33333333333, 0,5964), (5,00, 0,5548), (6,66666666667, 0,5148), (8,33333333333, 0,4765), (10,00, 0,4398), (11,6666666667, 0,4045), (13,3333333333, 0,3707), (15,00, 0,3383), (16,6666666667, 0,3072), (18,3333333333, 0,2774), (20,00, 0,2488), (21,6666666667, 0,2213), (23,3333333333, 0,1950), (25,00, 0,1697), (26,6666666667, 0,1455), (28,3333333333, 0,1223), (30,00, 0,1000)

UNITS: dmnl

DOCUMENT: The level of trust in the NBU among businesses is defined according to the deviation of forecasted inflation from real inflation.

It`s a graphical function based on the hypothesis/assumption that the higher are deviations, the lower trust in NBU is. However, the trust from businesses in the NBU is a little bit higher than households/ It`s based on the article “The Effectiveness of the Monetary Transmission Mechanism in Ukraine since the Transition to Inflation Targeting” by O.Zholud, V. Lepushynskyi, and S. Nikolaychuk.

trust_to_NBU_from_households = GRAPH(deviation_of_forecasted_inflation_from_real_inflation)

Points: (-10,00, 1,0000), (-7,89473684211, 0,9717), (-5,78947368421, 0,9419), (-3,68421052632, 0,9104), (-1,57894736842, 0,8773), (0,526315789474, 0,8423), (2,63157894737, 0,8055), (4,73684210526, 0,7667), (6,84210526316, 0,7258), (8,94736842105, 0,6826), (11,0526315789, 0,6372), (13,1578947368, 0,5893), (15,2631578947, 0,5388), (17,3684210526, 0,4855), (19,4736842105, 0,4294), (21,5789473684, 0,3703), (23,6842105263, 0,3080), (25,7894736842, 0,2423), (27,8947368421, 0,1730), (30,00, 0,1000)

UNITS: dmnl

DOCUMENT: The level of trust in the NBU among households is defined according to the deviation of forecasted inflation from real inflation.

It`s a graphical function based on the hypothesis/assumption that the higher are deviations, the lower trust in NBU is.

"war_shock_(alternative_scenario_1)"[Households] = IF TIME>=2022,25 AND TIME < 2024 THEN -20 ELSE IF TIME>2024 AND TIME <2025 THEN 5 ELSE 0

UNITS: %/year

DOCUMENT: In the alternative scenario №1 scenario the war lasts till the end of 2024. The inflation expectations of business will business reflect the published macro-forecast of the NBU, while the household expectations about price growth remain lower due to a weaker demand due and the pegged exchange rate for a longer time.

The "IF" function is used, and the values were calibrated manually and are a hypothesis of the author.

"war_shock_(alternative_scenario_1)"[Business] = 0

UNITS: %/year

DOCUMENT: In the alternative scenario №1 scenario the war lasts till the end of 2024. The inflation expectations of business will business reflect the published macro-forecast of the NBU, while the household expectations about price growth remain lower due to a weaker demand due and the pegged exchange rate for a longer time.

The "IF" function is used, and the values were calibrated manually and are a hypothesis of the author. "war_shock_(alternative_scenario_2)"[Households] = IF TIME>=2022,25 AND TIME < 2024 THEN -20 ELSE IF TIME>2024 AND TIME <2026 THEN 10 ELSE 0

UNITS: %/year

DOCUMENT: In the alternative scenario №1 the war lasts till the end of 2025. The inflation expectations of business will business reflect the published macro-forecast of the NBU, while the household expectations about price growth remain lower due to a weaker demand due and the pegged exchange rate for a longer time.

The "IF" function is used, and the values were calibrated manually and are a hypothesis of the author. "war_shock_(alternative_scenario_2)"[Business] = 0

UNITS: %/year

DOCUMENT: In the alternative scenario №1 the war lasts till the end of 2025. The inflation expectations of business will business reflect the published macro-forecast of the NBU, while the household expectations about price growth remain lower due to a weaker demand due and the pegged exchange rate for a longer time.

The "IF" function is used, and the values were calibrated manually and are a hypothesis of the author. "war_shock_(base_case)"[Households] = IF TIME>=2022,25 AND TIME < 2024 THEN -20 ELSE 0

UNITS: %/year

DOCUMENT: In the base case scenario the war lasts till the end of 2023. Looking at the real data of inflation expectations published by the NBU, the inflation expectations of businesses reflect the published macro-forecast of the NBU, and the household ones are much lower. The reason for it might be the weaker demand due to the loss of income and the pegged exchange rate.

Starting from 2024 the NBU will come back to the active inflation targeting regime, and there will be no indirect influence on households.

"war_shock_(base_case)"[Business] = 0

UNITS: %/year

DOCUMENT: In the base case scenario the war lasts till the end of 2023. Looking at the real data of inflation expectations published by the NBU, the inflation expectations of businesses reflect the published macro-forecast of the NBU, and the household ones are much lower. The reason for it might be the weaker demand due to the loss of income and the pegged exchange rate.

Starting from 2024 the NBU will come back to the active inflation targeting regime, and there will be no indirect influence on households.

war_shock_on_InfExp[Economic_agents] = IF BD.Base_case_scenario = 1 THEN "war_shock_(base_case)" ELSE IF BD.Alternative_scenario_1 = 1 THEN "war_shock_(alternative_scenario_1)" ELSE IF BD.Alternative_scenario_2 = 1 THEN "war_shock_(alternative_scenario_2)" ELSE "war_shock_(base_case)"

UNITS: %/year

DOCUMENT: War shock refers to the impact of the armed conflict on economic agents' expectations about future inflation. During times of war, significant disruptions occur in the economy, including changes in government spending, resource allocation, production, and trade patterns. These disruptions affect inflationary pressures and, in turn, influence inflation expectations.

The "IF" function is used, and the values were calibrated manually.

IRC:

Deposits(t) = Deposits(t - dt) + (change_in_deposits) * dt

INIT Deposits = historical_values_of_deposits

UNITS: UAH

DOCUMENT: Deposits refer to funds that individuals, businesses, and other entities place with banks and other financial institutions for safekeeping and various financial services. Deposits play a crucial role in the functioning of the banking system and serve as a fundamental source of funding for banks.

The initial value is taken from the website of the NBU, where they publish their statistics.

DIR(t) = DIR(t - dt) + (changes_of_DIR) * dt

INIT DIR = historical_values_of_DIR

UNITS: %

DOCUMENT: The deposit interest rate refers to the interest rate that banks offer to depositors for holding their funds in deposit accounts. When individuals or businesses deposit money into a bank account, they are essentially lending that money to the bank. In return, the bank provides interest on the deposited funds as a form of compensation for the use of the money.

The deposit interest rate is expressed as a percentage rate, and it is calculated and credited to the account on an annual basis.

The initial value is taken from the website of the NBU, where they publish their statistics.

IIR(t) = IIR(t - dt) + (change_of_IIR) * dt

INIT IIR = historical_values_of_IIR

UNITS: %

DOCUMENT: The interbank interest rate, also known as the interbank lending rate or the interbank rate, refers to the interest rate at which banks lend or borrow funds from one another in the interbank market. It is the rate at which banks can access short-term funds from other banks to manage their daily liquidity needs or meet regulatory reserve requirements.

The initial value is taken from the website of the NBU, where they publish their statistics.

LIR(t) = LIR(t - dt) + (change_of_LIR) * dt

INIT LIR = historical_values_of_LIR

UNITS: %

DOCUMENT: The loan interest rate, also referred to as the borrowing rate or the cost of borrowing, is the percentage of interest that a borrower pays to a lender as a fee for borrowing funds. It represents the cost of obtaining a loan and is expressed as an annualized percentage of the loan amount.

The initial value is taken from the website of the NBU, where they publish their statistics.

Loans(t) = Loans(t - dt) + (changes_in_loans) * dt

INIT Loans = historical_values_of_loans

UNITS: UAH

DOCUMENT: In the banking system, loans refer to the financial products offered by banks and other financial institutions to individuals, businesses, and governments. These loans are a significant component of a bank's lending activities and play a crucial role in the economy.

Banks provide loans as a way to allocate funds from depositors and other sources of capital to borrowers. Banks serve as intermediaries between those who have excess funds (surplus units) and those who need funds (deficit units).

The initial value is taken from the website of the NBU, where they publish their statistics.

Reserves(t) = Reserves(t - dt) + (changes_in_reserves) * dt

INIT Reserves = historical_values_of_reserves

UNITS: UAH

DOCUMENT: Reserves refer to the funds that banks are required to hold in reserve to fulfill regulatory requirements and maintain stability within the financial system. These reserves serve as a safeguard against potential liquidity shocks and are held in accounts at the central bank.

The initial value is taken from the website of the NBU, where they publish their statistics.

change_in_deposits = (indicated_deposits-Deposits)/time_adj_of_deposits

UNITS: UAH/Year

DOCUMENT: Changes in loans refer to fluctuations or variations in the number of deposits within a banking system over a given period (in our case, it`s 1 year). It is defined as a difference between the indicated deposits and the current value of deposits in the banking system, and it is adjusted on time to change these fluctuations.

change_of_IIR = (.Policy_Rate-IIR)/time_to_adjust_IIR

UNITS: %/year

DOCUMENT: The change in the IIR refers to the difference between the key policy rate or historical level of the rate and its current level. It represents the magnitude of the adjustment or movement in the interbank interest rate over a given period.

change_of_LIR = ((indicated_LIR-LIR)/time_to_change_LIR)+war_shock_on_LIR

UNITS: %/year

DOCUMENT: The change in the LIR refers to the difference between the indicated LIR and its current level. It represents the magnitude of the adjustment or movement in the lending interest rate over a given period.

changes_in_loans = (demand_for_loans-Loans)/time_to_adj_loans

UNITS: UAH/year

DOCUMENT: Changes in loans refer to fluctuations or variations in the number of outstanding loans within an economy over a given period (in our case, it`s 1 year). It is defined as a difference between the demand for loans and the current value of loans in the banking system, and it is adjusted on time to change these fluctuations.

changes_in_reserves = ((loans_reserves+deposit_reserves)-Reserves)/time_adj_of_reserves

UNITS: UAH/year

DOCUMENT: Changes in reserves refer to fluctuations or variations in the reserves within a banking system over a given period (in our case, it`s 0,25 years). It is defined as a sum of loan and deposit reserves and adjusted on time to change these fluctuations.

changes_of_DIR = (indicated_DIR-DIR)/time_to_change_DIR

UNITS: %/year

DOCUMENT: The change in the DIR refers to the difference between the indicated DIR and its current level. It represents the magnitude of the adjustment or movement in the deposit interest rate over a given period.

demand_for_loans = (initial_demand_of_loans*effect_of_GDP_growth_on_Loans`_demand*effect_of_LIR_on_Loans`_demand)

UNITS: UAH

DOCUMENT: The demand for loans refers to the desire and willingness of borrowers to obtain loans from financial institutions or lenders. It represents the aggregate or collective demand for credit in an economy. The demand for loans is influenced by the initial demand for loans and adjusted by two effects: LIR and GDP growth on Loan demand.

deposit_reserves = Deposits*fraction_of_deposits_to_reserves

UNITS: UAH

DOCUMENT: Reserve deposits, or required reserves, refer to the portion of deposits that banks are required to hold in reserve by regulatory authorities, typically central banks. These reserves are a percentage of the deposits held by banks and serve as a means to ensure the stability and soundness of the banking system.

They are defined as the product of deposits and a fraction of deposits that go to reserves.

effect_of_GDP_growth_on_Loans`_demand = GRAPH(BD.GDP_growth)

Points: (0,500, 1,0000), (0,631578947368, 1,0116), (0,763157894737, 1,0231), (0,894736842105, 1,0347), (1,02631578947, 1,0462), (1,15789473684, 1,0636), (1,28947368421, 1,0723),

(1,42105263158, 1,0896), (1,55263157895, 1,1012), (1,68421052632, 1,1127), (1,81578947368, 1,1243), (1,94736842105, 1,1387), (2,07894736842, 1,1503), (2,21052631579, 1,1676), (2,34210526316, 1,1879), (2,47368421053, 1,2110), (2,60526315789, 1,2399), (2,73684210526, 1,3208), (2,86842105263, 1,4191), (3,000, 1,5000)

UNITS: dmnl

DOCUMENT: Nominal GDP growth impacts loan demand positively. When the economy is growing, businesses may have increased investment opportunities, leading to a higher demand for loans to finance expansion, capital expenditures, and working capital needs. Similarly, individuals may have higher incomes and increased confidence in their financial prospects, leading to greater loan demand for purposes.

In our case, the effect of GDP growth on Loan demand is represented as a graphical function, and it was established manually.

effect_of_LIR_on_Loans`_demand = GRAPH(LIR/HISTORY(LIR; TIME-1))

Points: (0,300, 1,5000), (0,420, 1,3422), (0,540, 1,2329), (0,660, 1,1358), (0,780, 1,0468), (0,900, 0,9618), (1,020, 0,9133), (1,140, 0,8728), (1,260, 0,8243), (1,380, 0,8040), (1,500, 0,8000)

UNITS: dmnl

DOCUMENT: The loan interest rate has a significant impact on loan demand. Generally, there is an inverse relationship between loan interest rates and loan demand. When interest rates are high, loan demand tends to decrease, and when interest rates are low, loan demand typically increases.

In our case, the effect of LIR on Loan demand is represented as a graphical function, and it was established manually.

fraction_of_deposits_to_reserves = IF TIME < 2023 THEN 0,05 ELSE 0,15

UNITS: dmnl

DOCUMENT: The fraction of deposits that banks are required to hold in reserves is determined by the reserve ratio set by the regulatory authority, typically the central bank. The reserve ratio represents the percentage of deposits that banks must hold as reserves.

Before 2023, it was equal to 5% on average, and later it was increased to 15% on average. The data is given from the website of the NBU, where they publish the statistics.

fraction_of_loans_to_reserves = GRAPH(TIME)

Points: (2016,000, 0,3), (2017,000, 0,45), (2018,000, 0,5), (2019,000, 0,5), (2020,000, 0,4), (2021,000, 0,3), (2022,000, 0,25), (2023,000, 0,3)

UNITS: dmnl

DOCUMENT: The fraction of loans to reserve depends on each asset depending on the creditworthiness of the borrower and the associated risks. Based on this assessment, the bank sets aside a portion of its profits to establish loan loss reserves. The amount of reserves allocated for loans depends on factors such as historical loan loss experience, economic conditions, industry-specific risks, and individual borrower assessments.

It`s an exogenous variable, and the values were defined manually by comparing what value of reserves were formed from the loans.

historical_values_of_deposits = GRAPH(TIME)

Points: (2016,000, 843296599991,0), (2017,000, 881004148157), (2018,000, 932295000000,0), (2019,000, 957002000000,0), (2020,000, 1074184000000,0), (2021,000, 1352618000000,0), (2022,000, 1510280000000,0), (2023,000, 1829536000000,0)

UNITS: UAH

DOCUMENT: This variable represents the historical values of deposits, and data is taken from the official website of the NBU.

historical_values_of_DIR = GRAPH(TIME)

Points: (2014,000, 17,24), (2015,000, 20,47), (2016,000, 20,93), (2017,000, 17,74), (2018,000, 14,33), (2019,000, 16,08), (2020,000, 15,18), (2021,000, 8,78), (2022,000, 8,98), (2023,000, 13,43)

UNITS: %

DOCUMENT: This variable represents the historical values of the deposit interest rate, and data is taken from the official website of the NBU.

historical_values_of_IIR = GRAPH(TIME)

Points: (2014,000, 7,15), (2015,000, 15,57), (2016,000, 25,22), (2017,000, 17,36), (2018,000, 15,92), (2019,000, 19,22), (2020,000, 18,35), (2021,000, 7,89), (2022,000, 7,67), (2023,000, 19,8)

UNITS: %

DOCUMENT: This variable represents the historical values of interbank interest rates, and data is taken from the official website of the NBU.

historical_values_of_LIR = GRAPH(TIME)

Points: (2014,000, 14,1), (2015,000, 15,1), (2016,000, 17,5), (2017,000, 14,9), (2018,000, 15,8), (2019,000, 17,4), (2020,000, 14,9), (2021,000, 12,0), (2022,000, 12,9), (2023,000, 19,6)

UNITS: %

DOCUMENT: This variable represents the historical values of lending interest rates, and data is taken from the official website of the NBU.

historical_values_of_loans = GRAPH(TIME)

Points: (2016,000, 1009768000000,0), (2017,000, 1005923000000,0), (2018,000, 1036745000000,0), (2019,000, 1118860000000,0), (2020,000, 1033430000000,0), (2021,000, 960597000000,0), (2022,000, 1065347000000,0), (2023,000, 1036129000000,0)

UNITS: UAH

DOCUMENT: This variable represents the historical values of loans, and data is taken from the official website of the NBU.

historical_values_of_reserves = GRAPH(TIME)

Points: (2016,000, 321303000000,0), (2017,000, 484383000000,0), (2018,000, 511062000000,0), (2019,000, 556445000000,0), (2020,000, 492229000000,0), (2021,000, 388477000000,0), (2022,000, 308349000000,0), (2023,000, 368091000000,0)

UNITS: UAH

DOCUMENT: This variable represents the historical values of reserves, and data is taken from the official website of the NBU.

indicated_deposits = (11,35-0,01*DIR-0,02*IEC.average_inflation_expectations-0,39*(Reserves)-1,11*(HD.Personal_Saving)+1,47*(HISTORY(Deposits; TIME-1)))

UNITS: UAH

DOCUMENT: The indicated deposits refer to a sum of deposits that the banking system should attract. It serves as a preliminary or estimated amount of money that the bank will account for as its assets.

It`s defined as a linear regression equation using E.Views, and it depends on the DIR, deposits in the previous period, inflation expectations, personal savings, and reserves.

indicated_DIR = -11,7+0,65*HISTORY(DIR; TIME-1)+1,03*LIR

UNITS: %

DOCUMENT: The indicated loan interest rate (DIR) refers to a rate that banks should set on deposits. It serves as a preliminary or estimated rate that gives lenders an idea of the potential interest they may be charged on a deposit.

It`s defined as a linear regression equation using E.Views, and it depends on the DIR in the previous period and the LIR.

indicated_LIR = 17,06+0,41*IIR-0,55*HISTORY(LIR; TIME-1)

UNITS: %

DOCUMENT: The indicated loan interest rate (LIR) refers to a rate that banks should set on loans. It serves as a preliminary or estimated rate that gives lenders an idea of the potential interest they may be charged on a loan.

It`s defined as a linear regression equation using E.Views, and it depends on the LIR in the previous period and the IIR.

initial_demand_of_loans = 1009768000000,0

UNITS: UAH

DOCUMENT: The initial demand for loans refers to the initial desire or need of borrowers to obtain loans from financial institutions or lenders. It represents the aggregate or collective demand for loans at the beginning or early stages of the borrowing process.

In our case, it is the value of loans at the end of 2015.

loans_reserves = Loans*fraction_of_loans_to_reserves

UNITS: UAH

DOCUMENT: Loan reserves refer to the funds set aside by banks to cover potential losses arising from loan defaults or other credit-related risks. They contribute to the overall stability of the banking system and enhance the accuracy and transparency of financial reporting by reflecting the inherent risks associated with lending activities.

They are defined as the product of loans and a fraction of loans that go to reserves.

time_adj_of_deposits = 1

UNITS: year

DOCUMENT: The time to adjust loans refers to the time it is necessary for the banks to react to the new demand to them.

In our case, it`s 1 year. This value was derived from the manual calibration.

time_adj_of_reserves = 0,25

UNITS: year

DOCUMENT: The time to adjust reserves refers to the time it is necessary for the banks to react to the new reserves to them.

In our case, it`s 0,25 years or 3 months. This value was derived from the manual calibration.

time_to_adj_loans = 1

UNITS: year

DOCUMENT: The time to adjust loans refers to the time it is necessary for the banks to react to the new demand to them.

In our case, it`s 1 year. This value was derived from the manual calibration.

time_to_adjust_IIR = 0,4

UNITS: year

DOCUMENT: The time to adjust IIR refers to the time it is necessary for the interbank market to react to the new value of the key policy rate.

In our case, it`s 0,4 years or almost 5 months. This value was derived from manual partial testing.

time_to_change_DIR = 0,25

UNITS: year

DOCUMENT: The time to adjust DIR refers to the time it is necessary for the bank to react to the new value of the DIR.

In our case, it`s 0,25 years or 3 months. This value was derived from the manual calibration.

time_to_change_LIR = 0,25

UNITS: year

DOCUMENT: The time to adjust LIR refers to the time it is necessary for the bank to react to the new value of the IIR.

In our case, it`s 0,25 years or 3 months. This value was derived from the manual calibration.

war_shock_on_LIR = IF TIME > 2022 THEN 10 ELSE 0

UNITS: %/year

DOCUMENT: War shock on LIR represents how banks reacted to the full-scale invasion. According to the real data observations, they increased their loan interest rate significantly. It might be connected with increased credit risk, economic instability, market uncertainty, etc.

It has increased by 10 p.p. within 1 year.