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INTRODUCTION

Price stability is crucial for sustained long-term economic development of any country. In modern mainstream macroeconomics price stability is most often interpreted as a steady growth of the general price level. Though this condition is highly preferable, the actual price dynamics are often not so stable and predictable, especially in developing countries.

To ensure price stability central banks in most countries conduct active monetary policy. However, the specific design of monetary policy differs greatly from country to country. In the last decades, inflation-targeting as a monetary policy framework has grown greatly in popularity. It is a dominant monetary policy framework in major world economies like the US, Japan, and the UK. Interestingly, since 2021 numerous economies employing inflation-targeting have found themselves in a situation of severely elevated inflation compared to their targets. Failures to achieve the announced targets has raised concerns about the validity of such a monetary policy framework.

The National Bank of Ukraine has switched to inflation-targeting in 2015 with the hope that it would be beneficial for faster overcoming of the aftermath of the economic, banking, and currency crises. Since the beginning of the full-scale russian invasion, the NBU has been constantly communicating its commitment to inflation-targeting combined with some extra measures needed to stabilize the foreign exchange market and banking system. At the same time, the successfulness of inflation-targeting depends greatly on the strength of the links between monetary policy instruments and the real economy. The importance of these links for an adequate macroeconomic environment constitutes **the relevance of this research topic.**

The purpose of our research is to evaluate the successfulness of implementation of inflation-targeting in Ukraine since 2015. For this purpose, we have identified the following **research tasks:**

1. Review modern literature on features and prerequisites of inflation-targeting and on monetary transmission mechanism;
2. Assess the compliance of the economy of Ukraine with the prerequisites for inflation-targeting;
3. Compare inflation in Ukraine and peer countries, and identify the probable explanations for possible divergences;
4. Conduct statistical assessment of the first stage of monetary transmission (interest rates, financial market rates, foreign exchange market);
5. Conduct statistical assessment of the second stage of monetary transmission with a focus on interest rate, exchange rate, and inflation expectations channels;
6. Based on literature review develop a dynamic hypothesis and explanatory model for a small open economy with a central bank employing inflation-targeting, fixed exchange rate, or both of them;
7. Calibrate the model for the case of Ukraine based on the up-to-date literature and the results of statistical evaluation of the monetary transmission in Ukraine;
8. Perform model validation, identify to which parameters the model output is the most sensitive under chosen monetary policy regimes and what are the most promising directions for further research;
9. Propose recommendations for the improvement of monetary policy in Ukraine.

The object of this research is monetary policy in Ukraine, while **the subject of this research** is implementation of inflation-targeting and the challenges that monetary policy practitioners encounter while ensuring its effectiveness.

Among the key **methods of this study**, we should mention the following ones: analysis and synthesis of scientific research on inflation-targeting and monetary transmission mechanism, statistical analysis (correlation, regression) of the strength of the monetary transmission in Ukraine, panel regression with robust least squares (for simultaneous evaluation of the relative strength of monetary transmission channels in the context of industrial and consumer inflation), and system dynamics method for the development of an

explanatory model of monetary policy effects in a small open economy and policy testing with a focus on a choice of a monetary policy framework.

The information basis of this research comprises mainly of the working papers of the NBU, Bank of Canada, Bank of England, National Bank of Poland, Reserve Bank of New Zealand, the Central Bank of Turkey, and IMF, scientific papers of monetary policy theorist and practitioners (from US Fed, ECB, and other central banks), and of chief economists, data from the State Statistics Service of Ukraine, National Bank of Ukraine, and the World Bank, and the law of Ukraine on the National bank of Ukraine.

The results of this study have **practical significance** in the context of improving understanding about the strength and specific features of monetary transmission in Ukraine. Moreover, the results provide an alternative view on the long-term effect of monetary policy and international flows of goods, services, and capital on price stability in a country.

The research provides a systematic evaluation of a monetary transmission mechanism in Ukraine based on up-to-date data and implement the current mainstream macroeconomic theory into a system dynamics model that could be used by fellow researchers for policy testing. This constitutes the **scientific novelty** of the study.

This thesis has the following structure: 3 chapters, placed on 81 pages, conclusions, and a list of references used. The study contains 44 figures, 17 tables, 5 appendices.

CHAPTER 1

THEORETICAL FOUNDARIONS AND PRACTICAL FEATURES OF INFLATION-TARGETING

1.1 Features and prerequisites of inflation-targeting

Inflation targeting (IT) is currently one of the most popular monetary policy frameworks in both advanced and emerging economies [1]. As of 2022, more than 70 central banks around the world [2] have adopted it in some form, including the US Federal Reserve System, the ECB, the Bank of Japan, and the Bank of England.

IMF defines the inflation targeting framework the following way: “[IT] involves the public announcement of medium-term numerical targets for inflation, with an institutional commitment by the monetary authority to achieve these targets” [3]. As can be seen, from the definition, inflation-targeting has a simple and straightforward idea at its core: stirring inflation to the publicly announced goal with the means accessible to the central bank. However, the simplicity of the definition leads to frequent debates about the de jure and de facto adoption of the inflation-targeting framework by a central bank. The commonly recognized features of inflation-targeting are the following [1;4;5]:

- public announcement of a quantitative inflation target;
- price stability is explicitly recognized as the main and overriding goal of monetary policy (there should be an official commitment);
- increased communication with the public and the markets about the plans and objectives of monetary authority;
- increased accountability of the central bank for attaining its inflation objectives;
- inflation forecast is used as the main intermediate target

An official announcement of an unambiguous quantitative inflation target is required as such a target serves at least three goals. Firstly, it is meant to stabilize inflation expectations around a specific and commonly known figure. Secondly, it serves as a

benchmark for the evaluation of the performance of the central bank's actions. Lastly, it assists in refocusing of public's attention on price level from other measures of national currency value, e.g. nominal exchange rate, which is particularly important for emerging countries adopting inflation-targeting.

An inflation target is usually announced for the medium-term time frame. This is done intentionally to avoid the necessity to achieve an inflation target all the time, i.e. even in the short-term period. The latter could be harmful to the sustained development of an economy, as quite often prices grow faster or slower due to unforeseeable demand- and supply-side shocks. Such shocks, which are inevitable in their nature, make the goal of achieving an inflation target all the time both unattainable (as monetary policy actions almost always affect prices with a lag), and counterproductive (as too frequent and abrupt changes in monetary policy may further destabilize actual inflation and inflation expectations). The length of "medium-term" is rarely defined quantitatively by central banks, though some authors assume that it encompasses a horizon of around 2-3 years [6]. But the idea is that in the medium term, the above-mentioned shocks are offset primarily by the structural changes in an economic system [7]. While the inflation rate approaches its target as a result of the sustained development of an economy assisted with appropriate monetary conditions.

An inflation target is most commonly set as a point with an interval of possible divergences [5]. The point serves as a specific measure of an average change in the value of national currency over a longer time period, while an interval forms a range of comfortable fluctuations of the inflation rate, i.e. the range where no monetary policy response actions are required.

Official recognition of price stability as the highest priority goal of monetary policy is crucial to the implementation of inflation targeting. Price stability is obtained "when economic agents no longer take account of the prospective change in the general price level in their economic decision making" [8]. Importantly, a central bank that chooses to conduct its monetary policy following an inflation-targeting framework needs not only to announce its formal commitment to achieving and sustaining the rate of inflation that agrees with the

abovementioned definition of price stability but is also responsible for active actions of proving to the public that inflation target takes precedence in monetary policy decision-making. This is important as the success of inflation targeting depends heavily on the level of trust of the public and financial market players in the central bank.

Particularly for the aforementioned reason, inflation targeting requires increased communication with the public and the markets about the plans and objectives of monetary policy. Also, this increases awareness of the general public about price developments and their drivers. More importantly, increased communication makes the central bank's decisions more predictable, removing an additional source of uncertainty for economic agents.

Increased accountability of the central bank is meant to build the trust of the economic agents in a central bank's ability to achieve its announced goals. The declared numerical target for the inflation rate compared with the actual inflation serves as a simple way of evaluating monetary policy's successfulness which is transparent and comprehensible to any citizen. This is in contrast to another monetary policy framework, namely monetary aggregate targeting. The latter uses more complex concepts for targeting which hinders assessment of and therefore trust in monetary policy.

Svensson [9] and other authors in the last decades provided substantial arguments that "the best possible intermediate target is the current forecast of the goal itself". That is why inflation forecast is commonly used by inflation-targeting central banks as an operational goal of monetary policy. Moreover, such forecasts provide a sense of the expected trajectory for inflation over the coming time periods and constitute an important part of a central bank's communication to the general public about the foreseeable future and its planned actions.

Historically, an inflation-targeting framework was first adopted by economies that had already been advanced and had sound financial systems and credible central banks (e.g. New Zealand, Canada, United Kingdom [10]). And it was considered that such a framework had not been suited for emerging market countries due to numerous reasons [11;12], the most important of which constitute four groups:

- Institutional independence;
- Technical infrastructure;
- Financial system health;
- Economic structure.

Institutional independence incorporates primarily four elements:

1. Monetary policy needs to be independent, especially from the executive branches of state power [11]. This is needed in order to avoid the monetization of government debt and prevent statesmen who hold elective positions in the government from using their power to affect monetary policy and the business cycle in order to gain advantages during elections. The formal independence of a central bank is usually achieved by making it a separate institution with its own resources and legal authorities and excluding direct subordination of central bankers from any other body within the state.
2. Instrument independence. A central bank needs not only to be independent in making decisions about the current policy but in its choice of instruments used for achieving the announced goals. Deballe and Fischer [13] made a clear distinction between goal independence and instrument independence, while IMF [10] mentioned that the latter is the most important criterion for central bank independence, while the former is rare, as goals for monetary policy are typically determined by the elected government.
3. Security of employment for a governor and/or members of a board of governors of a central bank. It is particularly important that the tenures of key central bank policymakers exceed the tenure of elected statesmen who often are authorized for appointing them. Also, it is necessary that governors could not be fired without a substantial cause.
4. Freedom from commitment to another nominal anchor like the exchange rate or wages [12]. A central bank is highly unlikely to achieve several targets simultaneously, as it will most probably create antagonism in the operational design of monetary policy, e.g. fixed exchange rate makes the exchange rate channel of the monetary transmission mechanism inactive which makes it less likely that changes in the key policy rate will stir inflation

closer to the forecasted trajectory. That is why, if a central bank is committed to targeting inflation, it should be prohibited from targeting any other nominal indicator.

Technical infrastructure prerequisites include the following:

1. A central bank has adequate forecasting capabilities (i.e. a structural model of an economy) and its staff is able to use them to make macroeconomic “forecasts conditional on different assumptions for the monetary policy instrument” [10]. This is needed for two purposes: 1) to make reliable inflation forecasts that will serve as an operational target for monetary policy; 2) to link monetary policy instruments with its goals, to improve the understanding of the underlying mechanism of the monetary policy, build confidence in the central bank’s abilities to attain the announced goals, and most importantly make informed decisions.
2. A central bank has access to reliable and comprehensive data, needed for forecasting and substantiation of monetary policy decisions. And the lag in data collection is sufficiently small.
3. A central bank has “an operating procedure for adjusting monetary instruments” [12] and is able to conduct macroeconomic forecasting on a regular basis.

Financial system health prerequisites consist primarily of two main elements:

1. A sound banking system. This means that banks attract deposits from and provide loans to households and corporations, and have sufficient sources of own funding to sustain their operations. This is an important prerequisite as it directly influences the effectiveness of the main central bank’s instruments.
2. Developed stock and bond markets. This means that there should be a fairly extensive volume of financial operations designed for the redistribution of financial resources within a state. This precondition further strengthens the central bank’s ability to attain its announced inflation goals as it magnifies [14] the effects of changes in its key instruments.

Economic structure prerequisites are even harder to satisfy as they typically correspond to fairly rigid structural characteristics of an economy:

1. Low sensitivity of domestic prices and nominal exchange rate of a national currency to swings of commodity prices. This condition greatly simplifies the task of reaching an inflation target for a central bank.
2. Financial dollarization is minimized. A high level of financial dollarization imposes significant limitations on the efficacy of a central bank's key instruments as economic agents choose to conduct their business in a currency other than a national one.
3. Minor exchange rate pass-through into prices. This condition is usually stated for a so-called "fear of floating" [15], i.e. reluctance of a central bank to allow significant exchange rate changes so as to prevent high volatility of inflation and output. If an economy is characterized by a lower exchange rate pass-through, its central bank would be more prone to let a national currency float freely and conduct "classical" inflation-targeting.
4. Administered prices are either non-existent or their share in price indices is minimized. Inflation-targeting relies heavily on market forces in the attainment of its goals, which is why state-administered prices hinder its proper functioning.

Even though the above-mentioned prerequisites do help a central bank in the effective implementation of inflation targeting, most of them either could be achieved after the formal adoption of inflation targeting as a monetary policy framework. And there is a growing body of literature proving that the central bank's commitment to such a monetary framework speeds up structural and institutional changes in an economy so that it faster moves to the attainment of the aforementioned preconditions [10]. For example:

- exchange rate pass-through decreases after the adoption of IT [16], though some researchers argue that there is "little indication that inflation-targeting countries have lower pass-throughs" [17];
- high dollarization does not preclude the use of inflation-targeting as a policy rule [18], while inflation targeting has significant treatment effects on lowering actual financial dollarization [19];

- inflation targeting framework assists in a better macroeconomic performance of commodity-exporting economies [20;1].

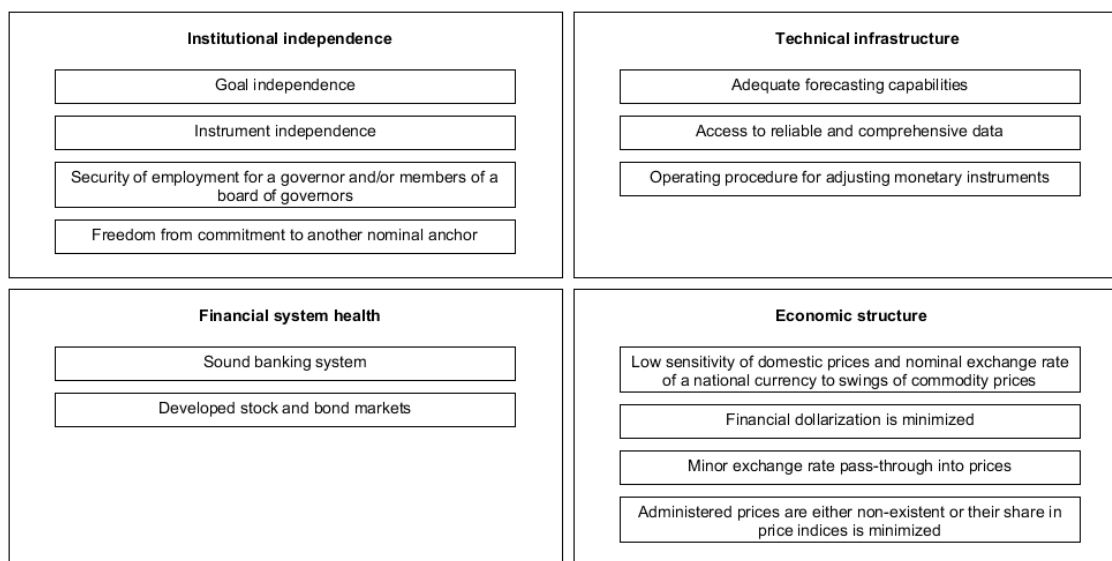


Figure 1.1 – Prerequisites for successful implementation of inflation-targeting

Source: developed by the author based on [10]

Figure 1.1 Summarizes key features that an economy is expected to have to have high chances of conducting inflation-targeting successfully.

1.2 Foundations of the monetary transmission mechanism

The monetary policy transmission mechanism is the heart of inflation targeting. This mechanism captures all the effects that arise in the economy due to monetary policy actions.

There is extensive literature about monetary policy transmission mechanism, concerning both its theoretical foundations and empirical assessment. Conceptually, researchers identify four core channels of monetary policy transmission mechanism: interest rate, exchange rate, asset price, and credit channels [22;23]. However, some authors offer more detailed classifications, like [24]. Most of the classification approaches are built either on the type of prices (money, national currency, equity) or on the type of spending that constitutes GDP (consumption, investment, net export). Also, different schools in

macroeconomic literature have distinctive approaches to the interpretation of processes behind the transmission. In this section, we will focus mostly on the ideas inherent to mainstream macroeconomic theory, and also will pay more attention to the channels present in Ukraine.

The interest rate channel. As a central bank raises its key policy rate and rates on its main operations (i.e. providing short-term loans and taking short-term deposits from commercial banks), the cost of short-term financing increases for commercial banks. As a result, commercial banks are nudged to increase the interest rates on their operations. Otherwise, they might face interest rate mismatches, inadequate capital structure, and losses in market share and/or revenue. Higher bank interest rates lead both to a decrease in investment (fewer projects will provide returns sufficient to cover the increased cost of borrowing) and consumer spending (households will be less eager to borrow for buying durable goods). As a result, aggregate demand drops which motivates firms to lower their prices in order to sell their products.

Also, the increase in the cost of short-term financing leads to an increase in expected returns from publicly traded bonds, especially in countries where commercial banks are key market players in the bond market as it is in Ukraine. As a result, the interest rates on new bond issues increase which inhibits new investments and government spendings.

The exchange rate channel. As described by [25], the exchange rate channel relies on the assumption that yields on assets in different currencies must be equal after taking into account the deviations imposed by the differences in the risk premium and the expected change in the exchange rate. Essentially, this channel works the following way: after an increase in the key policy rate and consequent increase in interest rates on publicly traded investment instruments, foreign investors (and domestic investors who hold assets in foreign currency) are nudged to invest more in the national currency as such an investment after the increase in market rates generates the return that is higher than on other investment of the same risk, which are nominated in other currencies. As a result of increased demand for national currency, it appreciates and affects net exports through deteriorating price

competitiveness of domestic companies in the international market as they bear production costs nominated in the national currency and receive payments for their products in foreign currency.

The asset prices channel. This channel heavily relies on the proper functioning of stock, bond, and real estate markets. An increase in the key policy rate through an increase in required yields on traded bonds leads to a decrease in bond prices, which is also associated with capital outflow from stock market as investors become more willing to invest in bonds. At the same time, the required returns on mortgages increase, which leads to a drop in prices for underlying real estate. As a result, households and corporations face a decrease in the net value of their holdings which makes them thriftier. Consequently, aggregate demand decreases and so do prices. Moreover, the drop in the value of most publicly traded investment assets also means a reduction in value of collateral, which makes the credit terms tougher both for actual and potential borrowers.

The credit channel. The findings of institutional and behavioral economics have laid the foundations [26] for the credit channel. Conceptually, it builds on the assumption that during the tightening of monetary policy the external finance premium rises, especially for small and medium-sized borrowers, as banks and other lenders tend to trust such counterparties less due to imperfect information about their true financial position and outlook. As a result, not only the cost of borrowing rises, but also the volume of available credit funds decreases, which further decreases investments and demand for durable goods.

The expectations channel. This channel is mentioned in the literature less frequently compared to the previously mentioned ones as in developed market economics with a credible central bank its effectiveness is often taken for granted. And due to the fact that expectation channel effectiveness directly affects all other channels, researchers focus on them. But in a developing market that has a fairly short history of inflation-targeting, expectations channel is crucial as it defines whether the economic agents believe in monetary policy's ability to attain inflation goal. Consequently, it affects the yield curve, producer's price-setting decision-making, and households' intertemporal spending-saving choices.

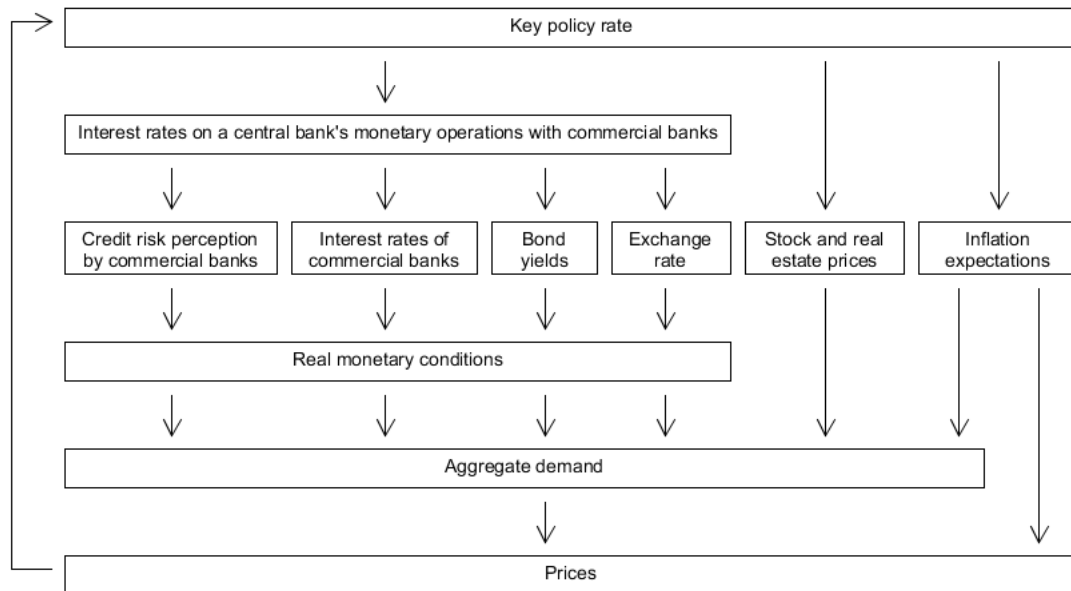


Figure 1.2 – Simplified version of the monetary transmission mechanism

Source: developed by the author based on [27]

The five above-mentioned channels are summarized in Figure 1.2 and represent key economic processes responsible for monetary policy effectiveness and we will devote most of the next sections of this research to the exploration of the peculiarities of their functioning in Ukraine.

1.3 The design of inflation-targeting in Ukraine

In this section, we will compare the design of the monetary policy regime in Ukraine to the previously discussed features of inflation-targeting, and also evaluate Ukraine's compliance with the prerequisites for the successful inflation targeting.

Since the adoption of Monetary Policy Strategy for 2016-2020 [28] in September 2015 Ukraine has been considered an inflation-targeting economy. According to that document, the National bank of Ukraine (the NBU) has announced the medium-term inflation objective of 5% for the annual increase in consumer price index. As shown in the paper on inflation-targeting implementation strategy [29], the chosen targeted inflation rate is substantiated by both national studies, like Petryk and Nikolaychuk [30], and international experience

(Gorodnichenko, 2014) [31]. The chosen rate is higher than in most developed economies and the reason for that is the expected convergence of productivity in Ukraine and developed economies of trading partners. For this convergence to happen, the level of wages and other prices needs to be allowed to increase faster. Moreover, the economic structure of Ukraine in 2015 was (and to a large extent still is) suboptimal with critically high dependence on imported energy and exported agriculture products and metals. The further economic development needs to be associated with structural shifts and for this reason the price dynamics need to be allowed a greater extent of volatility.

The transition to inflation-targeting in 2015 was accompanied with amendments to the Law “On the National Bank of Ukraine” that further highlighted that the fulfillment of the inflation objective is the top priority goal of the NBU. More importantly, as it is outlined in the Monetary Policy Strategy for 2016-2020, NBU has clearly communicated that it “will not tolerate any pressure and will not use monetary instruments for any goal which creates threat to price stability”. This claim has been substantiated by the increased role of the NBU’s Council in monetary policy supervision and through stronger reporting on NBU’s actions to the public and the Council of the NBU.

In practical terms, increase communication of NBU on monetary policy is achieved through:

1. Regular publication of Inflation report with inflation forecast that serve as an intermediate goal of monetary policy and, ideally, target for inflation expectations;
2. Monthly Macroeconomic and Monetary Review with up-to-date economic analysis with a focus on evaluation whether a previously published forecast is still relevant;
3. Monthly Inflation Update with explanation of the drivers behind price dynamics and its deviation from the expected developments of a previous Inflation Report;
4. Press conferences after policy decisions and publications of summary of Monetary Policy Committee discussions.

Since the beginning of a full-scale russian invasion, the NBU [32] has fixed the exchange rate, which is why the war-time monetary policy regime cannot be classified as classical inflation targeting.

For a deeper analysis of the prerequisites for the effective introduction of the inflation targeting regime, it is necessary to clarify the issues of financial system health and economic structure of Ukraine. As it was mentioned above, developed stock and bonds market are among crucial characteristics of a healthy financial system. In the case of Ukraine, stock market is still in its nascent stage. The proportion of market capitalization of listed domestic companies to nominal GDP has been less than 5% in 2016-2018 [33] compared with 33.0% in Türkiye, 29.6% in Poland, and 17.8% in Hungary in 2020 [34]. Stock market turnover (Figure 1.3) has also been depressed in the past decade as the market has been constantly experiencing the aftermaths of frequent and severe crises.

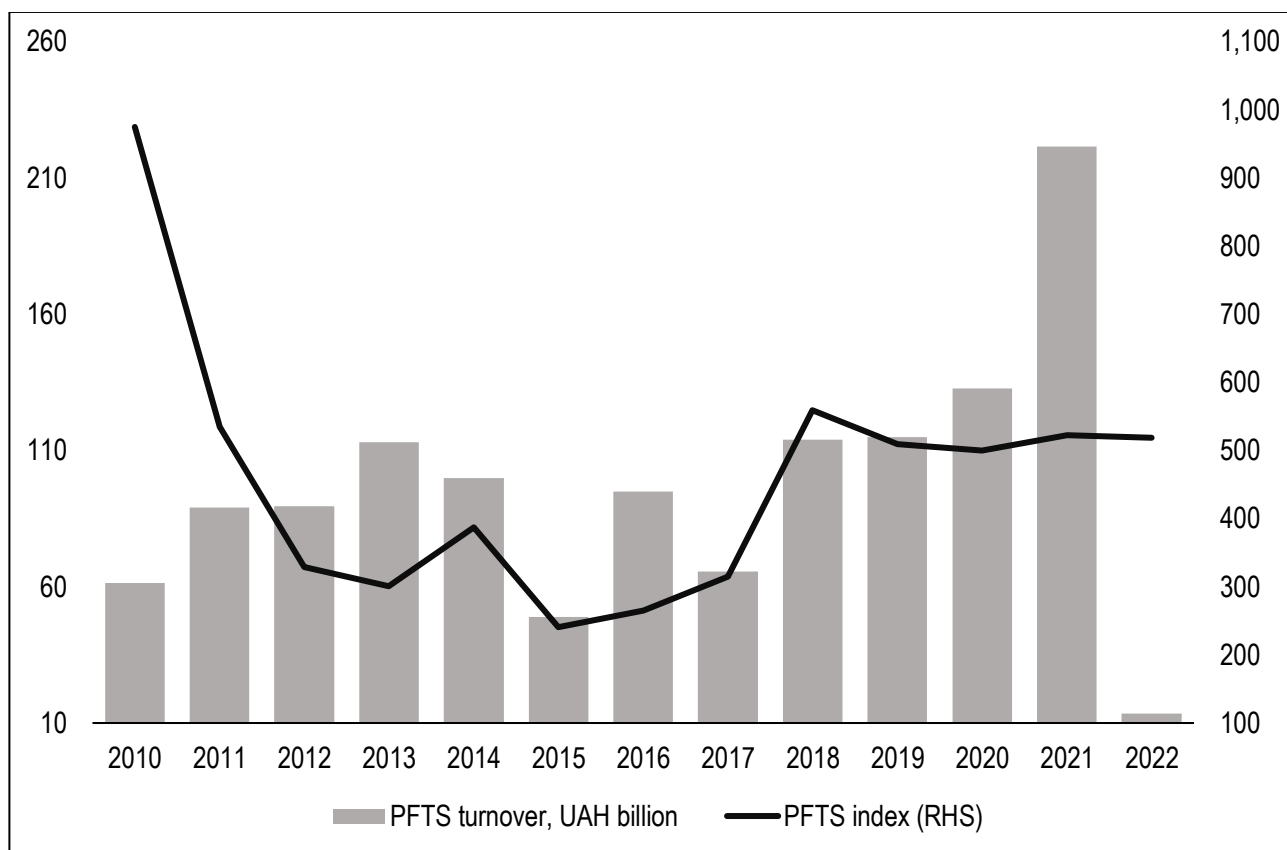


Figure 1.3 – PFTS Ukraine stock exchange turnover and index dynamics

Source: calculated by the author based on NBU data [35]

The development of this part of the financial market is restrained by insufficient number of businesses that are willing to go public under current regulatory conditions in Ukraine, more promising opportunities for raising equity capital in foreign stock exchanges, primarily Warsaw and London Stock Exchanges, and high vulnerability of Ukrainian financial system, particularly secondary capital markets, to external shocks.

Considering the bond market in Ukraine, it is developed to a greater extent compared to the stock market, but it is dominated by state issued financial instruments as there are few potential issuers with private ownership. Moreover, most of the issued bonds is held by the NBU and commercial banks (Figure 1.4), which is why there is clearly a lack of active market players present. In the last 4 years, the share of domestic government bonds that is held by non-residents has increased significantly which indicates a positive trend of integration of domestic bond market in global financial system.

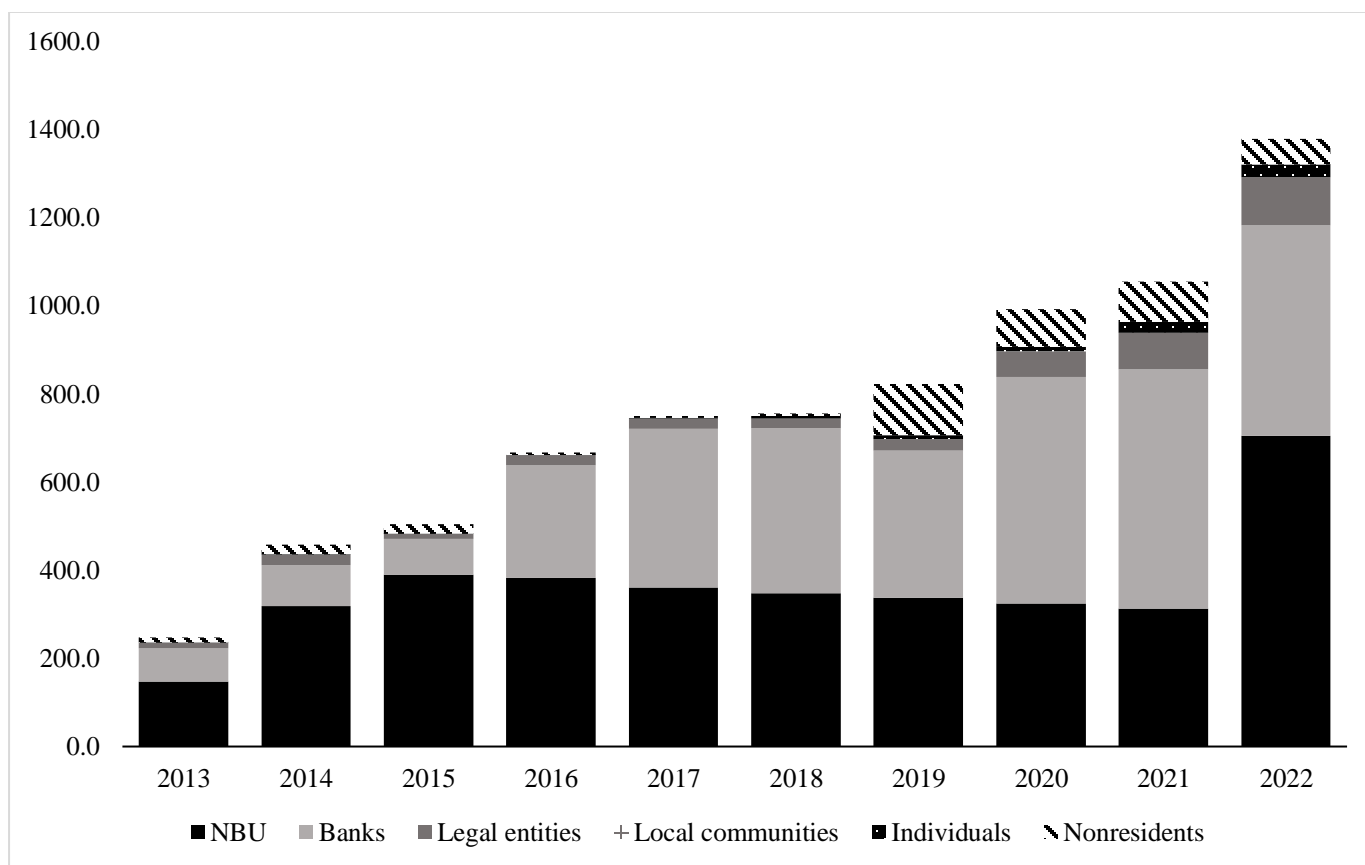


Figure 1.4 – Holders of domestic government bonds, UAH billion, nominal prices

Source: calculated by the author based on NBU data [35]

Still, there are concerns about the continuation of this trend after the victory of Ukraine as NBU is very cautious about lifting restrictions on international capital flows. For example, in late March 2023 it has been decided not to allow non-residents to repatriate abroad principal payments on government bonds [36].

Consumer set in Ukraine is formed predominantly by food and non-alcoholic beverages, housing and energy expenses, and transport costs (Figure 1.5). Food expenses has consistently constituted more than 40% of consumer set, which is higher than in Moldova, Romania, Poland, Hungary, and other comparable countries [37].

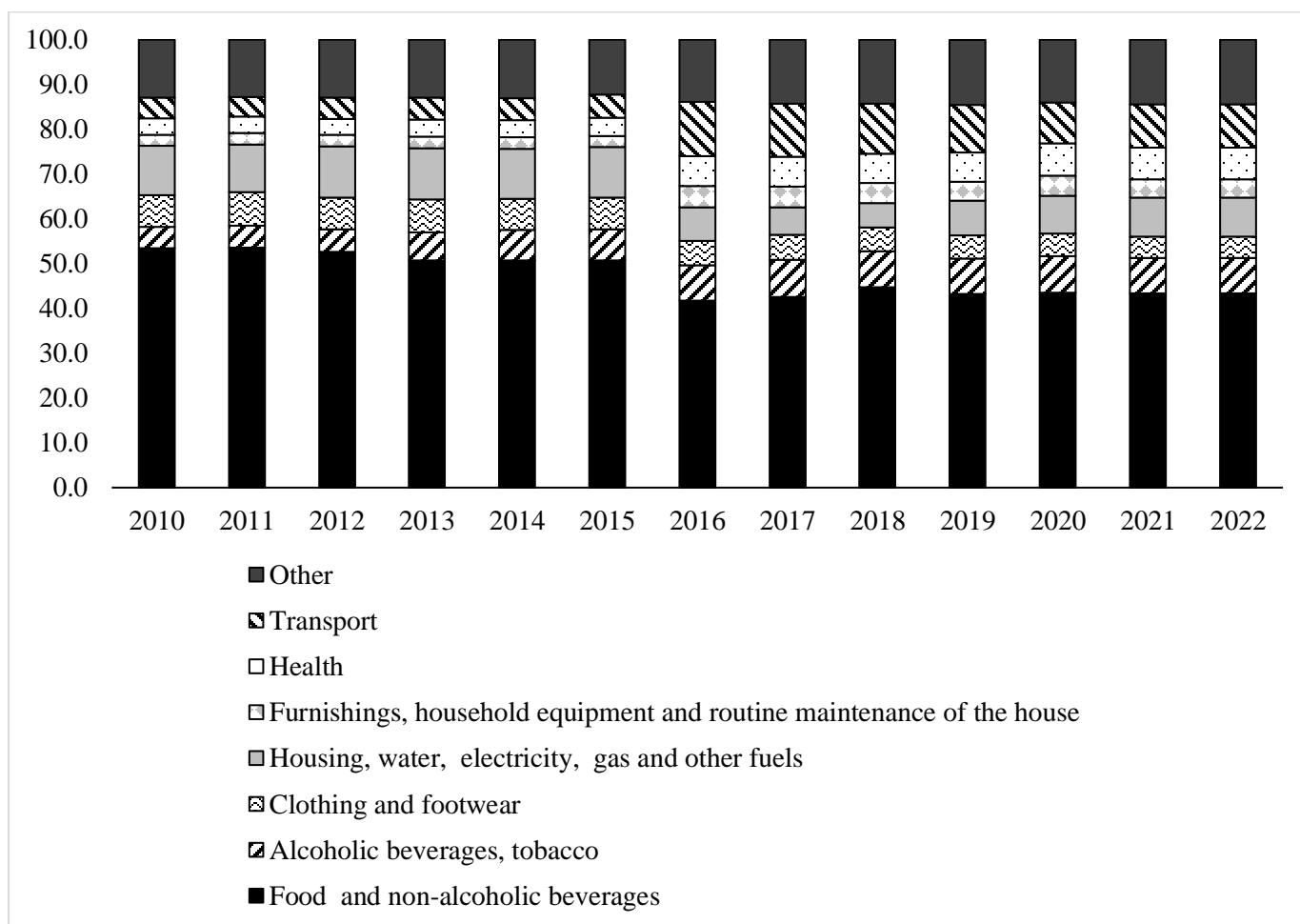


Figure 1.5 – Consumer set structure dynamics

Source: based on SSSU data [38]

Food prices tend to be more volatile which is why such a high proportion of these products in consumer set leads to a more volatile inflation in Ukraine compared with neighboring countries all else being equal. As we can also see on Figure 1.6 administrative

tariffs still amount to more than 20% of products in headline CPI and its proportion is not likely to decrease significantly soon driven by water, electricity, and gas prices, and transportation, alcohol, and tobacco products.

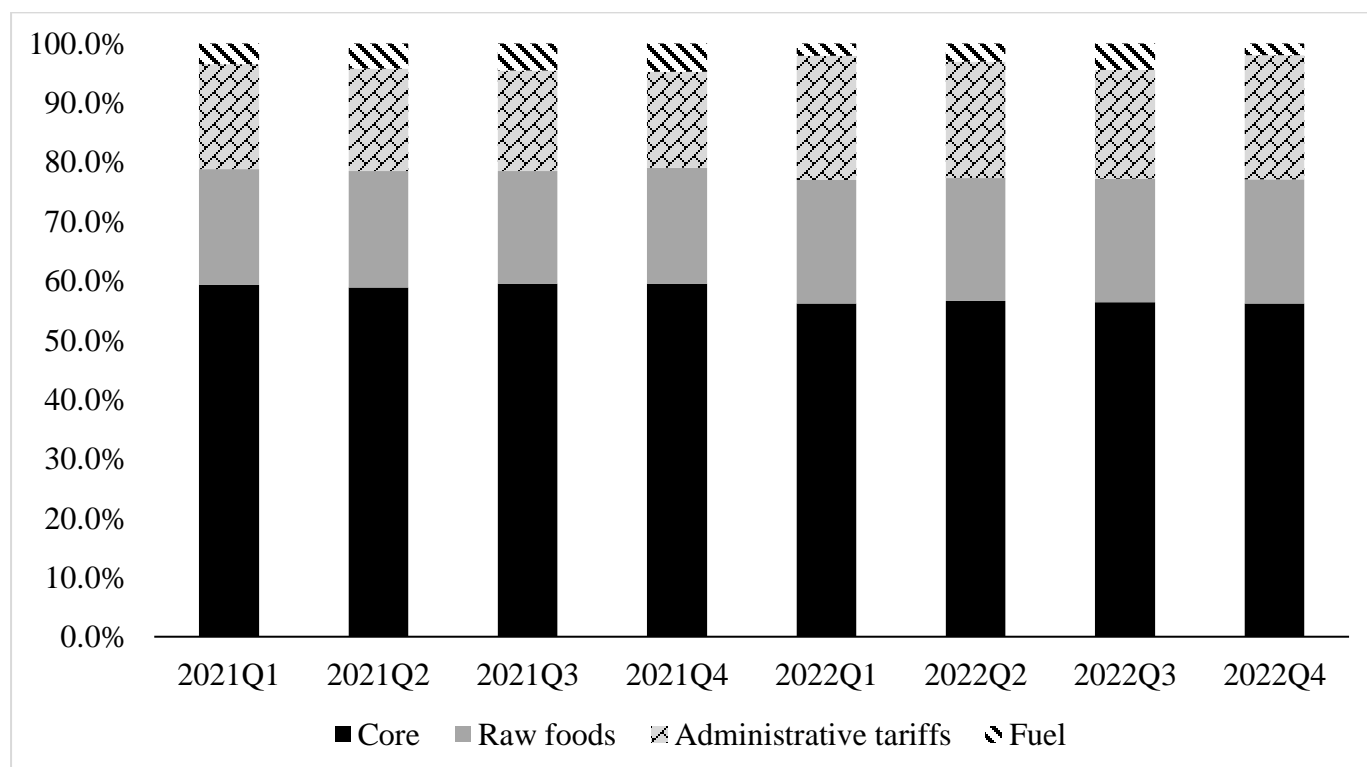


Figure 1.6 – Weights of headline CPI components in 2021-2022

Source: calculated by the author based on [39]

About the extent of financial dollarization, a proportion of foreign currency deposits in total deposits of banking system of Ukraine is significantly higher (Figure 1.7) compared with the natural level of deposits dollarization which is around 20% [40]. Moreover, there are estimates that households held around \$107 billion [41] in cash in 2022Q3, which is more than 50% of GDP in 2021 [42]. A high proportion of savings in foreign currency hinders the influence of interest rate transmission channel and makes the exchange rate channel highly significant as economic agents react actively to exchange rate swings.

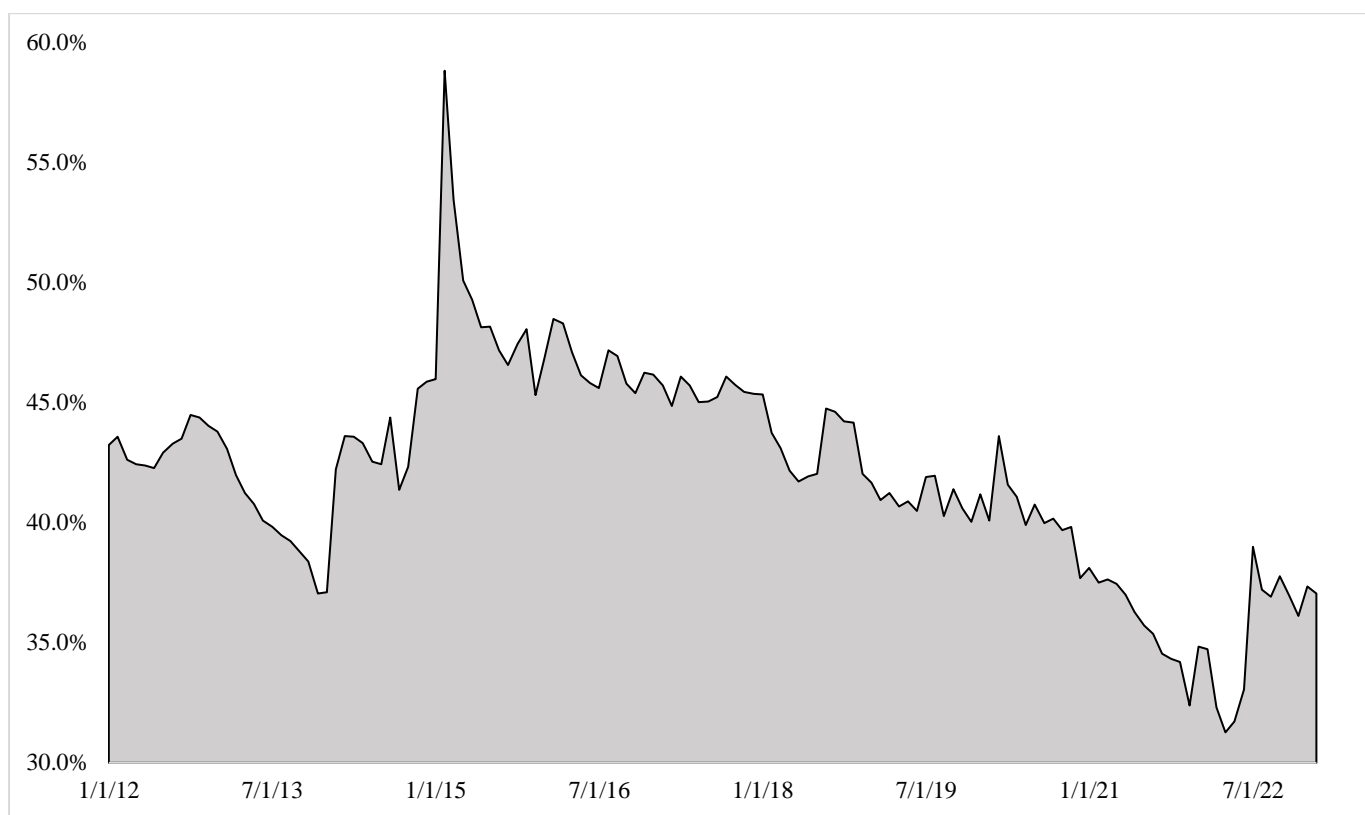


Figure 1.7 – Dynamics of the proportion of foreign currency deposits in total deposits of banking system of Ukraine

Source: calculated by the author based on NBU data [35]

Ukrainian economy sensitivity to international commodities markets is defined by steadily high proportion of agricultural and mineral products in its export and import of goods. Furthermore, since the beginning of the full-scale Russian invasion of Ukraine the share of agricultural merchandise in exports has increased even further (Figure 1.8) as ferrous and nonferrous metals export decreased due to a loss of metallurgy facilities in southern and eastern parts of Ukraine.

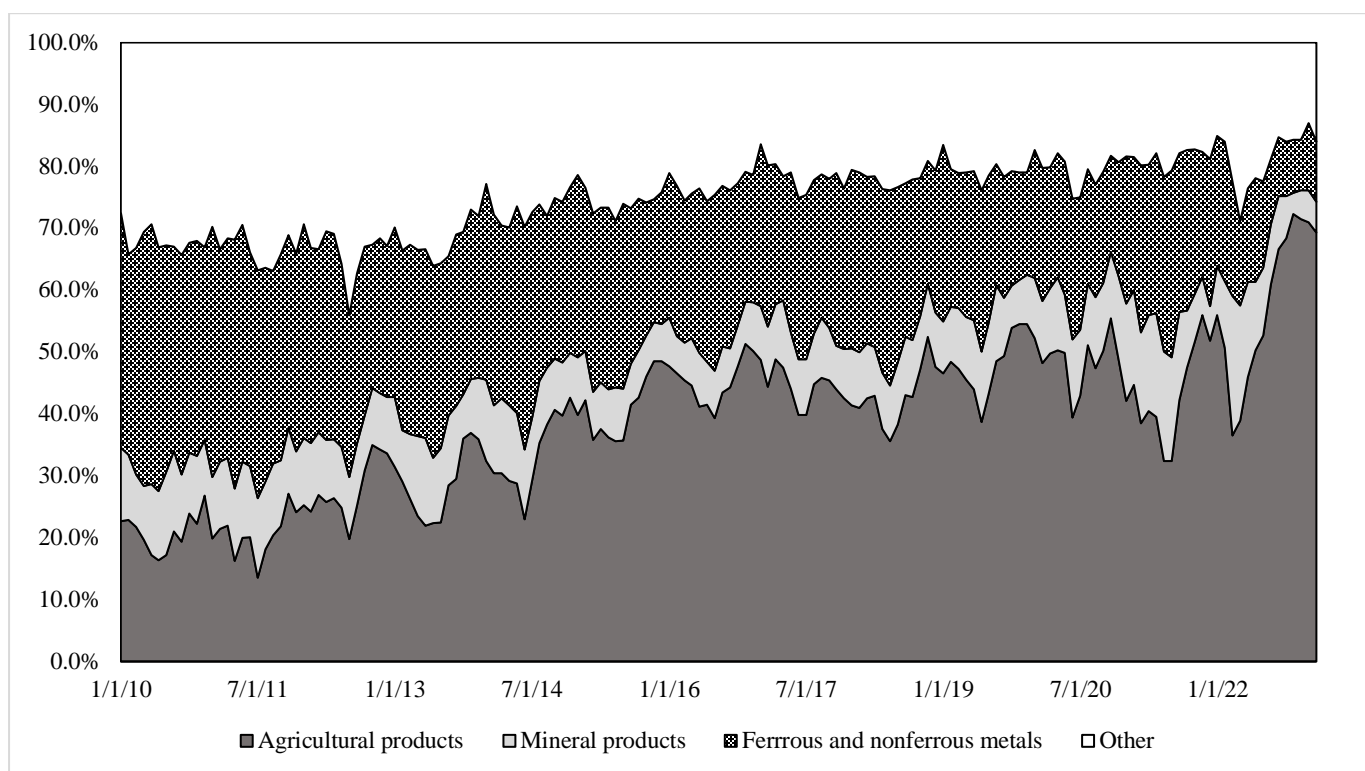


Figure 1.8 – Exports of goods by the product category

Source: calculated by the author based on NBU data [35]

At the same time, mineral products, particularly energy sources, still amount to more than 20% of merchandise imports (Figure 1.9). That makes hryvnia exchange rate and actual fuels costs highly sensitive to price movements in the world energy market.

Considering the exchange rate pass-through, empirical studies on the developed economies clearly indicate that before the global financial crisis consumer prices were almost neutral to local currency depreciation [43]. After the crisis, there are findings that pass-through rates in advanced economies have remained low and stable [44]. Also, evidence proves that pass-through rates in emerging economies are also declining during the periods of low prices volatility. In the cast of Ukraine, studies [45] show that exchange rate pass-through is substantial for small and large exchange rate movements, while it is insignificant for moderate changes.

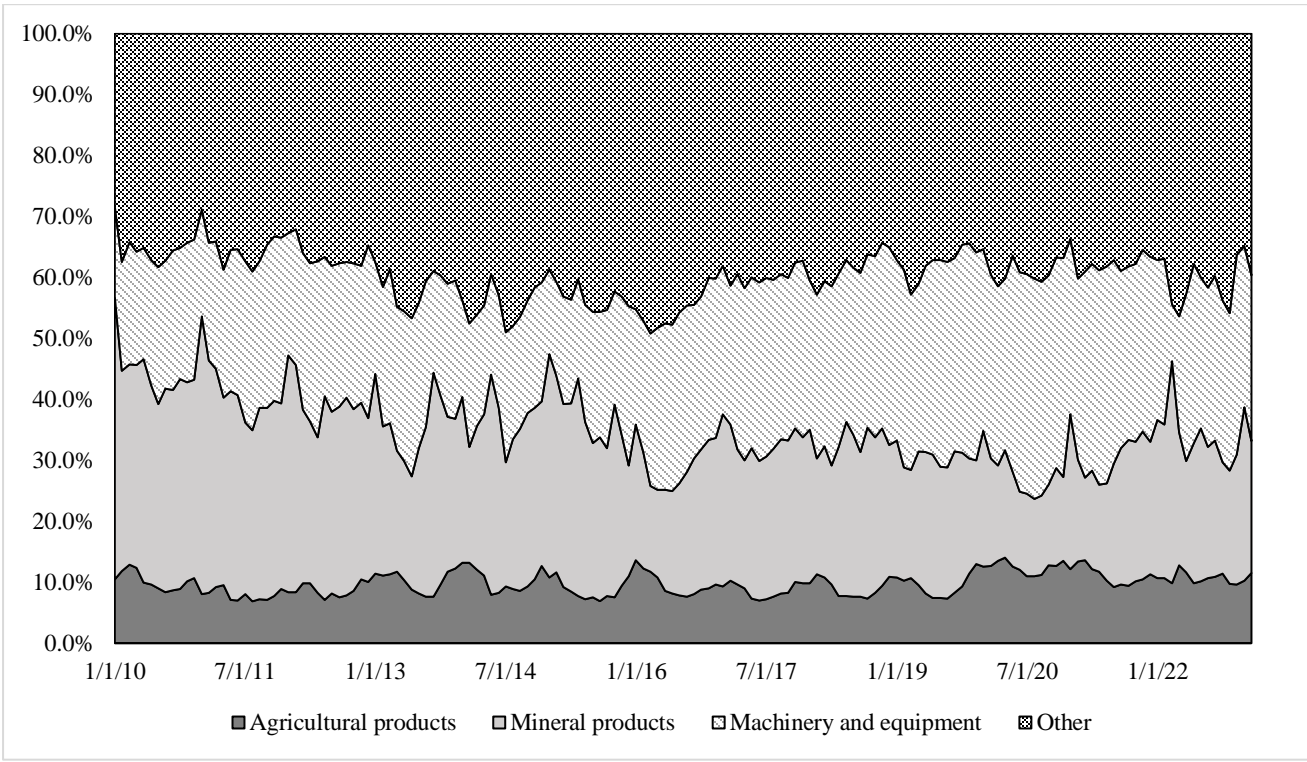


Figure 1.9 – Imports of goods by the product category

Source: calculated by the author based on NBU data [35]

As we have seen, Ukraine lacks prerequisites for successful inflation-targeting specified by financial system health and economic structure criteria. It leads to a significant volatility of inflation in Ukraine around the targeted range and shows that is still a lot to be done concerning structural reforms to make prices more susceptible to monetary policy.

Conclusions to Chapter 1

As a result, in this chapter we have outlined the conceptual foundations of inflation-targeting regime and monetary policy transmission mechanism. We have also discussed the design of inflation-targeting in Ukraine and specific features of Ukrainian economy that constrain the effectiveness of monetary policy.

Inflation-targeting main characteristics include publicly announced inflation goal, central bank's commitment to price stability, which must be constantly proven through extensive communication and explanation of monetary policy decisions and intentions, and increased accountability for attaining the declared objectives, which to a great extent relies on effective usage of inflation forecast as intermediate target.

Institutional independence and adequate technical infrastructure are required for a central bank to be able to start conducting inflation-targeting. Though healthy financial system and structure of the economy significantly simplify the task of attaining of the inflation target, an economy in transition to inflation-targeting is not required to have key indicators in the mentioned categories that meet reference levels for leading inflation-targeting economies.

The interest rate, exchange rate, asset price, credit, and expectation channels form a monetary transmission mechanism. All the channels are related by their names to the first stage of the transmission, but the relationships between financial market indicators, on the one side, and output gap and inflation, on the other side, are fuzzier and are harder to disentangle in individual channels.

Inflation-targeting in Ukraine has been introduced in September 2015. Current medium-term target of the NBU is 5% YoY change in headline CPI. Since the beginning of a full-scale russian invasion, the NBU has another nominal anchor, namely fixed foreign exchange rate, which is why its monetary policy regime cannot be classified as classical inflation targeting now.

CHAPTER 2

ASSESSMENT OF THE MONETARY TRANSMISSION MECHANISM IN UKRAINE

2.1 Inflation dynamics and its drivers

We start the analysis of the monetary transmission mechanism with prices dynamics overview in consumer and industrial product categories.

In Figure 2.1 we observe that in the last 16 years there were three periods of sharp inflation acceleration that coincided with severe external shocks and economic crises: the global financial crisis of 2008-2009, Crimea annexation and the beginning of the russo-ukrainian war in 2014 (together with economic, banking, and currency crises), and the full-scale russia invasion of Ukraine in 2022. At the same time, over the analyzed period Ukraine has also experienced deflation in 2012-2013 due to the perceived overpricing of hryvnia as it had at that time been pegged to the US dollar.

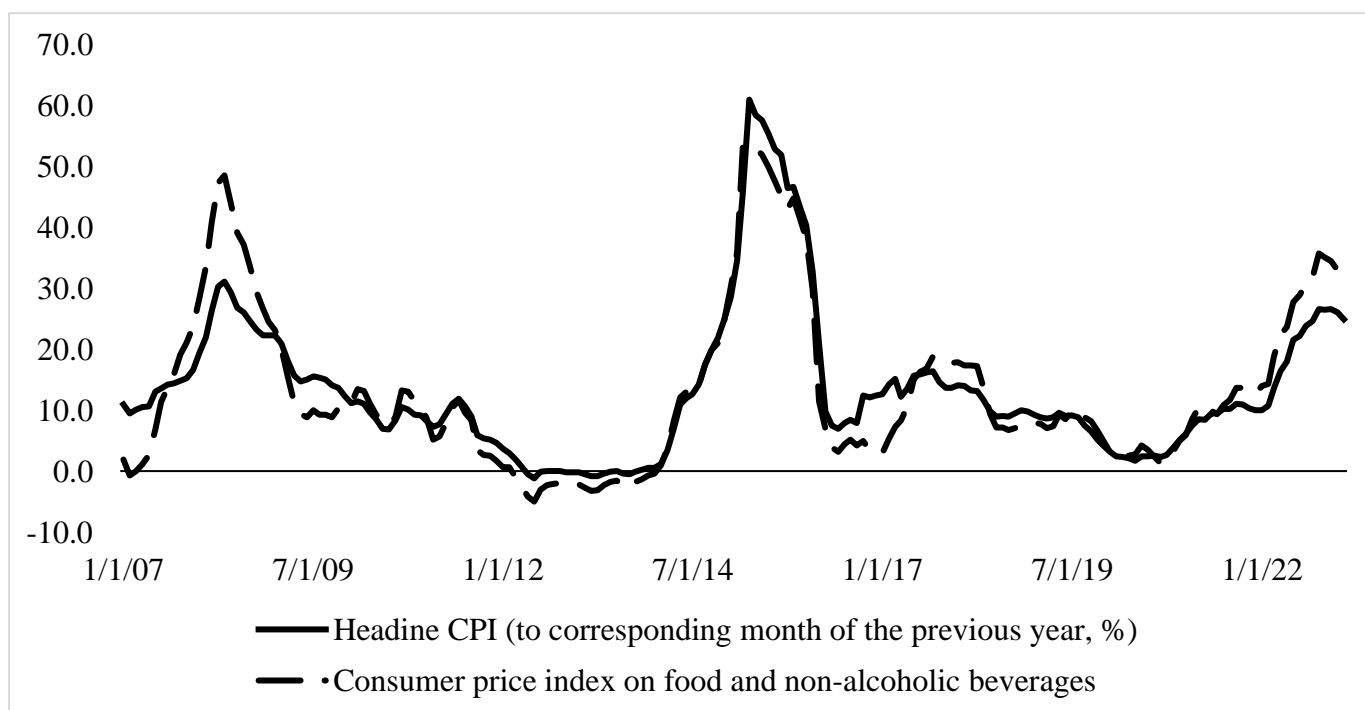


Figure 2.1 – Consumer inflation in 2007-2023

Source: NBU data [35]

Fixed exchange rate prevented the devaluation and forced the prices on the local market to decrease, which slowed down economic growth.

Figure 2.1 also indicates a close correlation between price index of food and non-alcoholic beverages and the headline CPI, which aligns with our expectations as such product category constitute a significant share of consumer set.

Table 2.1 Descriptive statistics on headline CPI and consumer prices by the type of product (based on monthly data on YoY change in prices in 2007M1 – 2023M2)

Indicator \ Statistics	Mean, %	Median, %	Standard Deviation, %	Min, %	Max, %	Coefficient of variation, %
Headline CPI	13.4	10.6	12.1	-1.2	60.9	90.0
Food and non-alcoholic beverages	13.4	9.5	13.7	-5.0	53.7	102.4
Alcoholic beverages, tobacco	17.4	15.1	9.5	5.9	47.1	54.7
Clothing and footwear	3.7	1.7	9.7	-8.2	44.6	264.8
Housing, water, electricity, gas, and other fuels	22.4	12.3	32.7	-13.1	188.2	146.3
Furnishings, household equipment and routine maintenance of the house	8.8	3.7	12.3	-1.4	54.8	139.7
Health	12.3	7.9	10.2	1.6	48.4	83.0
Transport	15.0	12.6	12.6	-6.6	65.5	84.0
Communication	5.4	4.7	6.1	-8.9	20.9	113.1
Recreation and culture	8.3	4.4	10.9	-2.9	47.4	131.9
Education	13.2	13.8	6.2	2.2	29.2	47.1
Restaurants and hotels	12.1	11.0	7.6	1.3	33.1	62.6

Source: calculated by the author based on NBU data [35]

Over the last 16 years, based on the calculations from the Table 2.1 clothing and footwear products have had the most volatile price dynamics in 2007-2023 as measured by the coefficient of variation. This is a bit misleading indicator in this case as the mentioned

product category has had a relatively low mean YoY change in prices. Considering the range of volatility, housing, water, electricity, gas, and other fuels prices have experienced the most significant degree of changes, primarily due to the structural reforms introduced since the Revolution of Dignity focused on deregulation of energy prices. Prices on education and communication have been growing most steadily as the influence of external shocks on these prices is limited.

Industrial inflation has been even more volatile over the last decade (Appendix A). Though coefficient of variation for headline Industrial Producer Price Index is estimated to be around 90.6% (close to 90.0% for headline CPI), its standard deviation has been substantially higher (17.5% vs. 12.1%), which is not extraordinary as intermediate goods and services tend to be more flexible compared to consumer prices in more competitive and customer-dependent markets. The least stable segments for Industrial PPI calculation are electricity, gas, steam, and air-conditioning supply, mining and quarrying, and coke and refined petroleum. The observed dynamics is a result of already mentioned structural reforms in energy sector, particularly the gradual substitution of russian energy sources in Ukraine's import and russian usage of gas and oil prices as a weapon in hybrid warfare [46]. Mining and quarrying prices volatility is also due to a high concentration of this sector production facilities in eastern and southern regions of Ukraine that has been most affected since the beginning of russo-ukrainian war in 2014. Most of the other manufacturing segments have exhibited significantly lower degree of prices volatility in 2016-2022.

Additionally, comparison of inflation in Ukraine with countries that have similar geographical location to some extent level of economic development (Figure 2.2) shows that prices in Ukraine are more volatile. Among the chosen states only Türkiye is characterized by a similar range of prices deviations. Conversely, those countries that are members of the European Union (Poland, Czech Republic, Hungary, Romania) have experienced significantly lower prices volatility and have had highly correlated inflation figures, especially since 2010.

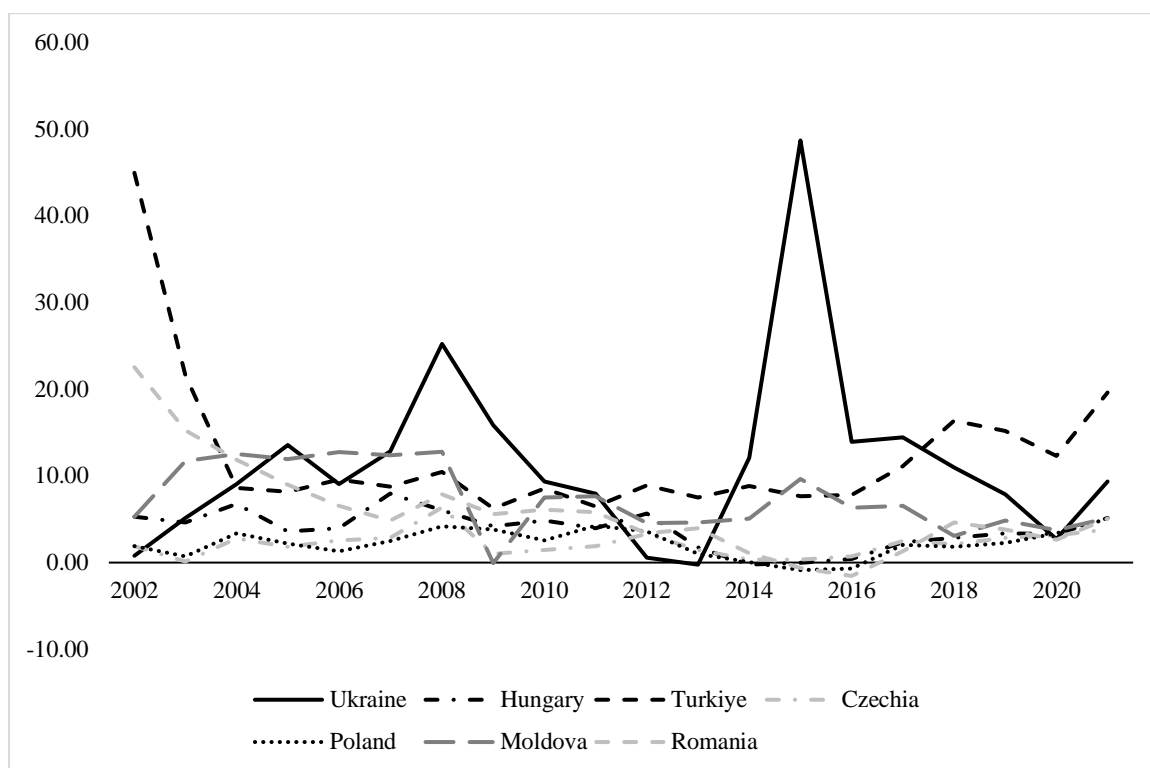


Figure 2.2 – Annual change in consumer prices in selected countries and in Ukraine

Source: World Bank (WDI) [47]

Thus, both consumer and industrial inflation in Ukraine have experienced drastic volatility over the past decade primarily due to external shocks, high share of agricultural products in consumer set, and Ukraine's dependence on imported energy sources.

2.2 The first stage of the monetary policy transmission

In this section, we will assess the extent of the monetary policy decision transmission into financial market indicators. Particularly, we evaluate interest rate, exchange rate, and expectations channels. The period under consideration is limited to 2016-2023.

The first link of monetary transmission is the impact of a change in the key rate on the interbank market. The strong relationship between the interbank market rates and monetary policy instruments is required for monetary authority to be able to affect interest rates in the economy. Since 2016 overnight rate in the interbank market follows the dynamics of the key policy rate closely (Figure 2.3).

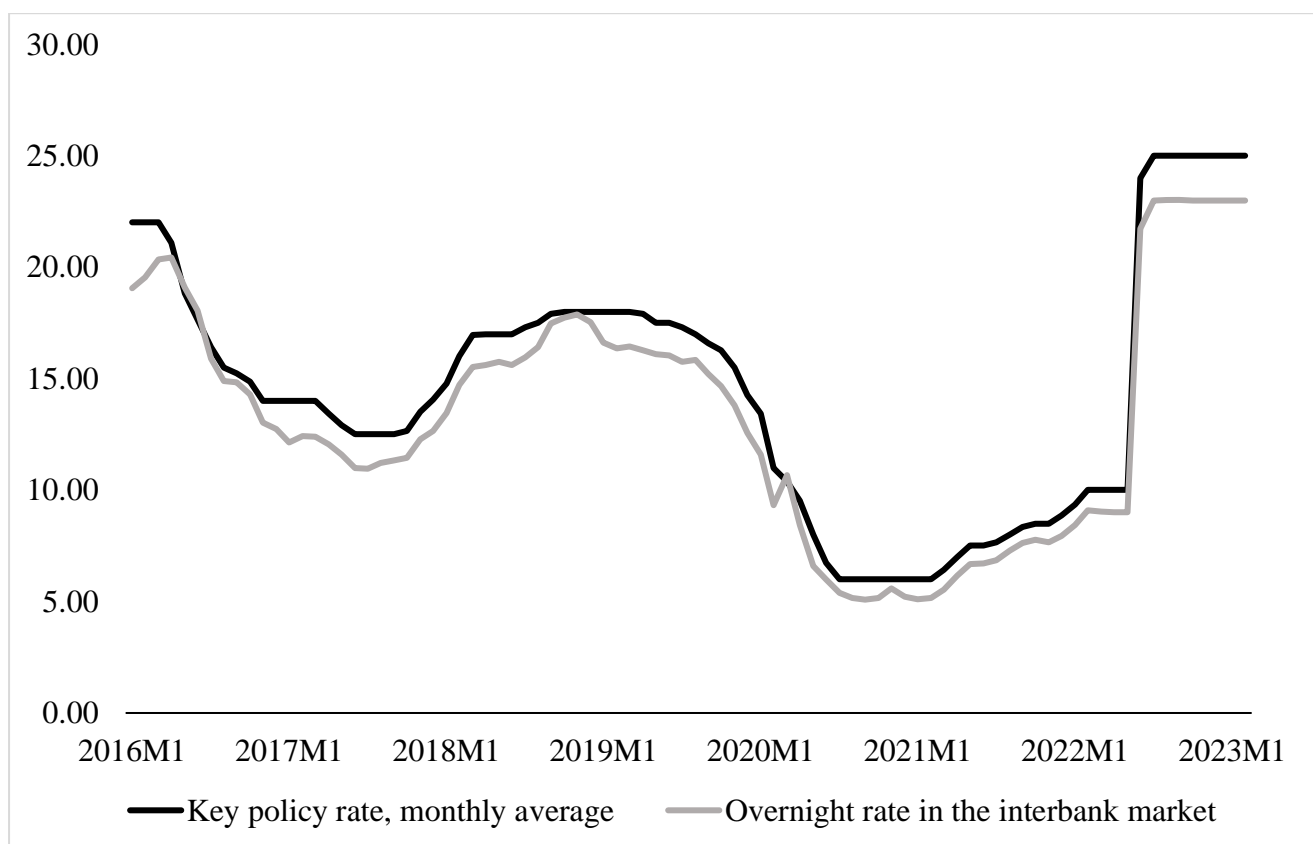


Figure 2.3 – Transmission of the policy rate into the interbank market

Source: calculated by the author based on NBU data [35]

At the same time, we can observe that it tends to be lower than key policy rate (Figure 2.4), which indicate that Ukrainian banks tend to operate in structural liquidity surplus environment. Particularly, this peculiarity of Ukrainian banking system has manifested itself in 2020-2021, and even to a greater extent since the beginning of the full-scale russian invasion. Substantial structural liquidity surplus is forcing the NBU to introduce new instruments to extract liquidity from the system and improve the design of monetary policy.

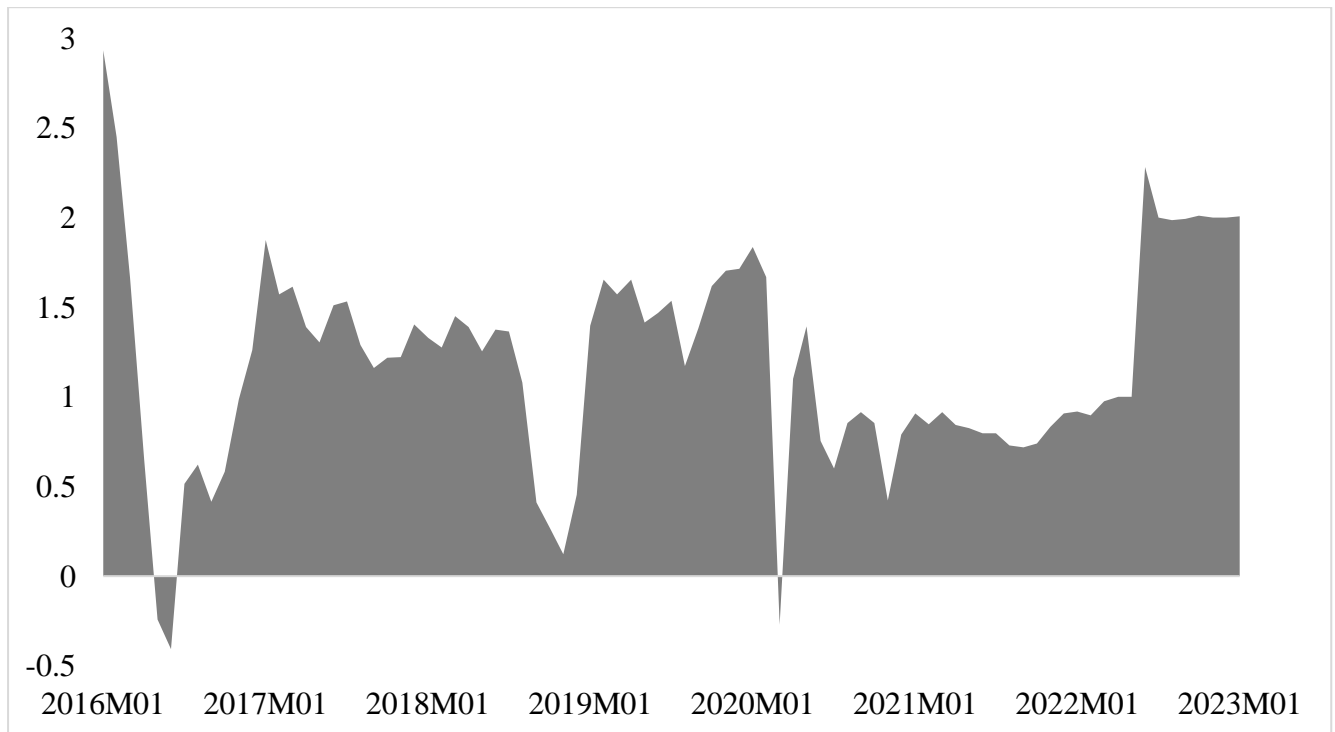


Figure 2.4 – Spread between the key policy rate and interest rate on overnight loans in the interbank market.

Source: calculated by the author based on NBU data [35]

For example, in March 2023 the NBU has lowered the interest rate on overnight deposit certificate to 20% [48] and it is steadily increasing the requirements for reserve ratio to freeze higher proportion of banking liquidity and increase the need for increasing interest rates on deposits [49]. The NBU is not the only central bank that has faced the problem of sluggish reaction of market rates to the monetary policy decisions in 2022. As indicated in the January Inflation Report [39] numerous central banks of emerging markets around the globe (e.g., Indonesia, India, Moldova, Egypt) were forced to increase the required reserve ratios simultaneously with interest rate hikes in order to ensure the expected extent of monetary policy tightening.

To further assess the transmission of the key policy rate into the rates in the interbank market, the following regression was estimated:

$$\text{Overnight} = \beta_0 + \beta_1 \cdot \text{Policy rate} + \varepsilon, \quad (2.1)$$

where *Overnight* – interest rate on overnight hryvnia loans in the interbank market, monthly average;

Policy rate – key policy rate of the NBU, monthly average.

Table 2.2 An evaluation of the transmission of the policy rate into the interbank market

Period (# of data points)	Correlation	Intercept	Slope	Average spread, %	Average spread standard deviation, %
2016M1 – 2018M12 (36)	0.973	-1.135*	1.001***	1.120	0.673
2019M1 – 2021M12 (36)	0.997	-0.329**	0.930***	1.085	0.457
2016M1 – 2021M12 (72)	0.993	-0.603***	0.963***	1.102	0.571
2016M1 – 2023M1 (85)	0.995	-0.414***	0.946***	1.181	0.595

Source: calculated by the author based on NBU data [35]

Note: level of statistical significance (based on t-statistics) in the table is indicated by the following symbols: * - 10%, ** - 5%, *** - 1%.

The results (Table 2.2) suggest that the relationship was the highest and average spread the lowest and least volatile in 2019-2021. In 2016-2018 the banking system was still adapting to a new monetary policy framework and recovering after numerous bank bankruptcies. The narrowing of the spread in 2021 was due to narrowing of the spread between NBU's overnight credit facilities and deposit certificates rates. Since June 2022 the spread has increased to its maximum possible level under current monetary policy design.

Now that we have assessed the transmission into the interbank market, we can proceed with the analysis of the relationship between the policy rate and interest rate on loans and deposits to the players of real economy.

Figure 2.5 shows that new loans interest rates of all resident sectors, except households, follow the policy rate. New loans interest rate to households has been consistently higher and relatively stable before the full-scale invasion, which might be explained by significant risk premiums commercial banks have charged on individual borrowers. This sector was second in terms of volume in 2016M1-2023M1 and accounted

for 11.9% of all new loans. The insensitivity of these interest rates to the policy rate and their relative importance in the banking system hinders the effectiveness of monetary policy.

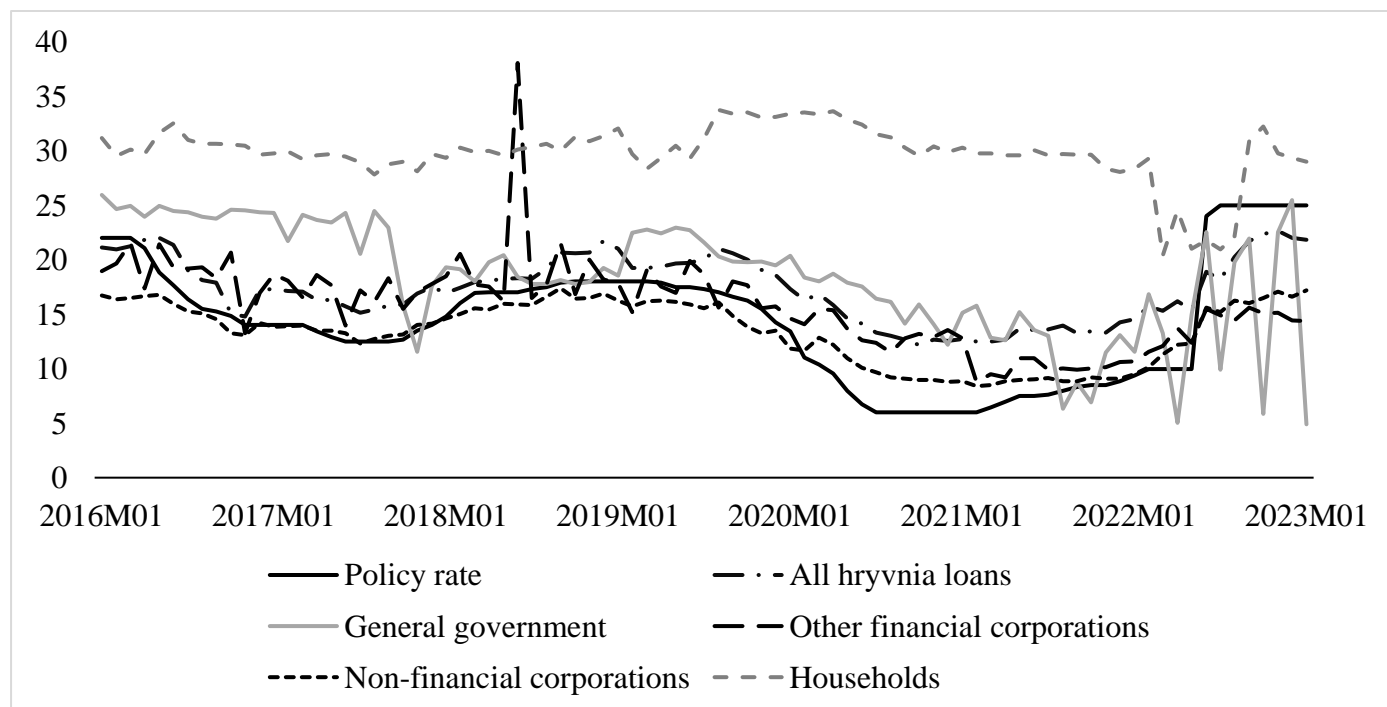


Figure 2.5 – Interest rates on new loans by resident sectors (excluding deposit-taking corporations)

Source: NBU data [35]

At the same time, the interest rate on new loans to non-financial corporations has been most closely correlated with the policy rate both the periods prior to the full-scale invasion and including it (Table 2.3). These loans have accounted for 86.6% of all new loans in 2016M1-2023M1 and have driven the dynamics of the hryvnia loan market.

Overall, since February 2022 the relationship between new loan interest rates and the policy rate has become weaker in all resident sectors. General government and other financial corporations sectors interest rate pass-throughs have been affected the most (Table 2.3), but their shares in the loan market are negligible. Interestingly, general government new loans interest rates have been more correlated with the policy rate than with overnight opposite to other sectors.

Table 2.3 Correlations between interest rates on new loans by resident sectors on the one side and policy rate with overnight rate on the other side

Correlations	2016M1 – 2021M12		2016M1 – 2023M1	
	Overnight	Policy rate	Overnight	Policy rate
All hryvnia loans	0.953	0.945	0.929	0.919
General government	0.667	0.683	0.402	0.402
Other financial corporations	0.717	0.716	0.541	0.528
Non-financial corporations	0.966	0.963	0.924	0.915
Households	0.098	0.086	-0.082	-0.097

Source: calculated by the author based on NBU data [35]

Non-financial corporations segment of the loan market has been found to be both most influential by loans volumes and most closely responsive to the monetary policy decisions. The next step of our research is to assess the sensitivity of the interest rates of different original maturities loans in that segment (Figure 2.6) to the policy rate.

The calculations indicate that term loans for the period of up to 1 year have the highest correlation with the policy rate. This loan category is most significant in Ukraine (75.6% and 79.3% of all new loans to non-financial corporations in 2021 and 2022 respectively) as banks are reluctant to provide medium- and long-term loans due to high interest, credit, and exchange risks.

Overdraft is the second most important category (13.7% and 9.4% of all new loans to non-financial corporations in 2021 and 2022 respectively), but its interest rate dynamics is not found to be associated with the policy rate (Table 2.4). It aligns with our expectations as overdraft loans market is driven by banks' liquidity and by individual arrangement between businesses and commercial banks. That is why, the relationship between the cost of borrowing for banks and overdraft rates is loose.

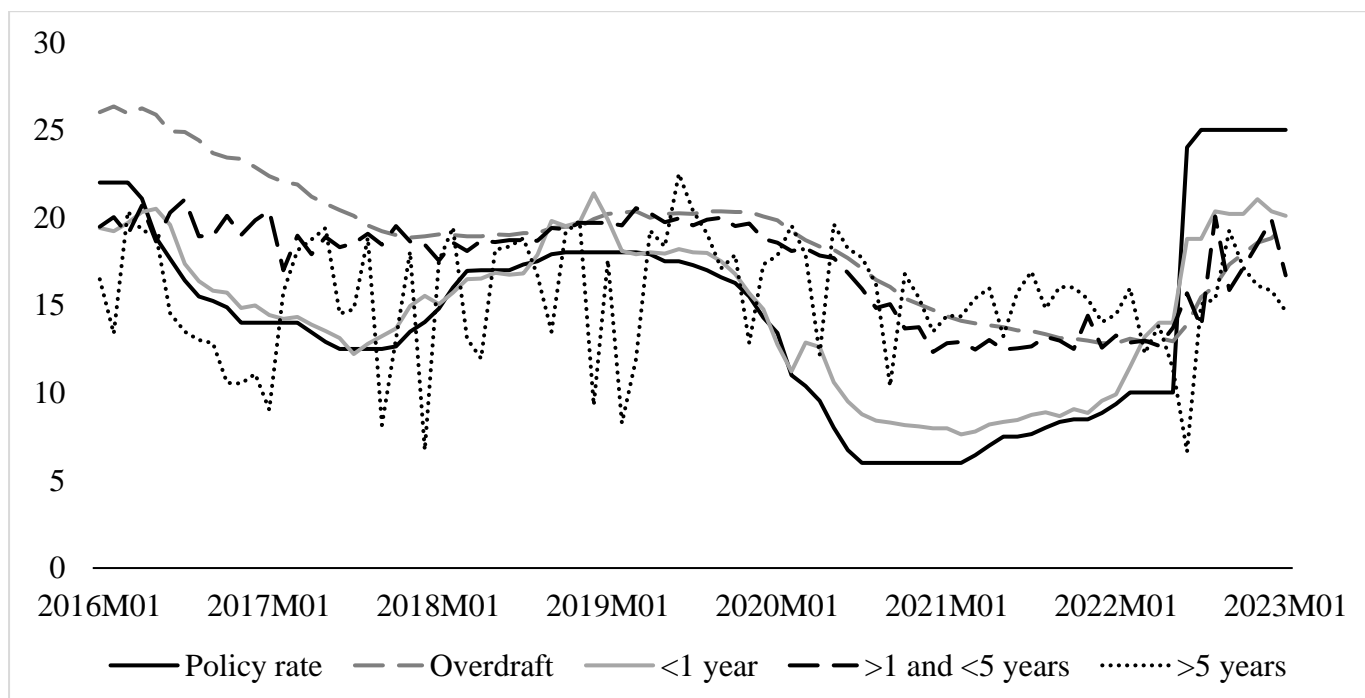


Figure 2.6 – Interest rates on new loans to non-financial corporations by original maturity

Source: NBU data [35]

Since the beginning of the full-scale invasion the correlations between all categories of new loans to non-financial corporations have weakened. Commercial banks have started increasing their interest rates, but it seems that by the end of 2022 they have reached plateau around 15-20% and the banks are unwilling to increase them further due to high structural liquidity and partly due to a weak debt service capacity of Ukrainian businesses.

Table 2.4 Correlations between interest rates on new loans to non-financial corporations by original maturity on the one side and policy rate with overnight rate on the other side

Correlations	2016M1 – 2021M12		2016M1 – 2023M1	
	Overnight	Policy rate	Overnight	Policy rate
Overdraft	0.798	0.801	0.550	0.537
<1 year	0.982	0.972	0.957	0.945
1-5 years	0.834	0.843	0.637	0.630
>5 years	0.116	0.116	0.089	0.084

Source: calculated by the author based on NBU data [35]

Even though households' loans segment has been found to be uncorrelated with the policy rate, it is still worth analyzing the dynamics of interest rates in this segment by original maturity of loans. Prior to the full-scale invasion only overdraft loans have shown a relatively high degree of transmission (Table 2.5). Interestingly, term loans to households with maturity in less than 1 year show negative correlation with the key policy rate.

Table 2.5 Correlations between interest rates on new loans to households by original maturity on the one side and policy rate with overnight rate on the other side

Correlations	2016M1 – 2021M12		2016M1 – 2023M1	
	Overnight	Policy rate	Overnight	Policy rate
Overdraft	0.735	0.742	0.262	0.248
<1 year	-0.460	-0.469	-0.271	-0.277
1-5 years	0.488	0.457	0.392	0.376
>5 years	0.156	0.165	0.218	0.229

Source: calculated by the author based on NBU data [35]

Now we can switch to the analysis of the transmission into deposit rates.

Deposits rates to other financial corporations and non-financial corporations have been most closely correlated with the policy rate both prior and including the period since the beginning of the full-scale invasion (Figure 2.7). In the deposits market, similarly to the loans market, non-financial corporations and households have the highest volumes of involvement: 76.4% and 18.5% in 2016M1 - 2023M1 respectively. Since the beginning of the full-scale invasion the transmission has also weakened in all segments of the deposits market.

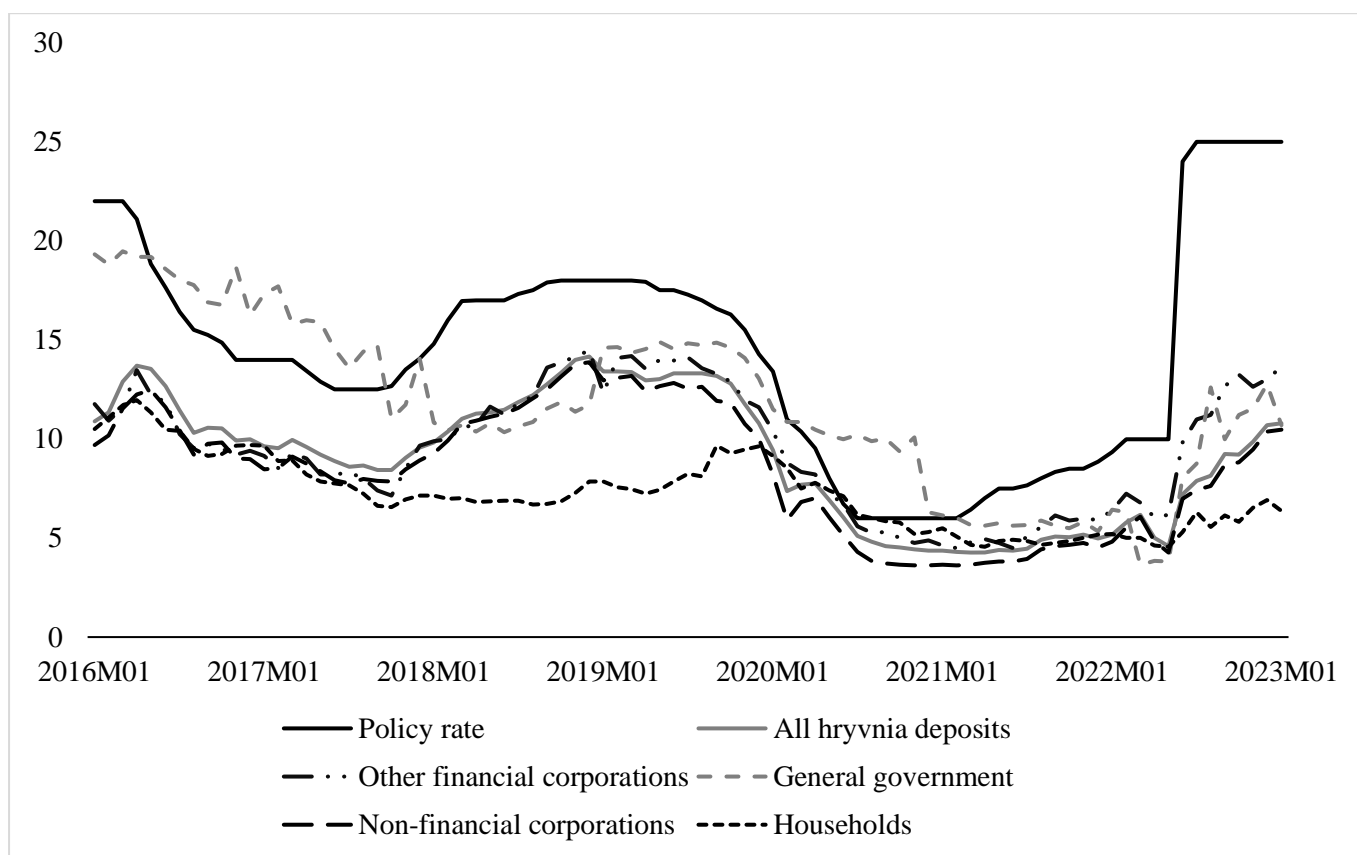


Figure 2.7 – Interest rates on new deposits by resident sectors (excluding deposit-taking corporations)

Source: NBU data [35]

In comparison with the loans market, the transmission of the policy rate in household deposits rate is quite strong. Though, it was affected the most in 2022 (Table 2.6).

Table 2.6 Correlations between interest rates on new deposits by resident sectors on the one side and policy rate with overnight rate on the other side

Correlations	2016M1 – 2021M12		2016M1 – 2023M1	
	Overnight	Policy rate	Overnight	Policy rate
All hryvnia deposits	0.953	0.948	0.760	0.741
General government	0.729	0.738	0.532	0.525
Other financial corporations	0.916	0.914	0.869	0.860
Non-financial corporations	0.946	0.938	0.771	0.751
Households	0.713	0.722	0.451	0.442

Source: calculated by the author based on NBU data [35]

We can now proceed with the analysis of the monetary policy transmission into non-financial corporations' deposits of different maturity. Here we observe similar results as with non-financial loans: term deposits with maturity in less than a year constitute the most prominent share of non-financial deposits and exhibit the highest degree of association with the policy and overnight rates (Table 2.7). The most stable relationship is estimated to be between the policy rate and term deposits with maturity in 1-2 years as its correlation has declined less in 2022.

Table 2.7 Correlations between interest rates on new deposits from non-financial corporations on the one side and policy rate with overnight rate on the other side

Correlations	2016M1 – 2021M12		2016M1 – 2023M1	
	Overnight	Policy rate	Overnight	Policy rate
On-demand deposits	0.857	0.854	0.676	0.660
<1 year	0.941	0.933	0.764	0.744
1-2 years	0.774	0.778	0.743	0.741
>2 years	0.602	0.628	0.454	0.464

Source: calculated by the author based on NBU data [35]

Among households' deposits interest rates the most correlated with the policy rate are interest rates on deposits with maturities in less than 1 year and in 1-2 years (Table 2.8). On-demand deposits have not displayed any association with the policy rate, while long term deposits have exhibited surprisingly high interest rate pass-through prior the full-scale invasion.

Table 2.8 Correlations between interest rates on new deposits from households on the one side and policy rate with overnight rate on the other side

Correlations	2016M1 – 2021M12		2016M1 – 2023M1	
	Overnight	Policy rate	Overnight	Policy rate
On demand deposits	0.106	0.102	-0.084	-0.095
<1y	0.855	0.866	0.532	0.522
1-2y	0.862	0.876	0.632	0.627
>2y	0.831	0.832	0.503	0.487

Source: calculated by the author based on NBU data [35]

As we have outlined in Chapter 1, government bonds market is a significant part of the capital markets in Ukraine. Thus, the pass-through of the policy rate into the government bond yields (Figure 2.8) is an important indicator of the strength of the monetary policy transmission.

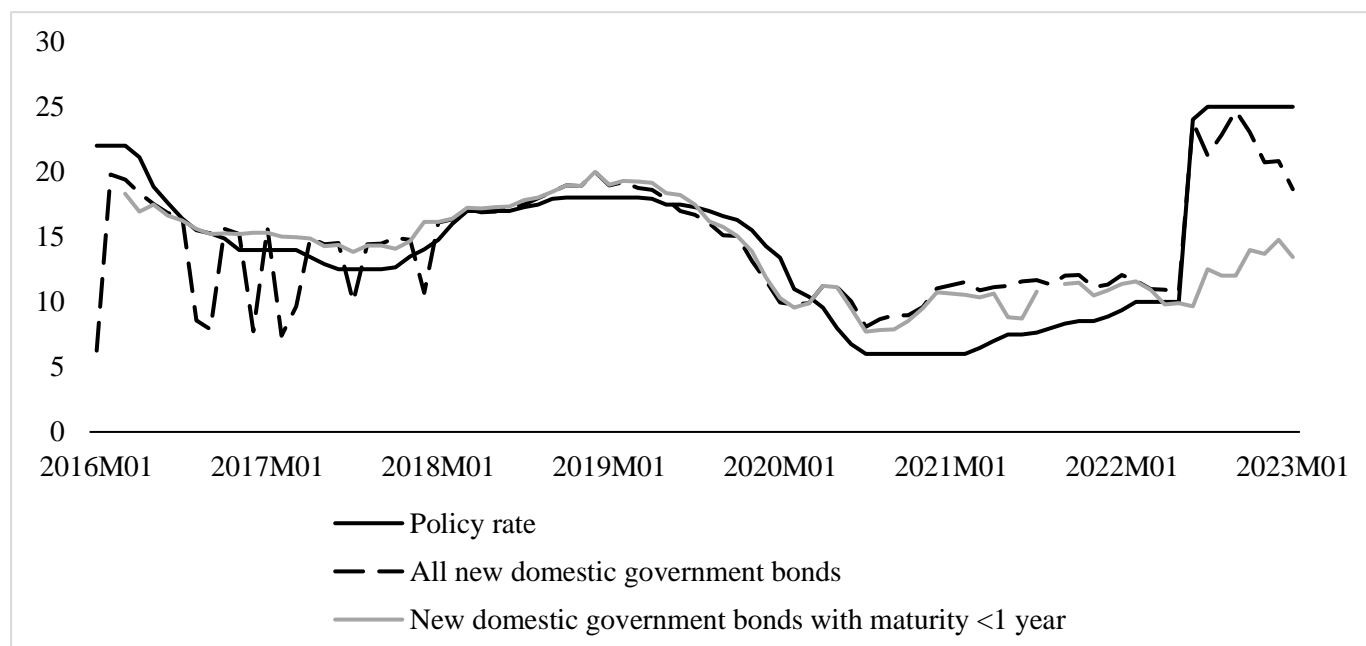


Figure 2.8 – Domestic government bonds yields in the primary market

Source: NBU data [35]

Calculations indicate a fairly high degree of association between the monetary policy and actual yields on domestic government bonds in the primary market (Table 2.9).

Table 2.9 Correlations between domestic government bond yields on the one side and policy rate with overnight rate on the other side

Correlations	2016M1 – 2021M12		2016M1 – 2023M1	
	Overnight	Policy rate	Overnight	Policy rate
All new issues	0.707	0.689	0.804	0.796
With maturity less than 1 year	0.722	0.709	0.541	0.519

Source: calculated by the author based on NBU data [35]

Still, in 2022 the yields have exhibited weaker reaction to key policy rate dynamics due to the unwillingness of the Ministry of Finance to substantially increase the cost of borrowing during the period of increased budget deficit of the wartime [50].

Figure 2.9 tries to explore the drivers behind the nominal effective exchange rate (NEER) dynamics from the perspective of the international flows of capital. It indicates that the volume of hryvnia domestic government bonds held by non-residents is most significantly positively correlated with contemporary NEER and the NEER in the next 2 months. This can be interpreted the following way. For the volume of the bonds held by nonresidents to increase they need to buy hryvnia. Ukrainian capital market is small, which is why international flows of capital can affect the exchange rate market significantly. Thus, the inflow of foreign capital that is meant to be allocated in hryvnia bonds leads to appreciation of hryvnia.

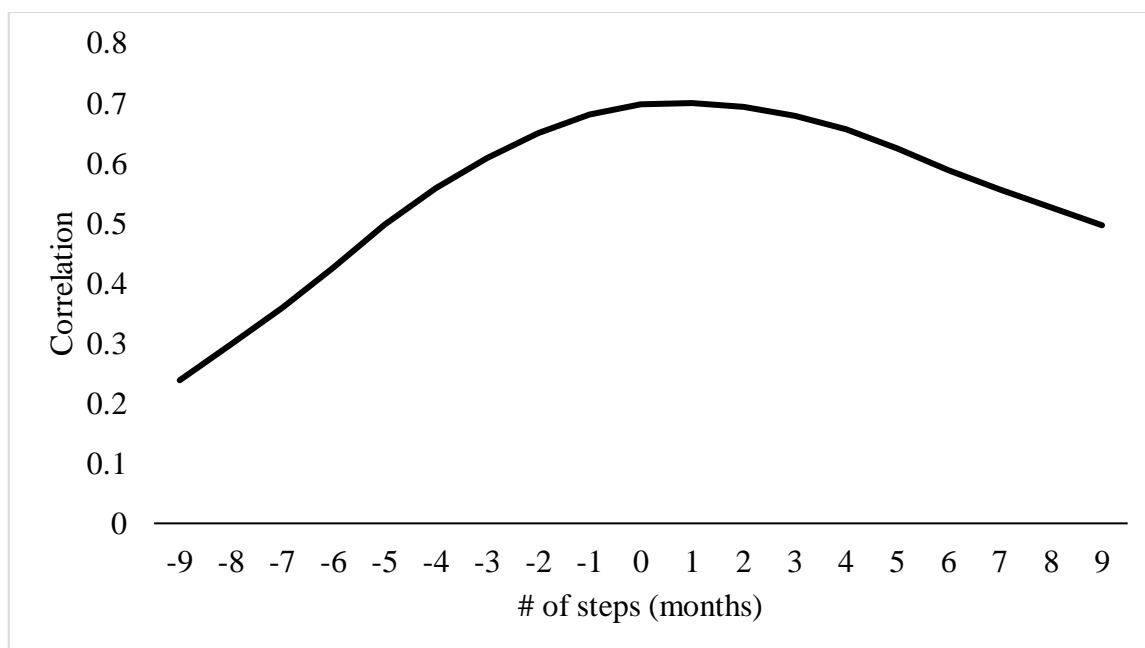


Figure 2.9 – Correlations between the nominal effective exchange rate, on the one side, and lagged and future volumes of hryvnia domestic government bonds held by nonresidents, on the other side

Source: calculated by the author based on NBU data [35]

Now we can take a closer look on another channel of the transmission – inflation expectations. In Figure 2.10 we are trying to evaluate what drives inflation expectations of

households. The results indicate clearly that households still have more backward-looking inflation expectations and tend to make unreliable inflation forecasts overall. This has important policy implication as it shows that general public tends to rely more on its own experience than on their knowledge of economics and on NBU's inflation forecasts.

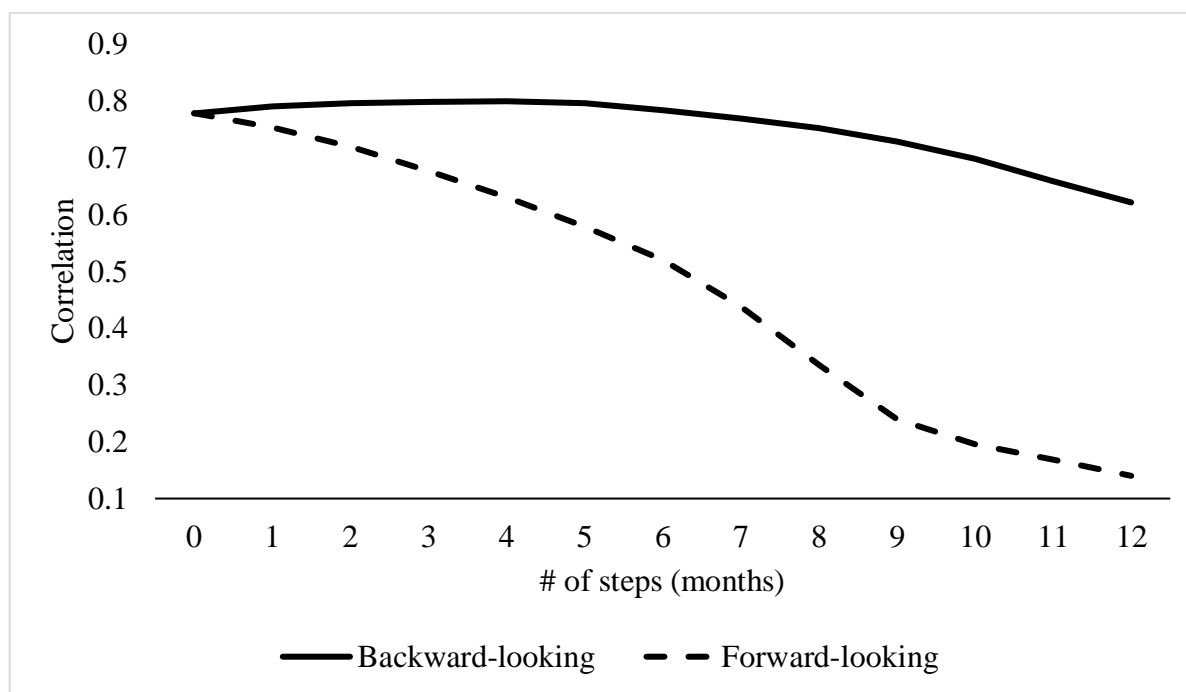


Figure 2.10 – Correlations between inflation expectations of households (12 months ahead headline CPI, YoY) on the one side and lagged and future inflation (headline CPI, YoY) on the other side (in 2015M07 - 2022M01)

Source: calculated by the author based on NBU data [35]

Interestingly, the results change substantially when we change the sample for estimations. For Figure 2.11 we have excluded the volatile periods of 2014-2015 and 2022. Consequently, the forward-looking component of household inflation expectations has improved significantly. This is to large extent due to a more stable inflation environment in the chosen timeframe and partly due to a gradually increasing level of financial literacy in Ukraine [51].

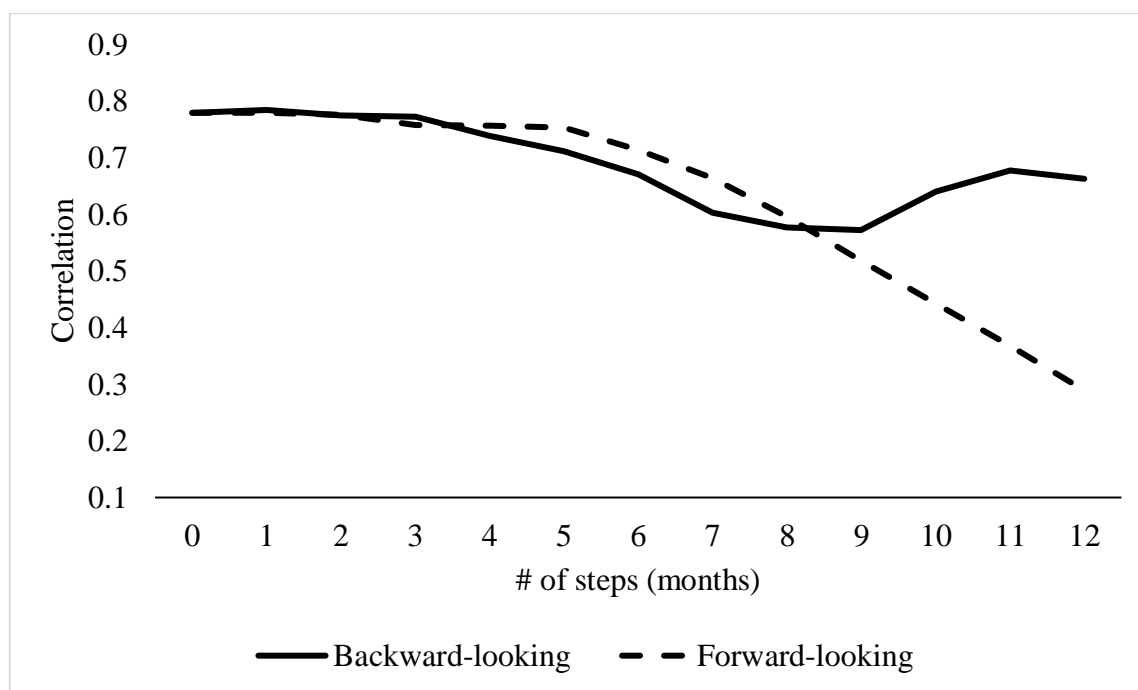


Figure 2.11 – Correlations between inflation expectations of households (12 months ahead headline CPI, YoY) on the one side and lagged and future inflation (headline CPI, YoY) on the other side (in 2017M01-2021M01)

Source: calculated by the author based on NBU data [35]

Inflation expectations estimates for other economic agents are available with quarterly frequency (Figure 2.12). The analysis indicates that firms' and financial analysts' expectations share similar characteristics and are again more closely correlated with the past inflation rather than with the future. Banks' expectations are even more backward-looking, which is a bit surprising as banks usually have better forecasting capabilities. Probably, this is due to a highly volatile inflation environment of the first few years following the adoption of inflation-targeting.

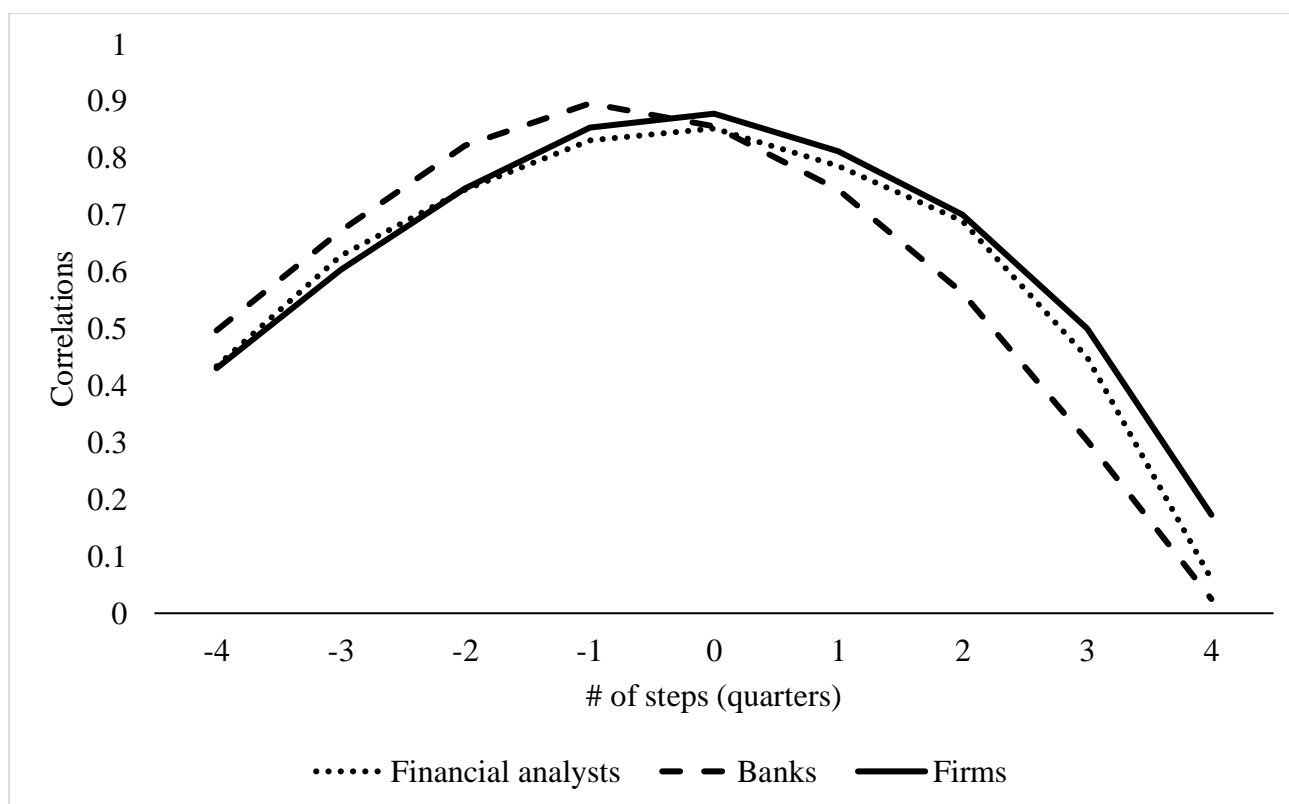


Figure 2.12 – Correlations between inflation expectations of financial analysts, banks, and firms, on the one side, and lagged and future inflation (headline CPI, YoY) on the other side (in 2015Q1 - 2021Q4)

Source: calculated by the author based on NBU data [35]

As a result, in this section we have identified that the policy rate pass-through has been the strongest for loans and deposits to non-financial corporations with maturity in less than 1 year, short-term households' deposits and government bond yields. Additionally, we have found evidence confirming sensitivity of the exchange rate dynamics to foreign capital movement. Also, during the assessment of the inflation expectations channel it has been found that inflation expectations of all economic agents are more backward-looking than forward looking. At the same time, the results indicate that during the less volatile period of 2016-2021 forward-looking orientation of inflation expectations was getting stronger at least for households.

2.3 The second stage of the monetary policy transmission

Now we can move further and evaluate the strength of the relationships between the monetary policy dependent indicators and prices dynamics.

First, we evaluate the association between the policy rate and industrial and consumer prices (Figure 2.13). The results show that there exists a considerable lag between the monetary policy decisions and the manifestation of their effects on prices dynamics. Both for consumer and industrial inflation this lag is around 9-15 months (3-5 quarters), though for core CPI it seems this lag is longer, around 12-18 months. In literature there is still a debate about the actual duration of the lag of from monetary policy actions to inflation.

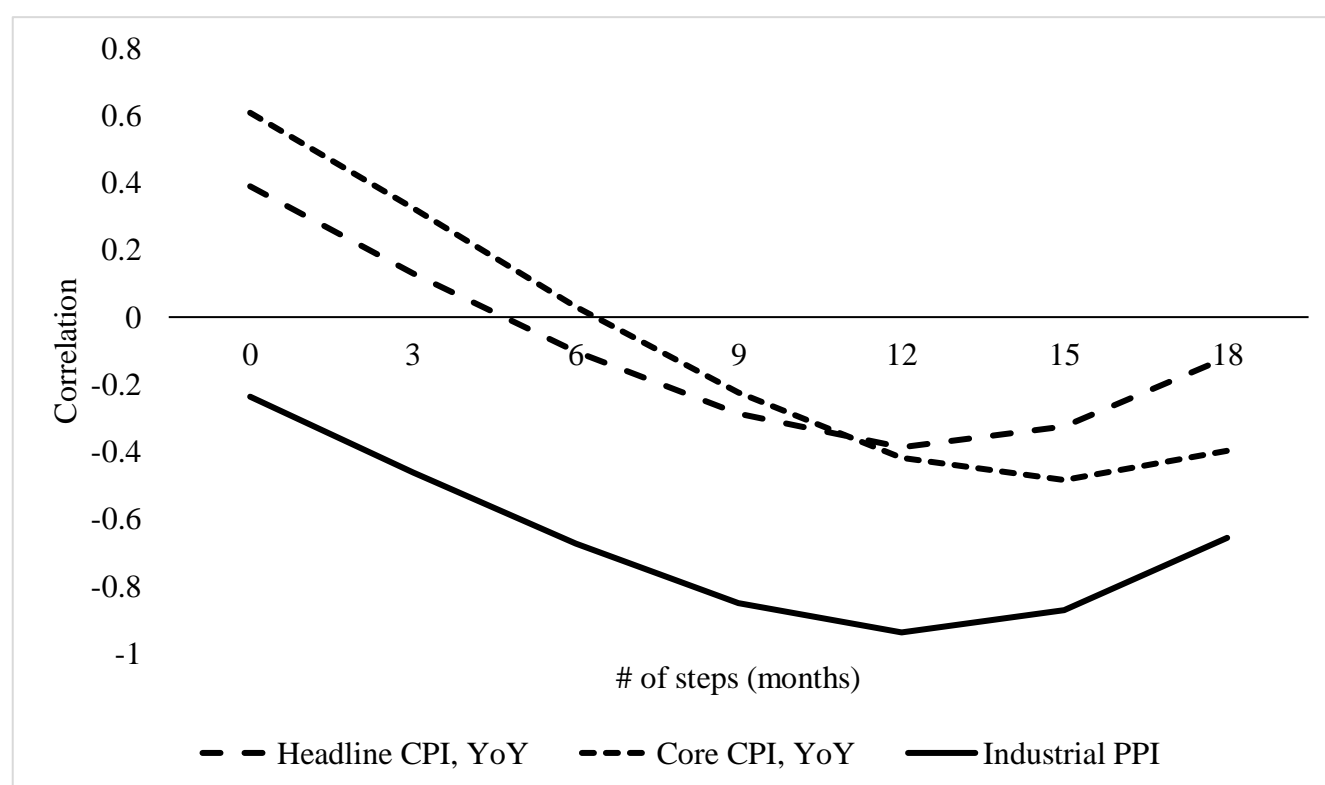


Figure 2.13 – Correlations between coincident and lagged policy rate, on the one side, and price indices, on the other side (in 2017M07 - 2022M02)

Source: calculated by the author based on NBU data [35]

In the quarterly projection model for Ukraine this value is assumed to be equal to 1/4 of a year: "The monetary conditions enter the output gap equation with a lag, modeling the one-quarter delay before monetary policy influences demand" [27]. But it should be stated,

that 1/4 of a year in that paper is not the time needed for monetary policy to reach its full effect, but to start influencing GDP and inflation. At the same time, M. Friedman in his paper long ago argued that this value should be in the range of 1-2 years [52]. And some of more recent papers confirm his reasoning: "it takes over a year before monetary policy actions have their peak effect on inflation" [53].

More importantly, the results in Figure 2.13 indicate that monetary policy is far more responsive to coincident consumer inflation. This aligns with our expectations as the NBU target is related to CPI.

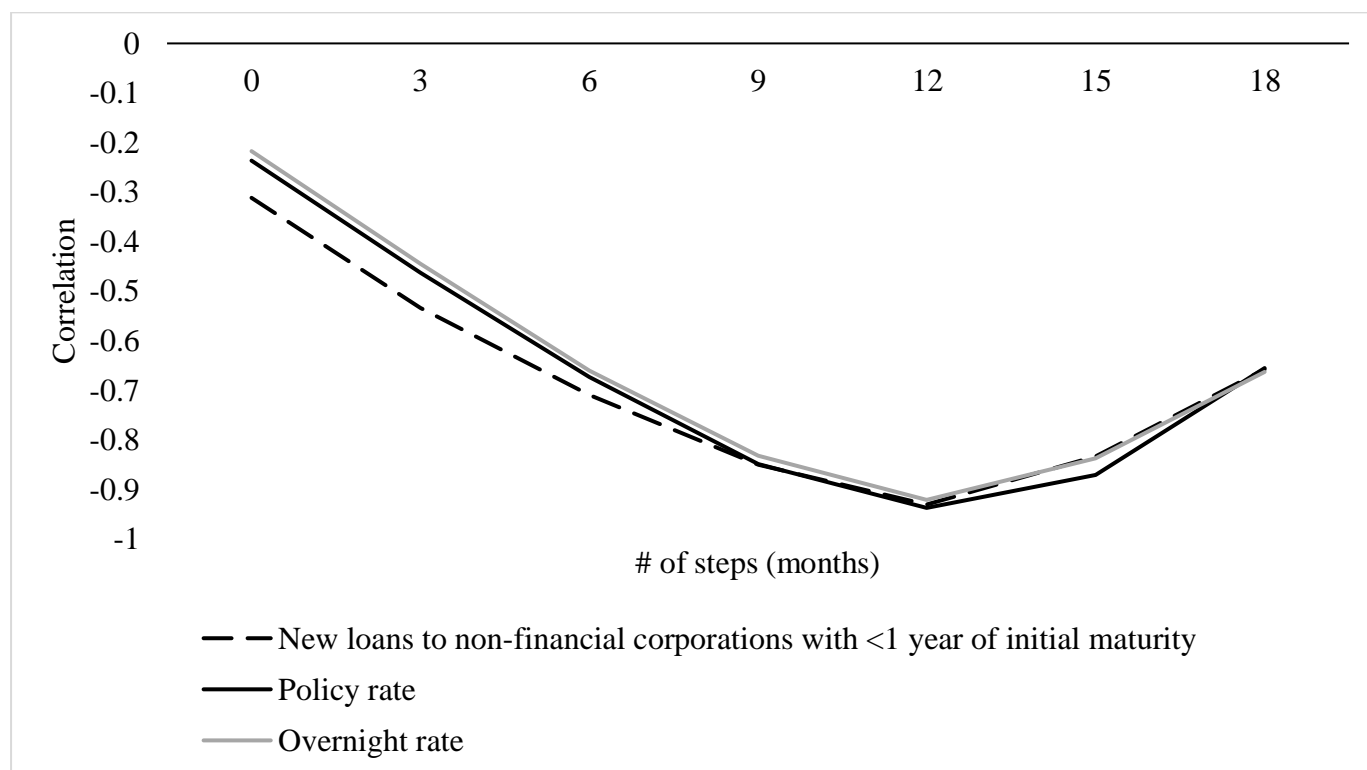


Figure 2.14 – Correlations between coincident and lagged interest rates (policy rate, interest rate on overnight loans in the interbank market, interest rate on new loans to non-financial corporation with <1 year of initial maturity), on the one side, and industrial producer price index, on the other side (in 2017M07 - 2022M02)

Source: calculated by the author based on NBU data [35]

At the same time, industrial prices are far more sensitive to monetary policy with coefficient of correlation reaching negative 0.94 with a 12-month lag for the policy rate changes to affect prices. This result is coherent with our assessment of the first stage of

monetary policy transmission as interest rates to non-financial corporations has been found to be the most correlated with the policy rate and the most prominent (by the volumes of transactions) in the banking system. Figure 2.14 further corroborates such a conclusion.

Next, we have made a preliminary assessment of the exchange rate pass-through into consumer and industrial prices. The results in Figure 2.15 indicate that an exchange rate pass-through also happens with a lag, but its length is shorter: for both industrial and consumer prices the coefficient of correlation reaches its lowest levels when the length of the lag is 3-9 months.

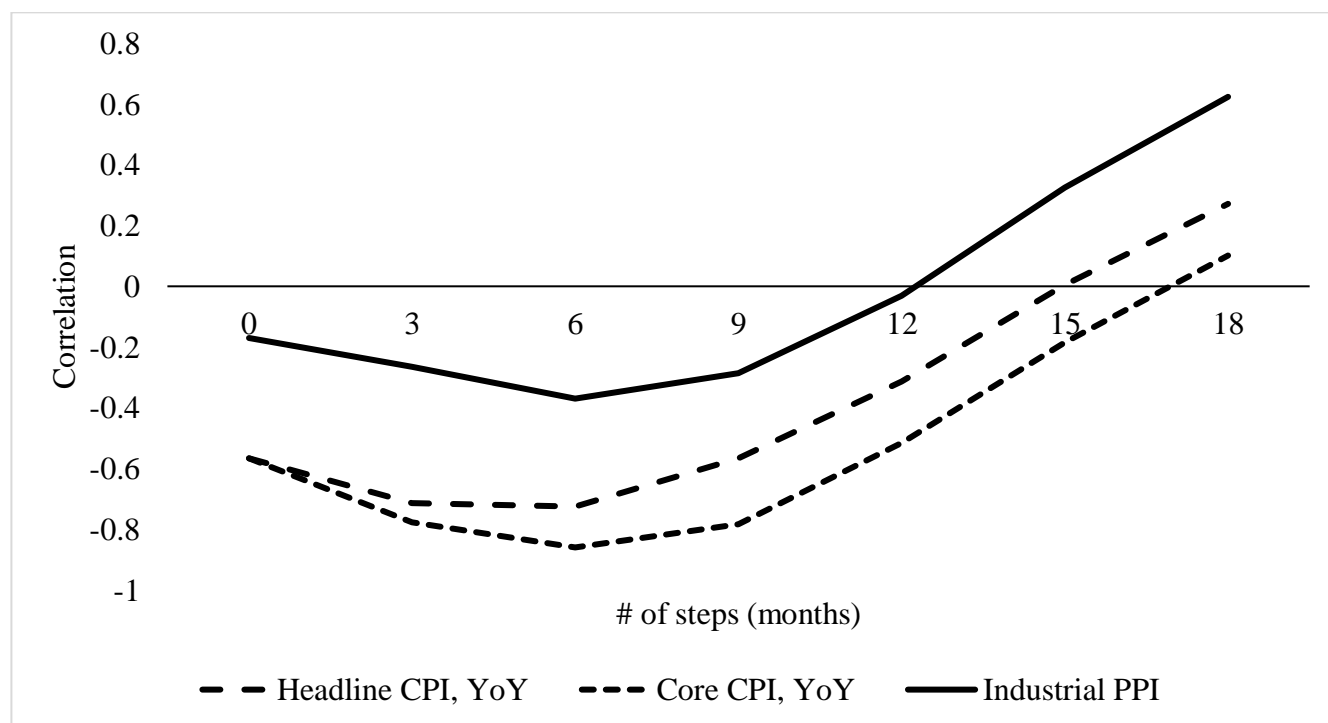


Figure 2.15 – Correlations between coincident and lagged nominal effective exchange rate, on the one side, and price indices, on the other side (in 2017M07 - 2022M02)

Source: calculated by the author based on NBU data [35]

Furthermore, the results indicate that consumer prices are far more sensitive to exchange rate dynamics than industrial prices. This is probably due to a high proportion of imported goods in households' consumption.

Figure 2.16 provides us with the most surprising results so far. It tries to explore the nature of the interrelationship between the monetary policy and foreign exchange market

during the period of free-floating exchange rate. The results can be interpreted the following way. A high policy rate tends to be associated with most significant hryvnia appreciation in the next 6-12 months. This is an important indicator of a strength of the exchange rate channel of monetary policy transmission as it indicates that central bank's interest rate policy affects foreign exchange rate without the need of foreign exchange interventions.

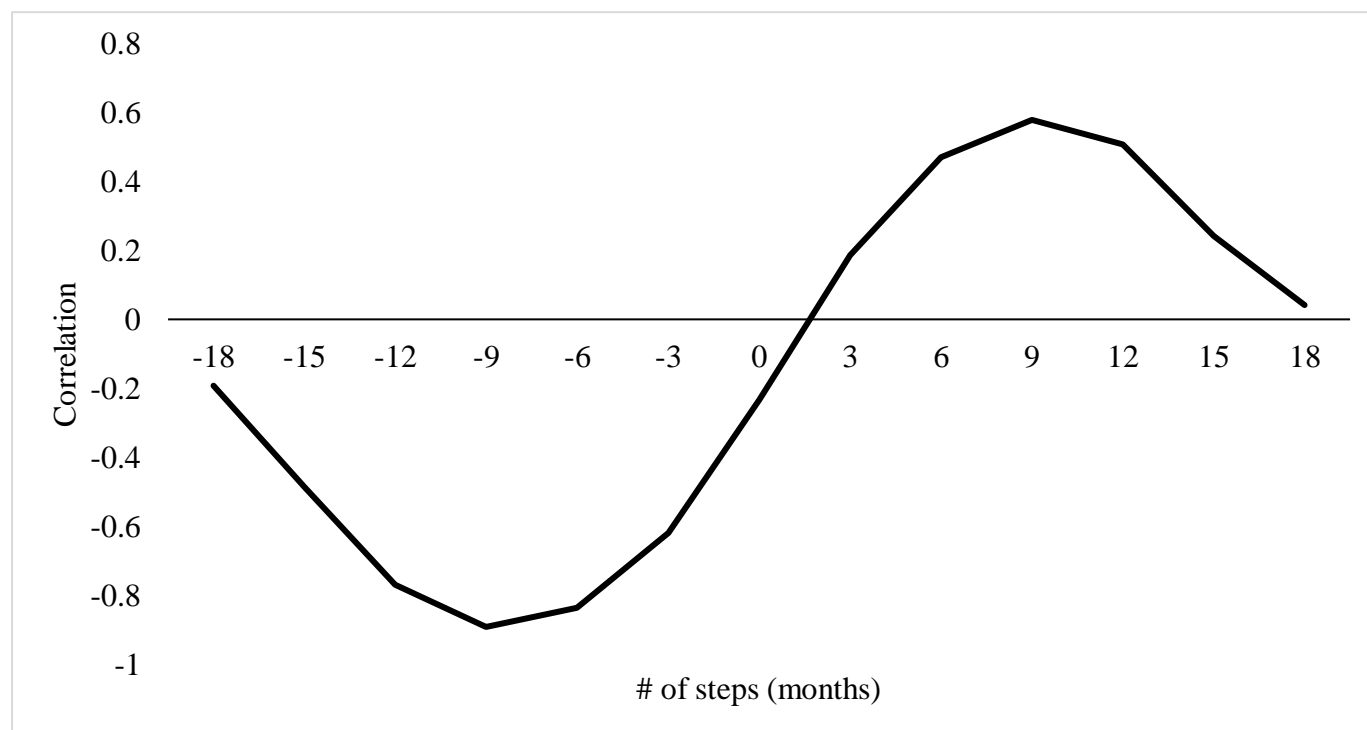


Figure 2.16 – Correlations between lagged, coincident, and future nominal effective exchange rate, on the one side, and key policy rate, on the other side (in 2017M07 - 2022M02)

Source: calculated by the author based on NBU data [35]

At the same time, Figure 2.16 also shows that hryvnia appreciation is associated with a lower policy rate in the next 6-12 months. Such a conclusion aligns with our expectations as stronger national currency, as we have seen previously, has relatively fast effect on consumer prices. And lower consumer inflation leads to a more accommodating monetary policy. On the other hand, depreciation of a national currency leads to acceleration of inflation and forces a central bank to increase its key policy rate.

Lastly, let's look at the relationships between the policy rate and real estate prices (Table 2.10). Overall, the results indicate that housing prices are moderately related to monetary policy with the primary market being more sensitive than the secondary market. The lag of the reaction is up to 1 year and it seems that two- and three-room apartments react more significantly in the secondary market, while one-room apartments are most sensitive in the primary market.

Table 2.10 Correlations between coincident and lagged policy rate, on the one side, and real estate price indices, on the other side (in 2016Q1 - 2021Q4)

Index	# of steps (quarters)				
	0	-1	-2	-3	-4
Total primary market	-0.44	-0.58	-0.51	-0.38	-0.59
One-room apartment	-0.42	-0.55	-0.48	-0.20	-0.48
Two-room apartment	-0.35	-0.46	-0.38	-0.31	-0.63
Three-room apartment	-0.34	-0.44	-0.36	-0.51	-0.39
Total secondary market	-0.22	-0.42	-0.20	-0.42	-0.35
One-room apartment	-0.08	-0.36	-0.10	-0.20	-0.17
Two-room apartment	-0.19	-0.43	-0.18	-0.33	-0.32
Three-room apartment	-0.29	-0.31	-0.23	-0.51	-0.44

Source: calculated by the author based on NBU and SSSU data [35;38]

Consequently, in this section we have assessed the industrial and consumer prices sensitivity to the policy rate and foreign exchange rate dynamics, explored the interrelationship between monetary policy and foreign exchange market, and taken a quick look on the monetary policy transmission into housing prices.

Panel estimation of the strength of the interest and exchange rate channels

In this section we will put the previously identified potential interrelationships into a panel regression to assess the relative strength of interest rate channel and foreign exchange rate channel. We will analyze the dynamics of consumer and industrial prices separately.

For consumer price dynamics we use data on 12 price indices that are included in the headline CPI calculation (2016M1-2022M2). The results of the estimation of the panel regression for consumer prices are displayed in Table 2.11. According to the results, the policy rate is marginally negatively affecting consumer prices with a 12-month lag. Its coefficient is significant with 90% confidence.

Table 2.11 Model estimation results (consumer prices)

Dependent variable: Consumer price index				
Variable	Coefficient	S.D.	t-stats	Prob.
Intercept	-4.562	1.108	-4.117	0.000
Consumer price index (-1)	1.166	0.035	33.091	0.000
Consumer price index (-2)	-0.248	0.034	-7.277	0.000
Policy rate (-12)	-0.022	0.013	-1.723	0.085
Log (NEER)	-5.103	1.024	-4.986	0.000
Total panel (balanced) observations: 744				

Source: calculated by the author in EViews 12

At the same time, inflation in all segments of consumer products (and services) is persistent as we observe that its first and second lags are significant. The nominal exchange rate has a negative statistically significant effect on consumer prices, and it affects consumer prices instantaneously. However, its coefficient does not seem to be in adequate range as it indicates that 1% of the exchange rate depreciation results in prices increasing by 5.1%. Additionally, the intercept coefficient is surprisingly low, though statistically significant. Diagnostics results (Table 2.12 and Appendix B) indicate that model coefficients are not reliable due to heteroskedasticity and abnormality of the distribution of the residuals.

Such results are probably due to high volatility (largely due to administrative regulations) in housing, water, electricity, gas, and other fuels prices as this segment exhibits significantly higher absolute residuals. Interestingly, the cross-section dependence test has shown that there is no cross-dependence in residuals in the model. This indicates that different segments of consumer products and services differ significantly in market structure and their sensitivity to foreign exchange rate and monetary policy.

Table 2.12 Diagnostics of the consumer prices model

Test	Comment
Regression equation significance	Prob(F-statistic): 0.000. At least one of the independent variables has a statistically significant effect on the dependent variable.
Degree of explanation of the dependent variable variance	R-squared: 0.958. The independent variables explain 95.8% of the variance of the dependent variable. This is largely because we have incorporated the lagged values of consumer inflation in the model specification.
Autocorrelation	Durbin-Watson: 2.125. There is no first-order autocorrelation of the residuals in the model.
Heteroskedasticity	The model was re-estimated without fixed effects for conducting the heteroskedasticity test. In both panel cross-section heteroskedasticity LR test and panel period heteroskedasticity LR test the null hypothesis of residuals being homoscedastic is rejected.
Multicollinearity	The policy rate correlation with consumer price index is rather low (-0.027), while the nominal exchange rate has a higher degree of association with consumer price (-0.235). Overall, there is a high chance of multicollinearity due to a high correlation between the lags of the consumer price index and relatively higher absolute correlation between NEER and the policy rate.
Normality of the residual's distribution	Prob(Jarque-Bera): 0.000. We reject the null hypothesis that residuals are normally distributed.
Fixed effects redundancy	Prob(Cross-section F): 0.002; Prob(Cross-section Chi-square): 0.002. We reject the null hypothesis that cross-section fixed effects are redundant.
Correlated random effects	Prob(Hausman test: cross-section random): 0.000. Fixed effects should be used [54].
Cross-section dependence	All three statistics of the residual cross-section dependence test indicate that we should not reject the null hypothesis of cross-dependence (correlation) in residuals being absent.

Source: developed by the author

For reliable coefficient estimation we have decided to change the estimation method from ordinary panel least squares to robust least squares. According to EViews tutorials M-estimation [55] of robust least squares “addresses dependent variable outliers where the

value of the dependent variable differs markedly from the regression model norm” [56] and this corresponds to the problem we have faced. The results are displayed in Figure 2.17 (c_price_index corresponds to consumer price index).

Dependent Variable: C_PRICE_INDEX				
Method: Robust Least Squares				
Date: 04/12/23 Time: 10:21				
Sample (adjusted): 2017M01 2022M02				
Included observations: 744 after adjustments				
Method: M-estimation				
M settings: weight=Bisquare, tuning=4.685, scale=MAD (median centered)				
Huber Type I Standard Errors & Covariance				
Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	-2.294012	0.516464	-4.441768	0.0000
C_PRICE_INDEX(-1)	1.232030	0.016215	75.98199	0.0000
C_PRICE_INDEX(-2)	-0.253276	0.015854	-15.97584	0.0000
POLICY_RATE(-12)	-0.025710	0.005961	-4.313455	0.0000
LOG(NEER)	-2.594966	0.473647	-5.478693	0.0000
Robust Statistics				
R-squared	0.769027	Adjusted R-squared	0.767776	
Rw-squared	0.991801	Adjust Rw-squared	0.991801	
Akaike info criterion	1063.137	Schwarz criterion	1088.167	
Deviance	426.4018	Scale	0.635713	
Rn-squared statistic	80179.80	Prob(Rn-squared stat.)	0.000000	
Non-robust Statistics				
Mean dependent var	8.226478	S.D. dependent var	7.333638	
S.E. of regression	1.547812	Sum squared resid	1770.438	

Figure 2.17 – Consumer prices model with robust least squares

Source: calculated by the author in EViews 12

Consequently, the policy rate coefficient has become statistically significant with 99% confidence as its standard deviation has decreased abruptly. The intercept coefficient has decreased significantly in absolute terms, the same is true about the coefficient of logarithm of NEER. After the re-estimation we can rely on model coefficient. We observe that consumer prices are weakly related to the monetary policy with 1 percentage point increase in the key policy rate decelerating inflation 12 months later by 0.026 percentage points. On the other hand, exchange rate dynamics affect consumer prices quickly and strongly: 1% of the foreign exchange rate appreciation results in the deceleration of inflation by 2.59 percentage points in the same month. This is in line with the results of Zholud et al (2019) [25].

For industrial price dynamics we use data on 21 price indices that are included in the industrial PPI calculation (2016M1-2022M2). The results of the estimation of the panel

regression for industrial prices are displayed in Table 2.13. As we can see, industrial prices are also highly persistent.

Table 2.13 Model estimation results (industrial prices)

Dependent variable: Industrial price index				
Variable	Coefficient	S.D.	t-stats	Prob.
Intercept	-23.774	7.085	-3.356	0.001
Industrial price index (-1)	1.227	0.026	46.648	0.000
Industrial price index (-2)	-0.311	0.027	-11.453	0.000
Policy rate (-4)	-1.596	0.327	-4.888	0.000
Policy rate (-6)	1.247	0.308	4.056	0.000
Log (NEER (-1))	13.741	6.343	2.166	0.031
Log (NEER (-5))	-40.915	9.036	-4.528	0.000
Total panel (balanced) observations: 1428				

Source: calculated by the author in EViews 12

The influence of the monetary policy on such prices is higher than on consumer price and is characterized by a smaller delay (the fourth and the sixth lags are both statistically significant, and if we take a sum of their coefficients the total effect on industrial prices is negative which is in line with our expectations). The influence of the foreign exchange rate requires a longer delay than with consumer prices, but it is still highly significant.

Diagnostics results (Table 2.14 and Appendix C) again indicate that model coefficients are not reliable due to heteroskedasticity and abnormality of the distribution of the residuals. Probably, this is due to high mining and electricity prices volatility because the absolute values of residuals are the highest for these sectors. Additionally, we observe that in this case the cross-section dependence test indicates that the cross-sections are correlated. This is a valuable insight as it shows that industrial prices (except some outliers) have more similarities in their drivers comparing with consumer prices.

During the re-estimation of the model with robust least squares it has been found that our initial choice of the lags for independent variables was wrong. As a result of further

research, model specification has been changed (Figure 2.18). I_price_index corresponds to industrial price index, while hh_expectations – inflation expectations of the households.

Table 2.14 Diagnostics of the industrial prices model

Test	Comment
Regression equation significance	Prob(F-statistic): 0.000. At least one of the independent variables has a statistically significant effect on the dependent variable.
Degree of explanation of the dependent variable variance	R-squared: 0.895. The independent variables explain 89.5% of the variance of the dependent variable. This is largely because we have incorporated the lagged values of industrial inflation in the model specification.
Autocorrelation	Durbin-Watson: 1.987. There is no first-order autocorrelation of the residuals in the model.
Heteroskedasticity	In both panel cross-section heteroskedasticity LR test and panel period heteroskedasticity LR test the null hypothesis of residuals being homoscedastic is rejected.
Multicollinearity	The correlation between the industrial price index and all independent variable other than the lagged values of the dependent variable are low (in absolute terms <0.3). Also, there are relatively higher correlations between lags of the policy rate, and between lags of the foreign exchange rate. Thus, there is a higher probability of multicollinearity.
Normality of the residual's distribution	Prob(Jarque-Bera): 0.000. We reject the null hypothesis that residuals are normally distributed.
Fixed effects redundancy	Prob(Cross-section F): 0.599; Prob(Cross-section Chi-square): 0.584. We do not reject the null hypothesis that cross-section fixed effects are redundant.
Correlated random effects	Prob(Hausman test: cross-section random): 0.009. Fixed effects should be used instead of random, but considering the result above, we do not use them either.
Cross-section dependence	All three statistics of the residual cross-section dependence test indicate that we should reject the null hypothesis of cross-dependence (correlation) in residuals being absent.

Source: developed by the author

Dependent Variable: I_PRICE_INDEX				
Method: Robust Least Squares				
Date: 04/12/23 Time: 10:01				
Sample (adjusted): 2016M06 2022M02				
Included observations: 1449 after adjustments				
Method: M-estimation				
M settings: weight=Bisquare, tuning=4.685, scale=MAD (median centered)				
Huber Type I Standard Errors & Covariance				
Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	0.612050	1.281951	0.477436	0.6331
I_PRICE_INDEX(-1)	1.069810	0.005964	179.3697	0.0000
I_PRICE_INDEX(-2)	-0.045134	0.006134	-7.358136	0.0000
POLICY_RATE(-1)	-0.184093	0.016092	-11.44008	0.0000
LOG(NEER(-2))	3.739570	1.497455	2.497284	0.0125
LOG(NEER(-5))	-4.405353	1.546681	-2.848263	0.0044
HH_EXPECTATIONS	0.086411	0.023313	3.706544	0.0002
Robust Statistics				
R-squared	0.601132	Adjusted R-squared	0.599472	
Rw-squared	0.989299	Adjust Rw-squared	0.989299	
Akaike info criterion	2892.740	Schwarz criterion	2933.432	
Deviance	10117.23	Scale	1.873474	
Rn-squared statistic	261365.5	Prob(Rn-squared stat.)	0.000000	
Non-robust Statistics				
Mean dependent var	15.70041	S.D. dependent var	27.90803	
S.E. of regression	9.719643	Sum squared resid	136227.8	

Figure 2.18 – Industrial prices model with robust least squares

Source: calculated by the author in EViews 12

Similarly to the consumer prices model, the absolute level of the intercept coefficient has fallen sharply after the re-estimation. The results indicate that the exchange rate channel is the most significant for industrial prices with 1% foreign exchange appreciation resulting in roughly 0.66 percentage points (-4.40 + 3.74) inflation deceleration five months later. However, the foreign exchange channel has been found to be less significant for industrial prices than for consumer prices. Interest rate channel is still weaker than the foreign exchange channel, but it is much more significant for industrial prices dynamics than for consumer prices with 1 percentage point increase of the policy rate resulting in inflation deceleration of 0.18 percentage points one month later. Interestingly, household inflation expectations have been found to be statistically significant independent variable for explaining industrial, but not consumer prices. As we can see, the increase in inflation expectations of the households by 1 percentage point results in industrial inflation accelerating by 0.08 percentage points in the same month.

Conclusions to Chapter 2

Thus, in this chapter we have seen that consumer and industrial prices have exhibited significant volatility over the last decade and a half, higher comparing with neighboring countries. The sources of such volatility are external shocks (global financial crisis, ongoing russia-ukrainian war), high share of agricultural products, especially imported ones, in consumer set, and Ukraine's dependence on imported energy sources.

The monetary policy rate transmission has been the strongest for loans and deposits to non-financial corporations with maturity in less than 1 year, short-term households' deposits and government bond yields. And these financial instruments have had the most significant volumes in their respective segments which indicate a strong basis for the proper functioning of the monetary policy transmission. Conversely, since the beginning of the full-scale russian invasions the strength of the relationship between the monetary policy and all market interest rates has decreased as a lot of market players have questioned NBU's decision to increase the key policy rate to 25%. The results have also shown that inflation expectations of all economic agents stay to a greater extent backward-looking than forward-looking.

Overall, it has been found that foreign exchange rate channel has the quickest and strongest impact on consumer prices. Interest rate channel has been found to be statistically significant, but its influence is still negligible. Also, it requires around 12 months for the key policy rate to affect consumer prices. Additionally, it has been found that foreign exchange rate channel is the most impactful for industrial prices, but its effect is less strong than in the case of consumer prices and takes from 3 to 5 months to manifest itself. At the same time, interest rate channel has been found to be more influential for industrial, than for consumer prices. Inflation expectations channel has been found to be significant for industrial inflation, but not for consumer inflation.

CHAPTER 3

EVALUATION OF THE SUCCESSFULNESS OF INFLATION-TARGETING IN UKRAINE

3.1 Problem identification and dynamic hypothesis

The main goal of this research section is to evaluate whether inflation-targeting has been more successful in decelerating and decreasing the volatility of inflation comparing with fixed exchange rate. Figure 3.1 summarizes the historical behavior of key performance indicators over time. The data on inflation expectation of the households was taken for the variable of expected inflation. Inflation in Figure 3.1 corresponds to headline CPI (YoY).

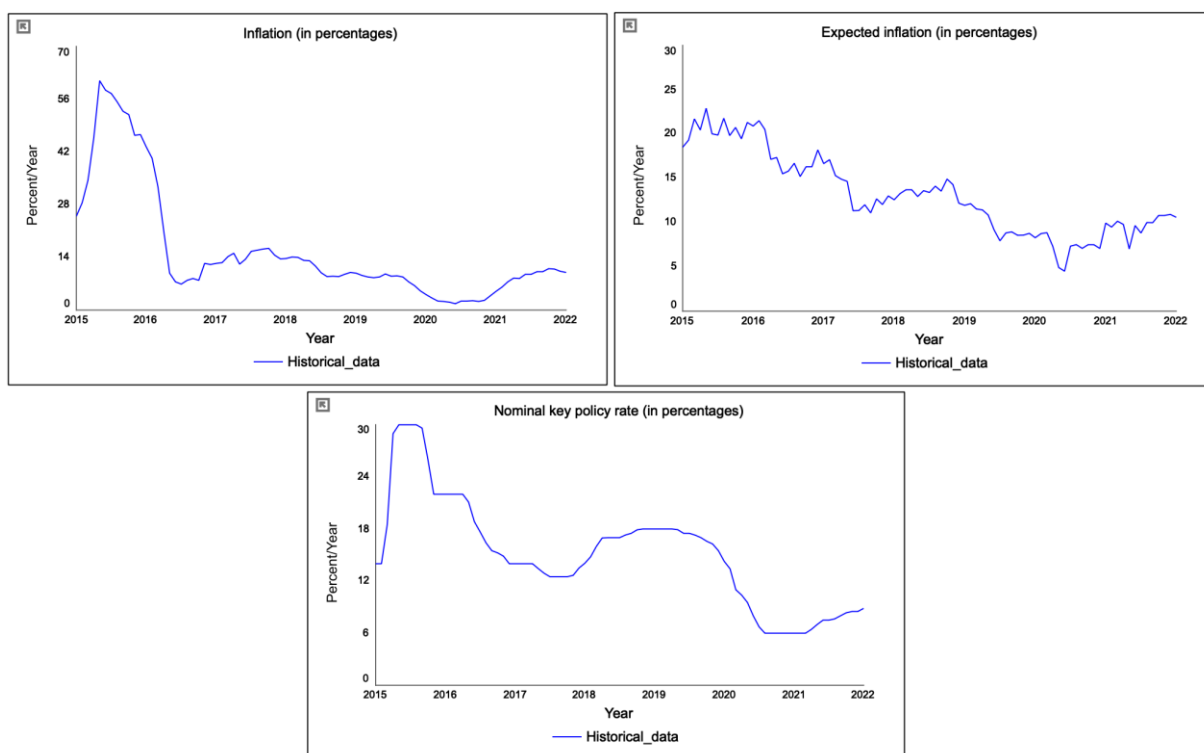


Figure 3.1 – Reference mode of behavior

Source: NBU data

The general approach used for modeling the causal relationships in a national economy follows the design of “a semi-structural, forward-looking New-Keynesian model of a small open economy” [27] that is used by the NBU for medium-term forecasting of key

macroeconomic variables. Also, the research of David Wheat [57] on modeling macroeconomics with system dynamics tools was a great source of inspiration for the development of this model.

There are 8 sectors in the model. Each of them represents either a part of a national or a foreign economy.

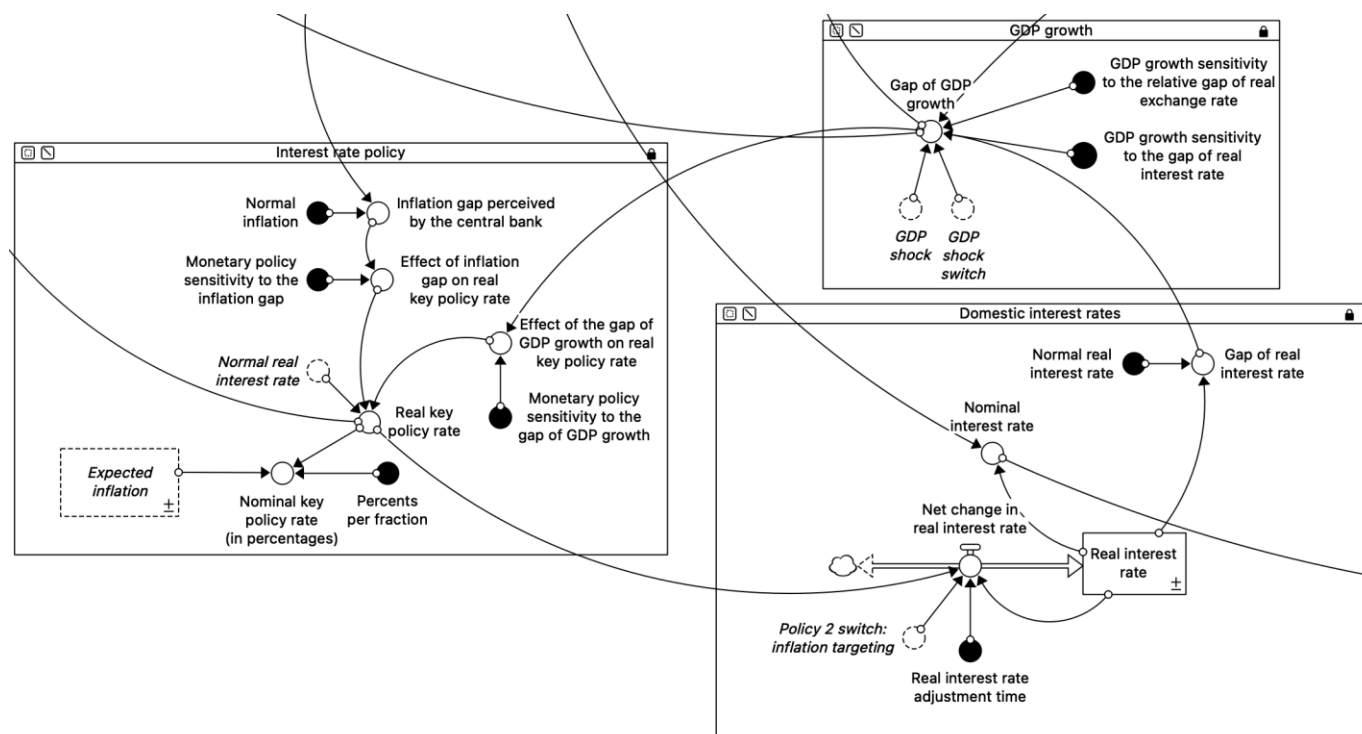


Figure 3.2 – Interest rate policy, GDP growth and domestic interest rates sectors

Source: developed by the author in Stella Architect

In Figure 3.2 the first three sectors are displayed. We start with the assumptions concerning domestic interest rates. It is assumed that inflation expectations are the same for all economic agents in an economy (which is an obvious simplification, but this is a simple model of a national economy) and for foreign investors too. The sum of the expected inflation and the required real interest rate is the required nominal interest rate in the economy. Normal real interest rate is assumed to be equal to 3% per year as it is estimated by the NBU that the neutral real interest rate in a steady state for Ukraine is 3% [27]. The neutral rate is the normal rate because at such a level the monetary conditions are neither tight, nor accommodating [58;59]. Additionally, it is assumed that the real interest rate

changes only if a central bank is changing its policy rate. And the policy rate of a central bank is a goal for real interest rate in the economy.

In the GDP growth sector real monetary conditions (real interest rate) and real conditions of international trade (real exchange rate gap) define the rate of change in GDP instantaneously. GDP growth sensitivities to the mentioned factors are assumed to be equal -0.035 and -0.065 respectively. The NBU modelers in the paper on the quarterly projection model for Ukraine [27] use these values and argue with a reference to another paper [60] that a reasonable range of the sum of absolute GDP growth sensitivity to the relative gap of real exchange rate and absolute GDP growth sensitivity to the gap of real interest rate is $0.1 - 0.4$. And this sum represents the pass-through from real monetary conditions to output gap. In the case of Ukraine, this pass-through "is on the lower bound of this range, which means there is a relatively low impact of monetary policy" [27]. And GDP growth sensitivity to the relative gap of real exchange rate is higher than GDP growth sensitivity to the gap of real interest rate, because of "the greater importance of the exchange rate channel [of the transmission mechanism] in the open Ukrainian economy" [27]. This is also in line with our findings from Chapter 2.

Interest rate policy sector represents a decision rule of a central bank. Monetary policy sensitivity to the gap of GDP growth is assumed to be equal 0.4 [27]. The lower bound for this parameter is equal to 0 , because usually, central banks are not willing to increase the interest rates to react to the positive gap of GDP growth as there are debates about whether the actual rate of GDP growth is higher or lower than the growth of the potential GDP. The upper bound for this parameter can't be higher than the lower bound for monetary policy sensitivity to the inflation gap because price stability is the overriding goal of monetary policy. Monetary policy sensitivity to the inflation gap is assumed to be equal to 2 [27]. This parameter probably can't be less than 1 , because in emerging economies the financial depth of the country is low, and it requires quite significant changes in interest rates to affect the real production and inflation. Also, because of high volatility, various risk premiums, and high dependence of domestic businesses, particularly of banks, on loans in foreign currency,

the transmission of the changes in the key policy rate into market interest rates could be incomplete, which will increase the need of higher sensitivity of monetary policy to the inflation gap. The upper bound is around 3 because too high sensitivity of monetary policy to inflation gap in real world might significantly restrain economic development, which would lead to dissatisfaction of the population with the policy of a central bank, which will cause the change of management in the central bank and less sensitive monetary policy. Normal inflation for the period under consideration (2016 - 2022) is assumed to be equal 13% annually. This value is higher than the current medium-term inflation target because the targeted rate of inflation has been gradually decreased in 2016-2019. There is also a simplifying assumption that there is no persistence in the reaction function of a central bank.

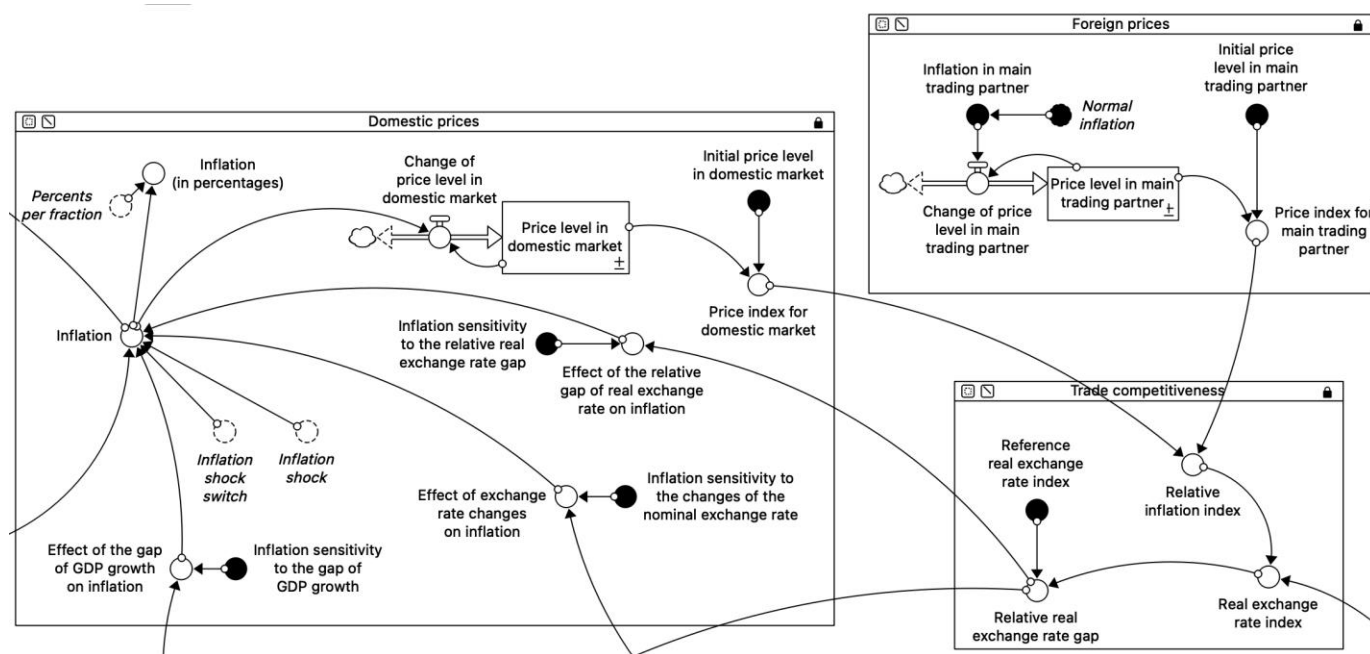


Figure 3.3 – Domestic prices, foreign prices, trade competitiveness sectors

Source: developed by the author in Stella Architect

In the domestic prices sector (Figure 3.3) it is assumed that inflation sensitivity to the changes in the nominal exchange rate is -0.05 as in the paper on the quarterly projection model for Ukraine [27] a respective parameter in the core inflation specification is calibrated to be equal -0.05 . Similarly, the inflation sensitivity to the gap of GDP growth is equal to

0.18, while inflation sensitivity to the relative real exchange rate gap is assumed to be equal -0.06.

For simplicity, we assume that there are only two currencies (two countries) in the world in this model. Thus, there exist only a national economy and an abstract version of main trading partners. Inflation in the foreign currency is constant and equal to the normal inflation for domestic economy, which is why in equilibrium the inflation rates are the same in two economies. This is a simplification, because we are not considering the difference of the level of technology in two countries, and do not consider the difference between emerging markets and developed economies. A trade competitiveness sector is needed for the purposes of real exchange rate calculations.

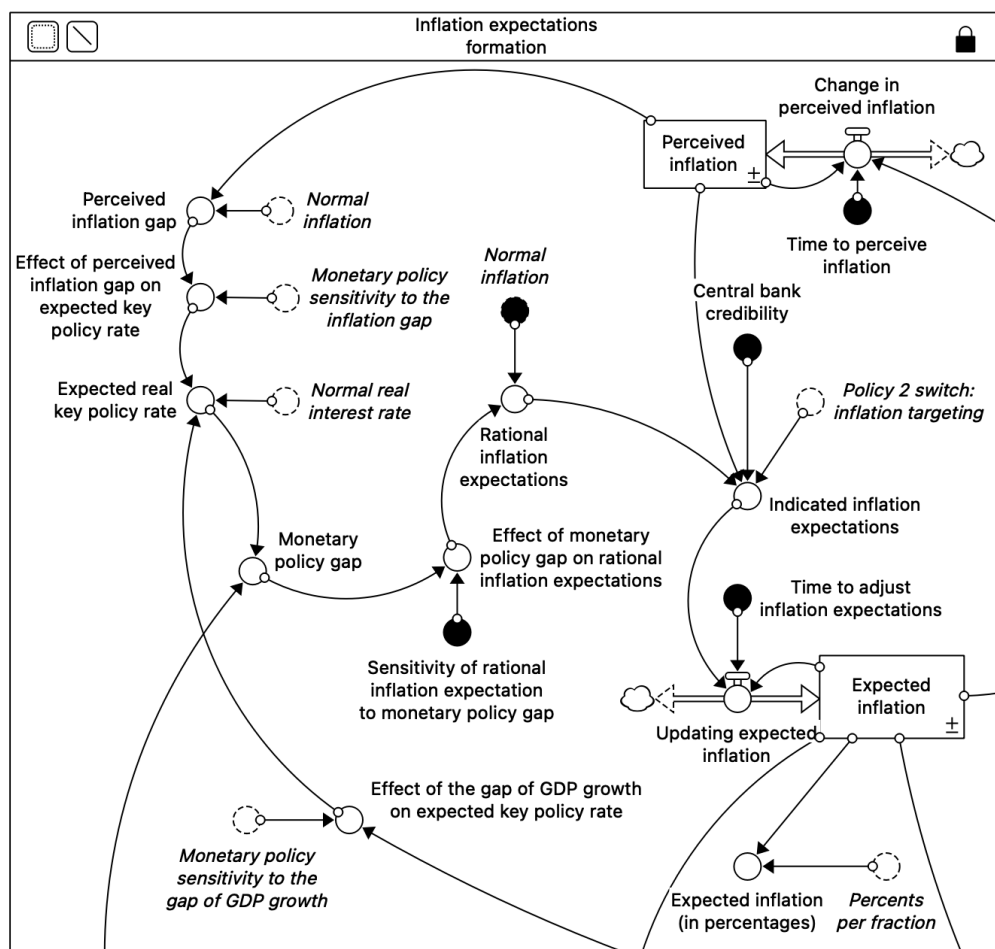


Figure 3.4 – Inflation expectations formation sector

Source: developed by the author in Stella Architect

Most important component of the inflation formations sector (Figure 3.4) is central bank credibility parameter. In the paper on the quarterly projection model for Ukraine [27] this parameter is assumed to be equal to 0.75 (the weight of backward-looking inflation expectations is 0.25, while the weight of forward-looking inflation expectation is 0.75), but during the calibration it was found that this value should be much lower, around 0.15. It makes more sense to assume that the central bank credibility is closer to its lower bound as the central bank of Ukraine has experienced severe decrease of trust in 2014-2015 and there have been major changes in the regulations about the central bank and its mandate in Ukraine.

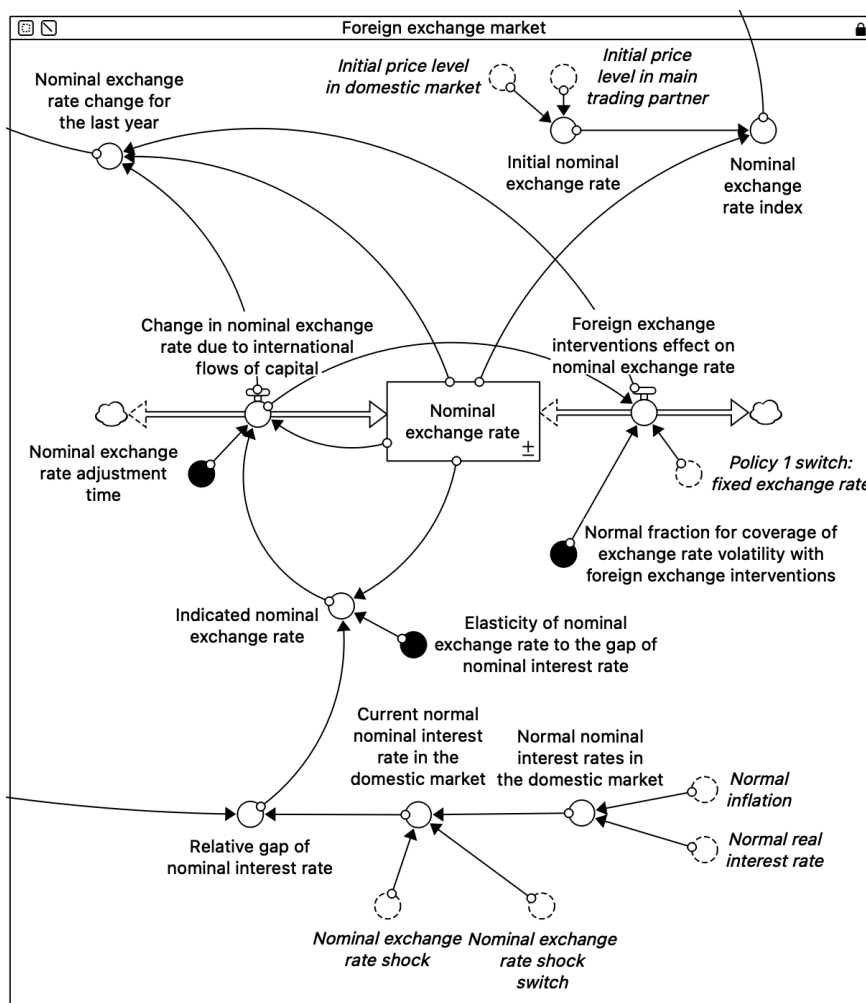


Figure 3.5 – Foreign exchange market

Source: developed by the author in Stella Architect

In the foreign exchange market (Figure 3.5) we assume that the nominal exchange rate sensitivity to the gap of nominal interest rate is around 0.25, because the effect of international flows of capital on the nominal exchange rate covers only one segment of the foreign exchange market and we are interested in the dynamics of this specific segment (demand and supply for money from investors). Other segments (e.g., balance of trade effects and the demand for foreign currency as an asset for holding by the population) are outside the boundary for this model and are assumed to have a neutral effect on the foreign exchange market during the simulation.

In this model the nominal exchange rate can change either because of international flows of capital (which can either increase or decrease the price of the national currency depending on the willingness or unwillingness of foreign investors to invest in the domestic economy) or because of foreign exchange interventions by the central bank (that are aimed at reducing nominal exchange rate volatility). This is a simplification, because there are other factors affecting nominal exchange rate like the revenues of exporters and the need for foreign currency to pay for imported goods. Because of the assumption that there are only 2 countries in the world of this model, the stock of the nominal exchange rate can also be considered a nominal effective exchange rate (NEER).

The nominal exchange rate adjustment time is assumed to be equal to 1 year because Ukraine has a shallow financial market. Normal fraction for coverage of exchange rate volatility with foreign exchange interventions equals to 0.15 (the same as in the paper on the quarterly projection model [27]).

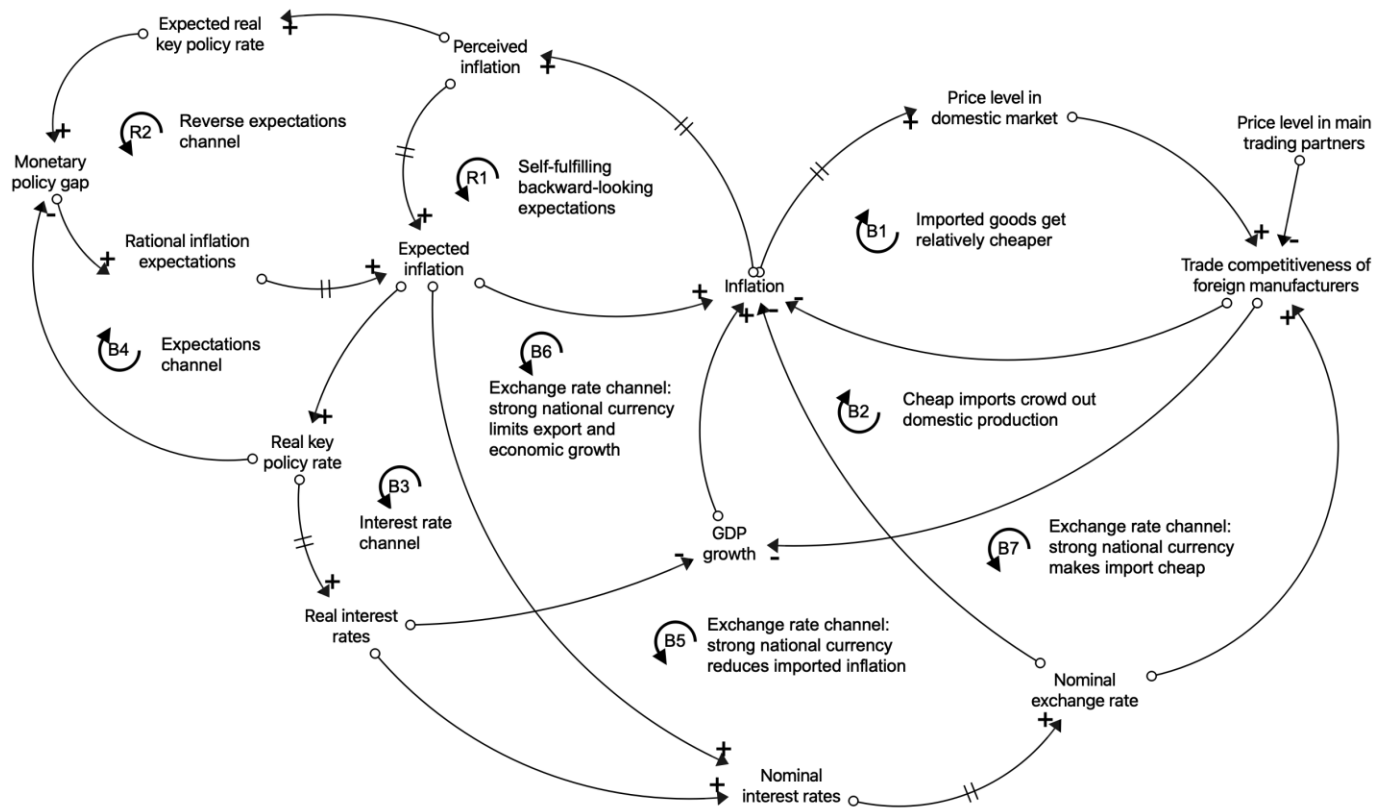


Figure 3.6 – Causal Loop Diagram for key feedback mechanisms

Source: developed by the author in Stella Architect

Now that we have described the structure of the model, we will move to the dynamic hypothesis about the key structural relationships that drive the behavior of our system. The most important feedback loops integrated in the model are summarized in the form of a causal loop diagram (Figure 3.6). First, we should discuss the mechanisms that are independent of monetary policy of any type.

Self-fulfilling backward-looking expectations (R1). It is assumed that inflation expectations have persistent nature and are affected by the historical events which the population has seen. In Business Dynamics (chapter 16, section 16.4) [61] J. Sterman shows that expectations about prices tend to be primarily dependent on the past even when there is an abundance of complex methods for inflation forecasting. At the same time, the actual price changes are heavily dependent on inflation expectations, because manufacturers account for expectations when they set their prices.

Imported goods get relatively cheaper (B1). Ukraine is a relatively small economy, but at the same time it is extensively involved in international trade (the ratio of exports and imports to GDP has rarely fallen below 80% over the last few decades). Due to that, the inflation in the main trading partners of Ukraine affects the dynamics of prices in Ukraine through its effects on the relative trade competitiveness of foreign and domestic manufacturers. For example, if for a long period of time inflation stays higher in Ukraine than in the main trading partners, prices of goods and services of foreign firms will become very attractive for households in Ukraine. They will buy more imported goods and services and the general price level in the domestic economy will move towards the world price level (with the adjustments for the changes in the nominal exchange rates).

Cheap imports crowd out domestic production (B2). This feedback loop is like B1, but here the influence of trade competitiveness on GDP growth is also considered. If we take the previously mentioned example of high persistent inflation in the domestic market, then we can also add that the increase in the demand for imported goods and services will decrease the demand for domestic ones. Also, exporters would not be able to sell as much as before in the foreign markets, because their prices became relatively high. As a result, GDP in the domestic economy will decrease and it will lead to a reduction in the demand-driven pressure on inflation.

Secondly, we need to discuss the feedback processes that are added when a central bank is using inflation-targeting monetary policy regime. Here we repeat some of the concepts described in Chapter 1 to stress the ones that are present in the model.

Interest rate channel (B3). When the forecasted inflation is higher than the inflation target, a central bank must increase its key policy rate. Real interest rates in the economy will increase as well because the key policy rate represents the cost of short-term borrowing for commercial banks. As a result, it will become more costly for firms to borrow money. Thus, investments will fall, and GDP growth will slow down. Slower GDP growth means less competition for resources in the domestic economy and smaller final demand, which would lead to a deceleration of inflation.

Expectations channel (B4). One of the key characteristics of inflation-targeting is public communication of the inflation target. A central bank is trying to convince the population that its actions will lead to the stabilization of inflation around the targeted rate in the medium term (1-2 years). And if a central bank is acting according to its vows, then the expected inflation will approach the inflation target.

Reverse expectations channel (R2). Conversely, if the actual actions of a central bank contradict the expected actions, inflation expectations will destabilize.

Exchange rate channel. It is assumed that higher interest rates in the domestic economy attract foreign investors, which is why the nominal exchange rate appreciates. This has a direct effect on inflation because the prices for imported goods become relatively lower (B5). At the same time, the appreciation of national currency increases the demand for foreign goods and services, which limits GDP growth (B6) and increases the proportion of relatively cheap imports in consumption (B7).

As you might have noticed, the credit channel and the asset prices channel are not represented in the model due to their low influence in Ukraine.

3.2 Model validation and analysis

A series of validation tests were performed to ensure that the model design correctly represents the main processes that are present in the real economy. Tests were designed following the recommendations of Y. Barlas [62].

The structure of the model was developed as it was already mentioned based on the forecasting model that in its turn had been developed relying on modern mainstream macroeconomic thought. Rational inflation expectations were added to the sector of inflation expectations to make the expectations channel of the monetary transmission mechanism more explicit compared to the econometrics model. Most of the values for constant parameters in the model are taken from the quarterly projection model for Ukraine [27]. The values for other constant parameters are based either on assumptions or on the hand

calibration of the model to historical data on inflation, inflation expectations, and the policy rate in Ukraine in 2015-2021 (calibration was used for estimation of the central bank credibility and normal inflation). The model is dimensionally consistent both mathematically and conceptually. But it should be mentioned that some of the model parameters represent aggregated effects which makes them more abstract, which is why their real-world meaning is obscured to some extent. Unfortunately, it was necessary for the correct translation of the econometrics model into system dynamics.

During extreme conditions tests, it was found that the elasticity of the nominal exchange rate to the gap of the nominal interest rate must be in the range of 0.125 and 0.5 representing the fact that international capital flows capture only one segment of the foreign exchange market while others (e.g., trade deficit) are assumed to be outside of the model boundary. Overall, the obtained results of extreme conditions tests were reasonable and expected.

The model was tested with two integration methods: Euler and Runge-Kutta 4. The smallest time constant used in the model is 1/12 of the year (i.e., 1 month), which is why the initial time step used for the integration error test with Euler integration method was 1/32. It is a value that can be calculated by taking 2 to an integer power, which is why the additional rounding errors are not added, and it is more than two times smaller than the smallest time constant used in the model. Runge-Kutta 4 integration method with a timestep of 1/128 was chosen because even relatively small integration errors might affect the conclusions about the simulation results for the chosen problem area, especially when it comes to the comparison of the simulation results with a fast deceleration of inflation in 2015-2016 in Ukraine. The model behavior stays the same with half (1/64) and double (1/256) timestep.

Validation: sensitivity analysis

The model's sensitivity analysis is divided into 4 parts. The first three parts explore the sensitivity of key performance indicators to different values of individual parameters, and the parameters are separated into three groups because their involvement in the system behavior depends on the monetary policy regime that is used by a central bank. Also, policy

sensitivity tests were conducted to explore the model sensitivity to constant parameters under different monetary policy regimes. The last part of the sensitivity analysis includes a global sensitivity test. No table functions are used in the model.

Table 3.1 Summary of results of the sensitivity tests for the parameters that are influencing the system independently of the monetary policy regime

Parameter [unit]	Range			Sensitivity	Uncertainty about the actual value
	Min	Used in the model	Max		
Time to perceive inflation [Year]	0.042	0.083	0.250	Numerical	Low
Time to adjust inflation expectations [Year]	1.000	2.000	4.000	High Numerical / Policy	High
GDP growth sensitivity to the relative gap of real exchange rate [(dmnl/Year)/(dmnl/Year)]	-0.400	-0.065	-0.010	Numerical	Average
Inflation sensitivity to the gap of GDP growth [(dmnl/Year)/(dmnl/Year)]	0.040	0.180	0.360	Numerical	Average
Inflation sensitivity to the relative real exchange rate gap [dmnl/Year]	-0.200	-0.060	-0.010	High Numerical / Policy	Average
Normal inflation [dmnl/Year]	0.010	0.130	0.250	Numerical	Average
Normal real interest rate [dmnl/Year]	0.015	0.030	0.060	Numerical	Average
Initial price level in domestic market [Units of national currency]	0.500	1.000	2.000	No	Low
Initial price level in main trading partner [Units of foreign currency]	0.500	1.000	2.000	No	Low

Source: calculated by the author in Stella Architect

Parameters that are influencing the system independently of the monetary policy regime (3 policy settings). This group consists of constant parameters that stay active under each of the scenarios described in this chapter. That is why they were tested under all three scenarios to investigate the possible presence of leverage points that are independent of the

monetary policy. Parameters were changed one at a time while other parameters remained the same for each of the tests in this part of the sensitivity analysis discussion. Stella's Model Analysis Tools were used with the following settings: Distribution – Uniform, Latin Hypercube sampling (Noise seed = 21), and 200 runs for each parameter under each scenario (monetary policy regime). The key results are presented in Table 3.1.

An important thing to note here, there is no observed sensitivity of inflation and inflation expectations to the initial price levels in domestic and foreign economies (economies of main trading partners) because it is assumed that the difference between the initial price levels directly defines only the initial nominal exchange rate and respective price levels, while the behavior of the key performance indicators is driven by the deviations of these variables from their initial levels. The results indicate that the model is most sensitive to two variables: the adjustment time of inflation expectations and inflation sensitivity to the relative real exchange rate gap.

The model shows both high numerical and policy sensitivity to the time to adjust inflation expectations parameter (Figure 3.7). This makes sense: if it takes longer to adjust inflation expectations then an ability of an exogenous shock to push inflation expectations higher would be limited (the reinforcing loop of self-fulfilling backward-looking expectation is weakened) and vice versa. Also, the results indicate that under inflation-targeting the development of inflation and inflation expectations show enhanced oscillatory behavior. This happens because the feedback loops that are added with inflation-targeting monetary policy regime force inflation to decelerate, while the actual monetary policy decisions are primarily dependent on the expected inflation which gets more volatile if there is a faster adjustment of the expectations. We could also see that under a combination of the monetary policy regimes (inflation-targeting and fixed exchange rate combined) oscillatory behavior is dampened. The reason for that is the fact that the fixed exchange rate makes the exchange rate channel of the monetary transmission mechanism inactive, which is why monetary policy becomes less effective in the deceleration of inflation. At the same time, it makes the

deceleration of inflation smoother. There is also quite significant uncertainty about the real value of this parameter, which is why future research on this topic seems necessary.

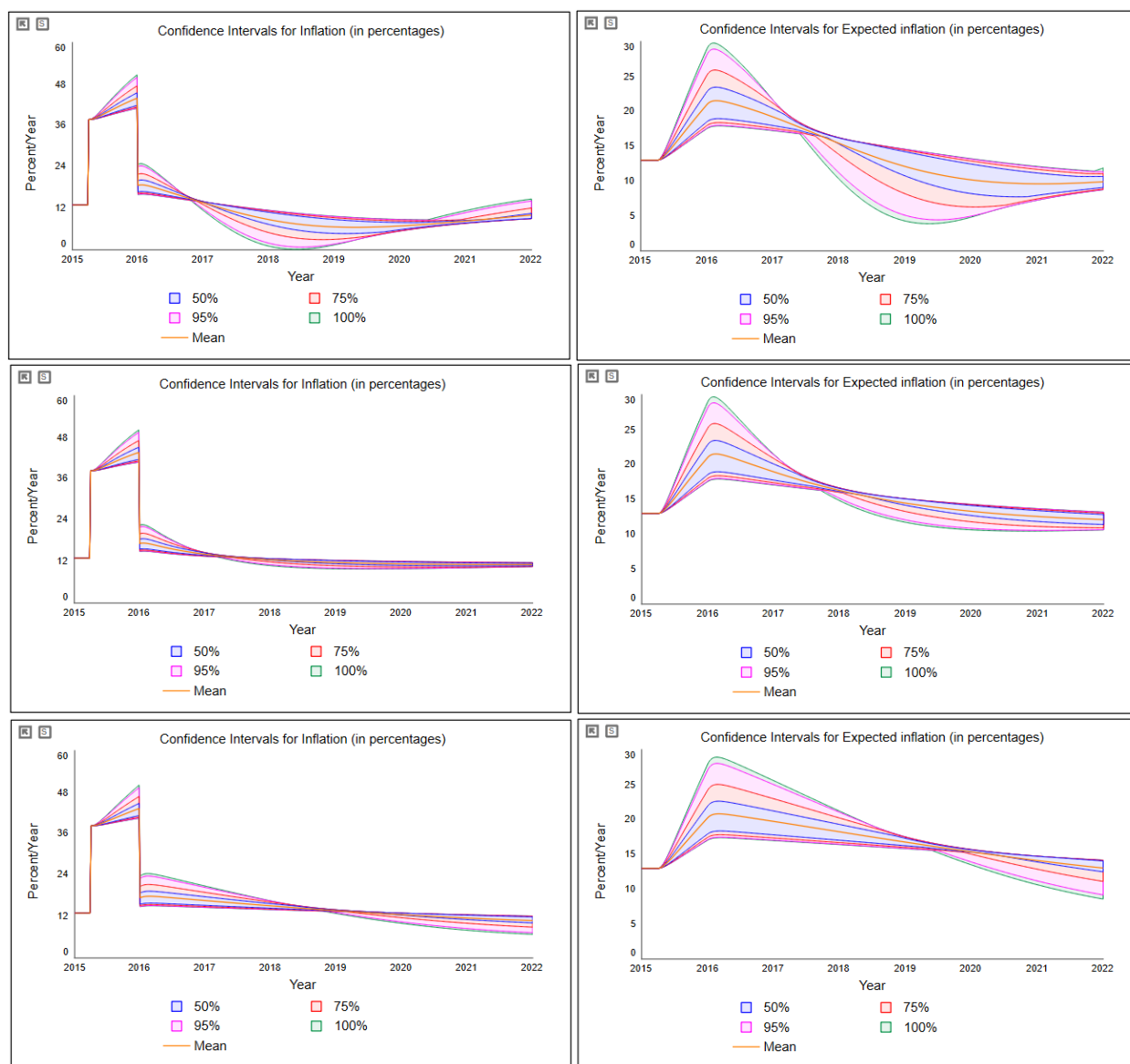


Figure 3.7 – Key performance indicators sensitivity to the time to adjust inflation expectations (range: 1 – 4 years) under: 1) inflation-targeting monetary policy regime; 2) fixed exchange rate monetary policy regime; 3) fixed exchange rate and inflation-targeting monetary policy regimes combined

Source: developed by the author in Stella Architect

The model shows both high numerical and policy sensitivity to the inflation sensitivity to the relative real exchange rate gap parameter (Figure 3.8). As it is discussed in the

documentation (Appendix D), this parameter represents the influence of marginal costs of importers for inflation.

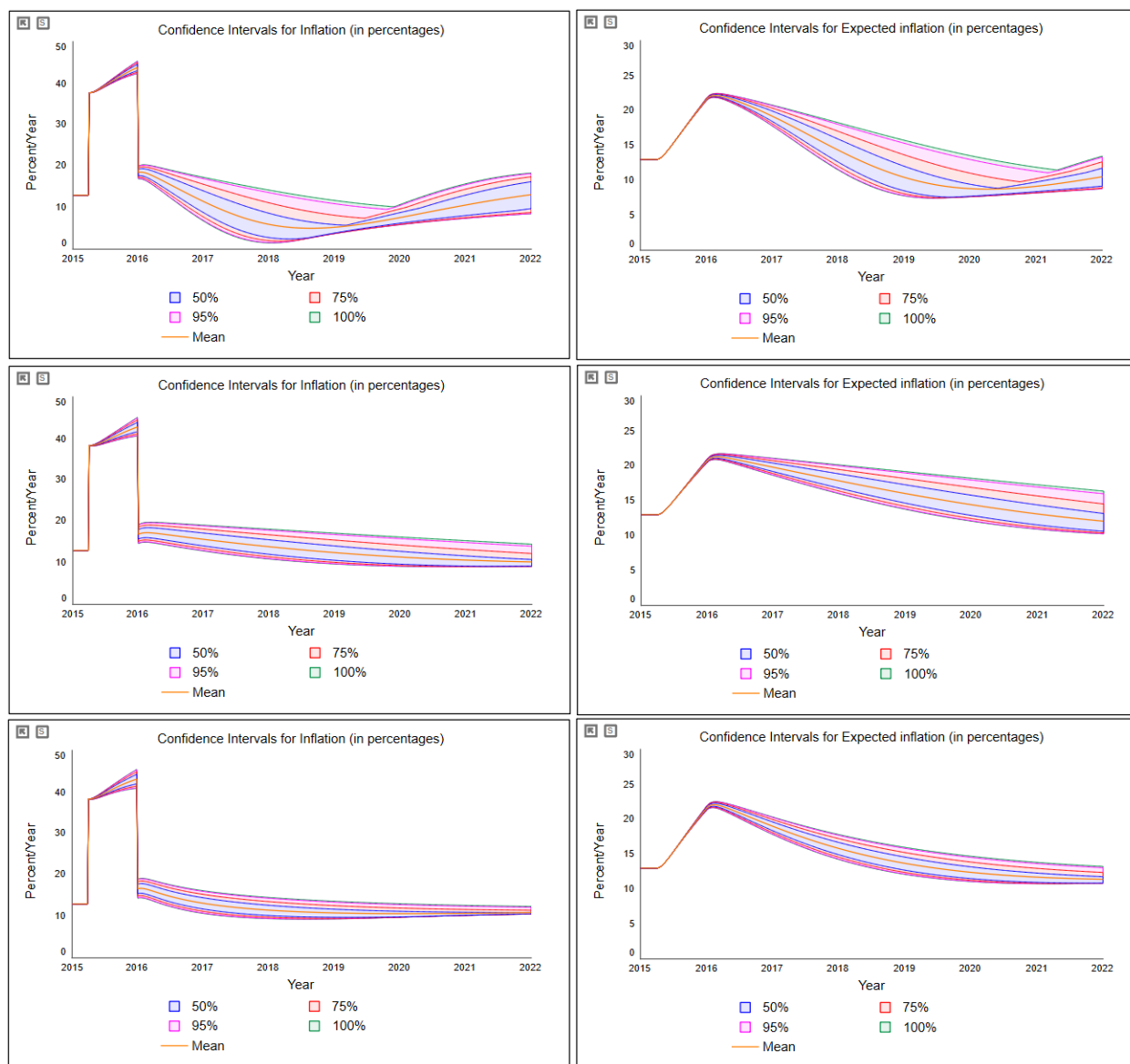


Figure 3.8 – Key performance indicators sensitivity to the inflation sensitivity to the relative real exchange rate gap (range: $(-0.2) - (-0.01)$) under: 1) inflation-targeting; 2) fixed exchange rate; 3) fixed exchange rate and inflation-targeting

Source: developed by the author in Stella Architect

And similarly to the adjustment time of inflation expectations, under inflation-targeting monetary policy regime, the variation of this parameter affects the amplitude of oscillations of the key performance indicators. The reason for that is the dependency of the

efficiency of the exchange rate channel of the monetary transmission mechanism on this parameter. A relatively large negative value of inflation sensitivity to the relative real exchange rate gap strengthens one of the balancing loops (B7 - Exchange rate channel: strong national currency makes import cheap) in the exchange rate channel, which is why monetary policy decisions affect inflation and inflation expectations faster.

Table 3.2 Summary of results of the sensitivity tests for the parameters that are introduced with inflation-targeting regime and stay active even if exchange rate is fixed

Parameter [unit]	Range			Sensitivity	Uncertainty about the actual value
	Min	Used in the model	Max		
Real interest rate adjustment time [Year]	0.250	0.500	1.500	Numerical	High
Monetary policy sensitivity to the gap of GDP growth [(dmnl/Year)/(dmnl/Year)]	0.000	0.400	1.000	Numerical	Average
Monetary policy sensitivity to the inflation gap [(dmnl/Year)/(dmnl/Year)]	1.000	2.000	4.000	High numerical / Policy	Average
GDP growth sensitivity to the gap of real interest rate [(dmnl/Year)/(dmnl/Year)]	-0.400	-0.035	-0.010	Numerical	Average
Sensitivity of rational inflation expectation to monetary policy gap [(dmnl/Year)/(dmnl/Year)]	0.500	1.000	2.000	Numerical	High
Central bank credibility [dmnl]	0.000	0.150	1.000	High numerical	High

Source: calculated by the author in Stella Architect

Parameters that are introduced with inflation-targeting regime and stay active even if exchange rate is fixed (2 policy settings). This group consists of constant parameters that stay active either under a pure inflation-targeting monetary policy regime or under a combination of inflation-targeting with the fixed exchange rate regime. Parameters

were changed one at a time while other parameters remained the same for each of the tests in this part of the sensitivity analysis discussion. Stella’s Model Analysis Tools were used with the following settings: Distribution – Uniform, Latin Hypercube sampling (Noise seed = 21), and 200 runs for each parameter under each scenario. The key results are presented in Table 3.2. Also, here we extend the number of key policy indicators and include the nominal key policy rate because this rate is the most important instrument of a central bank that is targeting inflation.

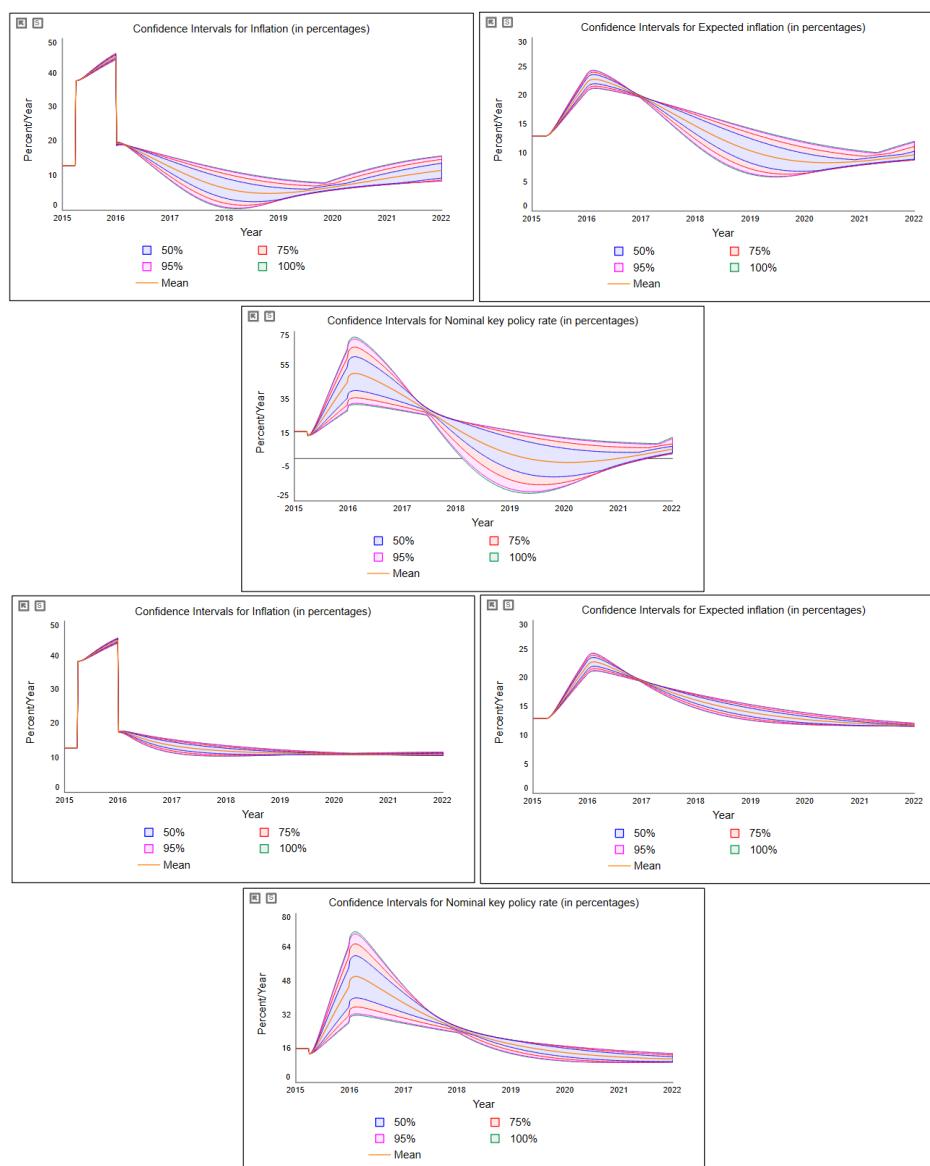


Figure 3.9 – Key performance indicators sensitivity to the monetary policy sensitivity to the inflation gap (range: 1 - 4) under: 1) inflation-targeting; 2) inflation-targeting and fixed exchange rate

Source: developed by the author in Stella Architect

The model shows relatively high numerical sensitivity to the monetary policy sensitivity to the inflation gap parameter under pure inflation targeting monetary policy regime (Figure 3.9). This is expected because higher monetary policy sensitivity to the inflation gap strengthens the link from the expected inflation to the real key policy rate, which is why the nominal key policy rate takes higher values faster and its effects on inflation appear faster as well.

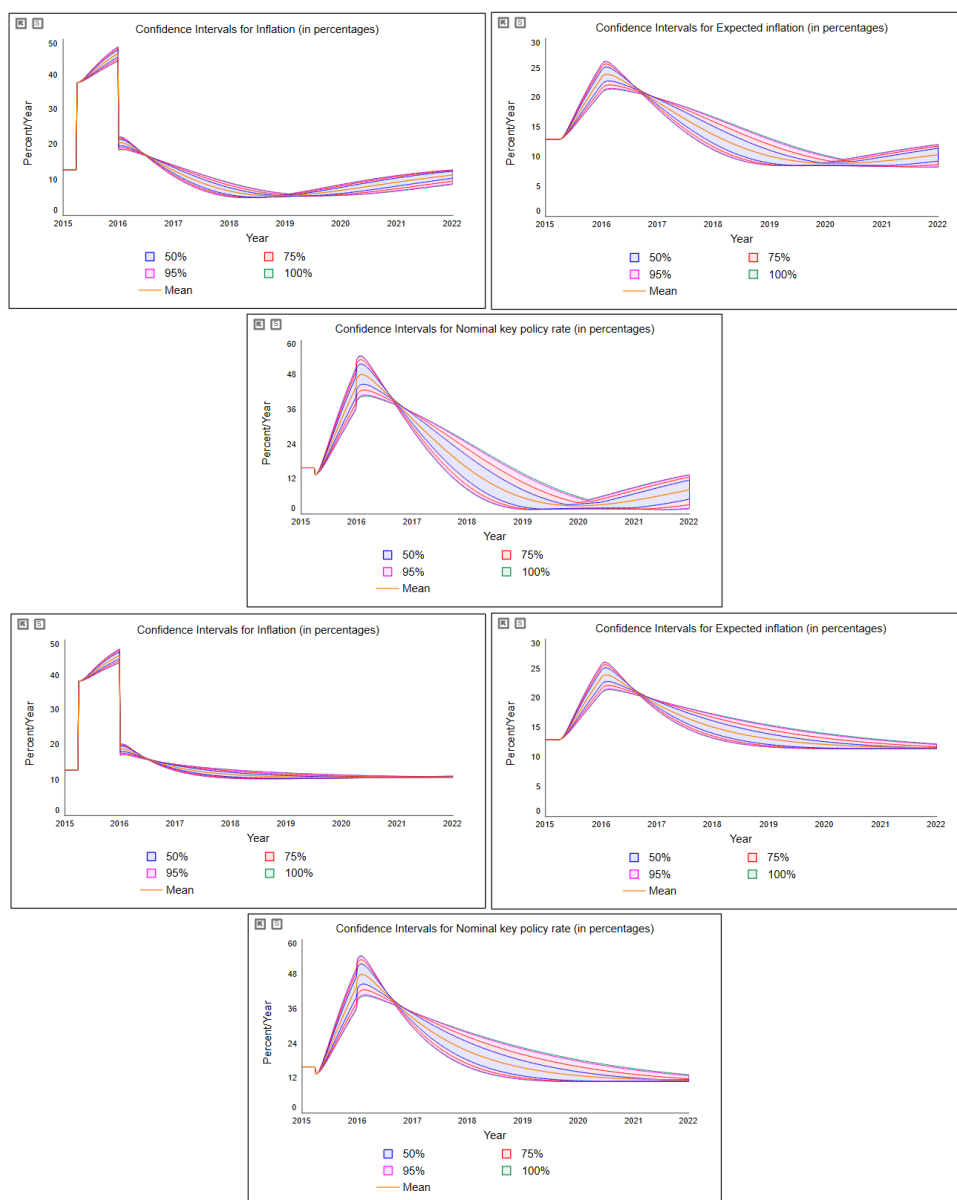


Figure 3.10 – Key performance indicators sensitivity to the central bank credibility (range: 0 - 1) under: 1) inflation-targeting; 2) inflation-targeting and fixed exchange rate

Source: developed by the author in Stella Architect

Under the combination of inflation-targeting and fixed exchange rate high numerical sensitivity is observable only for the nominal key policy rate, while inflation and inflation expectations do not change that much as under pure inflation-targeting. This is due to the inactivity of the exchange rate channel of the monetary transmission mechanism when the exchange rate is kept constant. In other words, even though the nominal exchange rate has already increased a lot, it does not affect inflation and inflation expectations that much. As a result, the deceleration of inflation is caused primarily by the loops that are not dependent on monetary policy (B1 – imported goods get relatively cheaper; B2 – cheap imports crowd out domestic production).

The model shows relatively high numerical sensitivity to the central bank credibility parameter under pure inflation-targeting (Figure 3.10). This happens because increased central bank credibility makes both B4 (“Expectations channel”) and R2 (“Reverse expectations channel”) feedback loops stronger. On the one hand, higher central bank credibility makes it easier to decrease inflation expectations as the population has trust in its central bank. On the other hand, inflation expectations become much more sensitive to monetary policy decisions and react faster to the discrepancies between the expected key policy rate and the actual one.

Parameters that become inactive if exchange rate is fixed. This group consists of constant parameters that stay active only if the nominal exchange rate is allowed by a central bank to float. Parameters were changed one at a time while other parameters remained the same for each of the tests in this part of the sensitivity analysis discussion. Stella’s Model Analysis Tools were used with the following settings: Distribution – Uniform, Latin Hypercube sampling (Noise seed = 21), and 200 runs for each parameter under only one scenario – inflation-targeting. The key results are presented in Table 3.3.

Table 3.3 Summary of results of the sensitivity tests for the parameters that become inactive if the nominal exchange rate is fixed

Parameter [Unit]	Range			Sensitivity	Uncertainty about the actual value
	Min	Used in the model	Max		
Nominal exchange rate adjustment time [Year]	0.500	1.000	1.500	Numerical	Average
Elasticity of nominal exchange rate to the gap of nominal interest rate [dmnl]	0.125	0.250	0.500	Numerical	High
Inflation sensitivity to the changes of the nominal exchange rate [(dmnl/Year)/(dmnl/Year)]	-0.700	-0.050	-0.010	High numerical / Behavioral	High
Normal fraction for coverage of exchange rate volatility with foreign exchange interventions [dmnl]	0.075	0.150	0.300	Numerical	Low

Source: calculated by the author in Stella Architect

The results indicate that the model is highly numerically and to some extent behaviorally sensitive to the parameter of inflation sensitivity to the changes in the nominal exchange rate (Figure 3.11). This is a result of high uncertainty about the actual value of this parameter, especially during times of high macroeconomic volatility (a detailed discussion about the possible ranges of this parameter can be found in the model documentation). As we can see from the sensitivity test, if this parameter is set to be equal to a relatively large negative value (-0.7), the inflation rate decreases fast after the end of the exogenous shocks because of a sharp increase of the nominal exchange rates that attract foreign capital in Ukraine, which is why the national currency appreciates. As a result, imported inflation slow down, and headline inflation slow down as well.

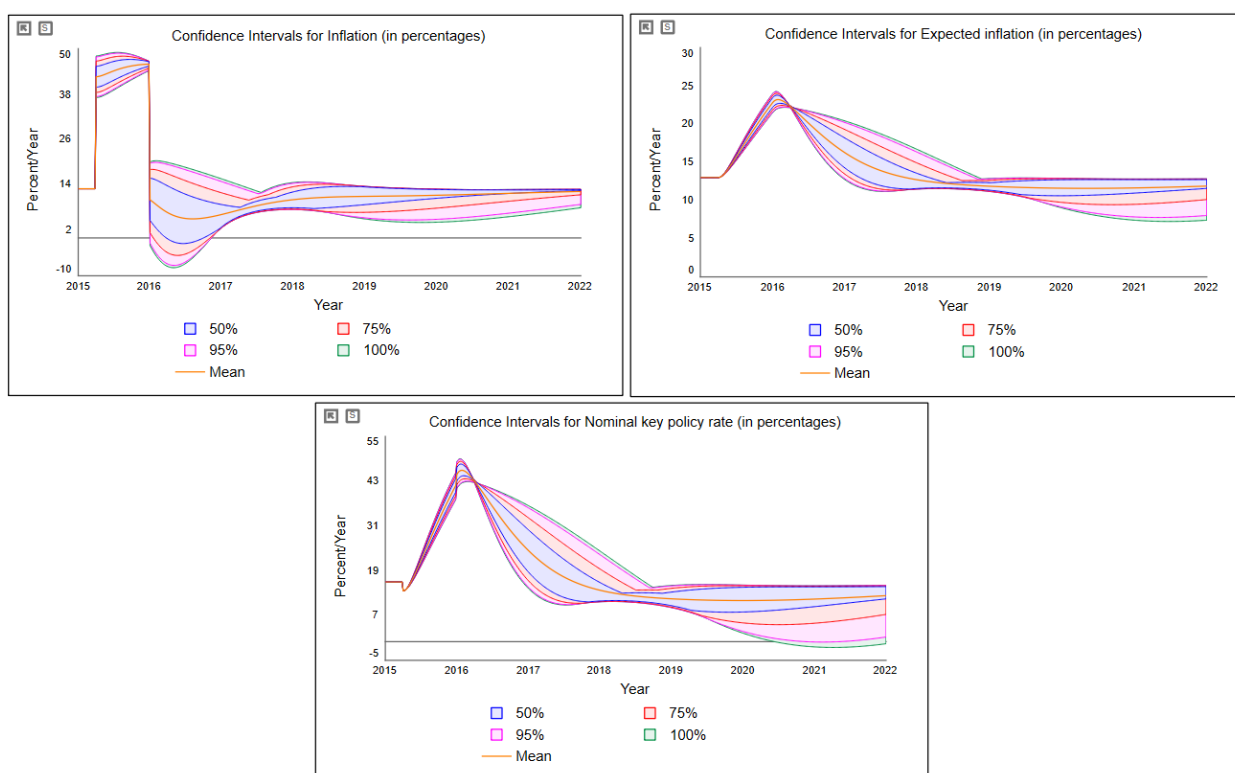


Figure 3.11 – Key performance indicators sensitivity to the inflation sensitivity to the changes of the nominal exchange rate (range: $(-0.7) - (-0.01)$) under pure inflation-targeting
Source: developed by the author in Stella Architect

Global sensitivity test. The global sensitivity test was conducted for 16 of the 19 parameters that were analyzed previously (normal inflation and initial price levels in the domestic market and in the main trading partner have not been included, because they have a very small effect on the behavioral patterns of the key performance indicators). The ranges for the parameters were the same as for the individual tests. Stella’s Model Analysis Tools were used with the following settings: Distribution – Uniform (for each of the parameters), Sobol Sequence sampling (for each of the parameters), 1000 runs under only one scenario – inflation-targeting.

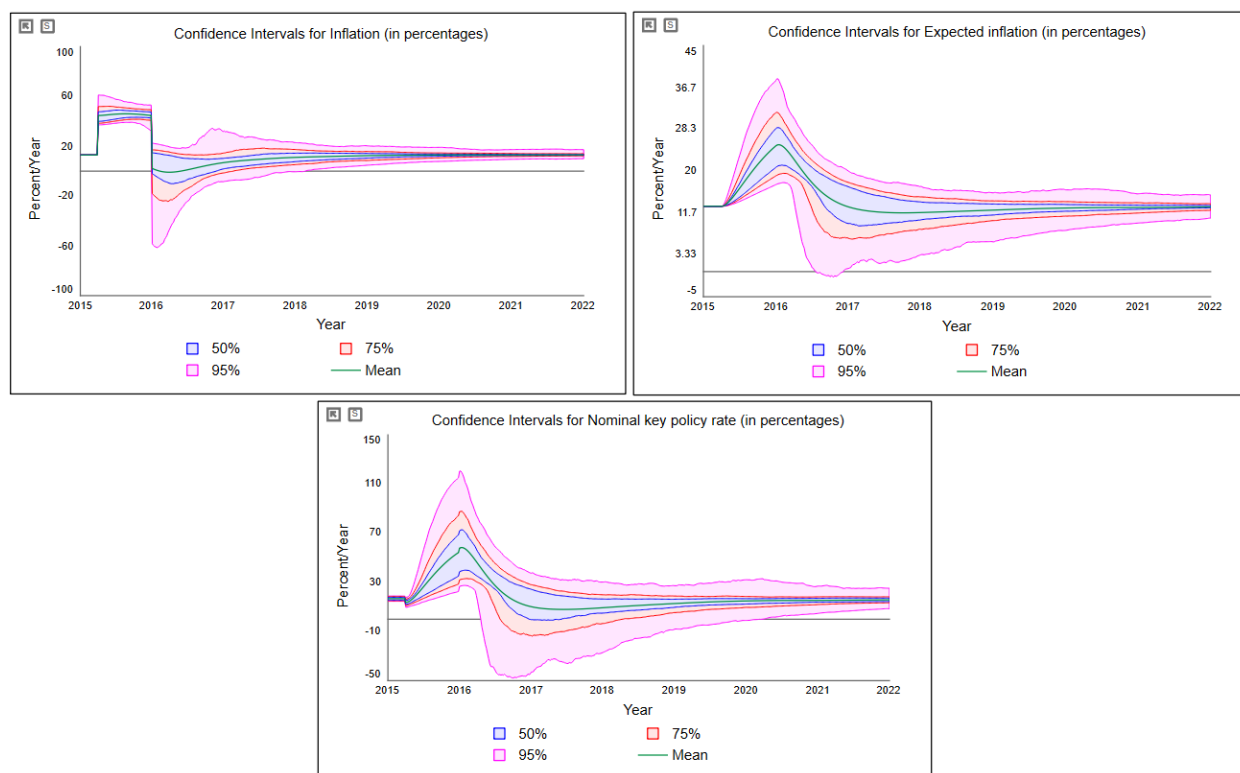


Figure 3.12 – Global sensitivity test results

Source: developed by the author in Stella Architect

The results indicate that under certain circumstances there is a probability of having a very significant deflation. After a more detailed analysis, it has been found that this happens if we simultaneously set high monetary policy sensitivity to inflation gap, high monetary policy sensitivity to GDP growth gap, quick adjustments of inflation expectations, and very large negative value of inflation sensitivity to the changes of the nominal exchange rate. This situation can be viewed as a highly unrealistic scenario because a monetary policy needs to have strict priorities and cannot be very sensitive to inflation gap and GDP growth gap simultaneously. At the same time, there is significant uncertainty about the actual values of inflation expectation adjustment time and inflation sensitivity to the changes in the nominal exchange rate. This topic needs further research.

In general, the sensitivity of the key performance indicators to the changes of individual constant parameters is relatively small which could be expected as macroeconomic indicators are usually quite rigid and it takes a lot of effort to affect the whole economy significantly.

Baseline simulation scenario: inflation-targeting monetary policy regime

The first simulation scenario represents the actual monetary policy used in 2015-2021. The graphs in Figure 3.13 show the comparison of the historical behavior of the key performance indicators with the results of the simulation. Accounting for the role of exogenous inflationary shock in 2015, the model was able to reproduce the historical trends relatively well. But the simulated development of the nominal key policy rate shows higher ranges of fluctuations. It can be explained by the fact that, in reality, the central bank of Ukraine is not willing to increase its key policy rate above the range of 25-30% as the productive influence of such changes on inflation degrades on such levels of interest rates, which is why the central bank is forced to use its other instruments (e.g., changing the requirements for the reserves of the commercial banks, capital flows limitations, exchange rate management, etc.) to affect prices. But such other instruments of the central bank are not considered in this model.

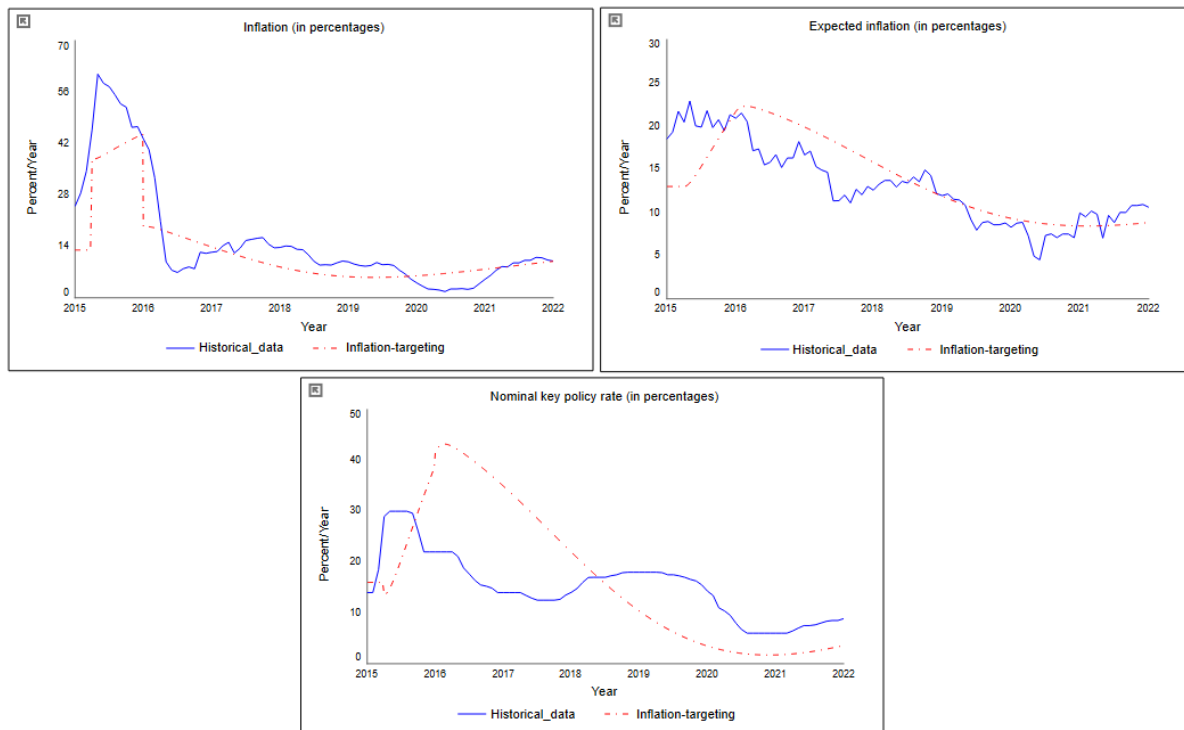


Figure 3.13 – Behavior of key performance indicators under inflation-targeting

Source: developed by the author in Stella Architect

In the first year of the simulation (Figure 3.13), we observe that in addition to exogenous shocks inflation also accelerates due to self-fulfilling backward-looking inflation expectations (R1), while it takes a long time for inflation to affect trade competitiveness and international trade, which is why B1 and B2 have small effects amid the crisis. At the same time, the nominal key policy rate is growing sharply as the central bank is trying to counteract the reinforcing loop of inflation expectations and deal with the aftermath of the exogenous inflationary shock for inflation expectations. After the exogenous shock is gone, the monetary transmission channels and the major balancing loops that are independent of the monetary policy start to decelerate inflation. But their effects have unequal delays, which is why in 2017 inflation is already lower than the initial normal level (13%) and still decelerating. It reaches the range of 5-6% in 2019 and starts to accelerate again as the monetary policy becomes expansionary. It should be noted that in the model the monetary policy has two goals: 1) stabilization of inflation around its normal level (i.e., inflation target); 2) promotion of sustained economic growth when this goal does not contradict the first one. The same is true in the real world [63]. That is why, after inflation has been significantly decelerated, the second goal starts to grow in importance for the central bank and the nominal key policy rate becomes even lower to stimulate the growth of GDP. As a result, by the end of the simulation inflation is around 10% per year and is close to its anchor i.e., inflation expectations (around 9%).

Regarding the overall role of inflation-targeting in its effect on inflation and inflation expectations, it has been found again that the exchange rate channel is the most influential in the monetary transmission mechanism in Ukraine. At the same time, the interest rate channel still has a relatively low effect on the economy.

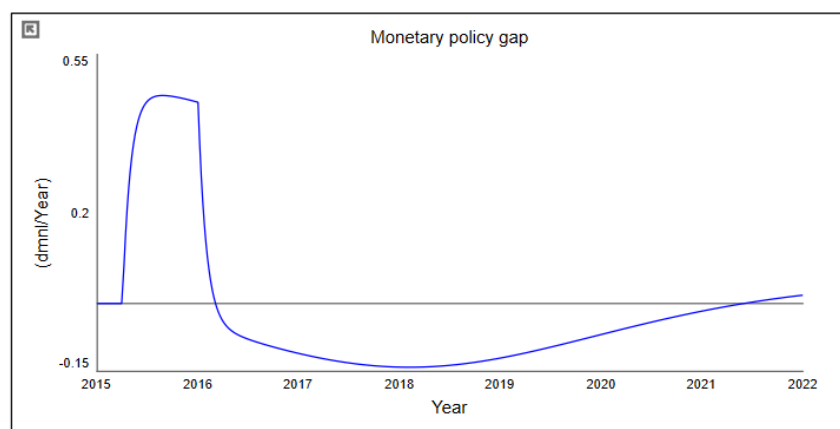


Figure 3.14 – The development of the monetary policy gap under inflation-targeting
 Source: *developed by the author in Stella Architect*

The role of the expectations channel is ambiguous. In the real world, people judge the actions of the central bank by looking at the current inflation rate, while the central bank does not care and should not care that much about the currently perceived inflation rate which represents the past events, but about the future inflation as its policy is always future-oriented. In the model, this difference in anchors is captured by assuming that the central bank sets its key policy rate by looking at the inflation expectations which is a dynamic anchor for actual inflation, while the population judges the appropriateness of the nominal key policy rate by looking at the perceived inflation. As a result, during the simulation, the perceived (by the population) difference between the required key policy rate and the actual one (monetary policy gap) is very high in 2015 (Figure 3.14): the central bank increases its key policy rate after it observes that inflation expectations get out of control, but such actions are viewed by the population as too weak and too delayed. On the other hand, in 2016-2020 the monetary policy is perceived to be too contractionary (i.e., the interest rates are too high and will lead to slower GDP growth and slower inflation in the future), which is why the future-oriented component of inflation expectations falls significantly.

Fixed exchange rate monetary policy regime scenario

If we consider the hypothetical situation in which in 2015 the central bank of Ukraine decided to adhere to its conventional policy of the fixed exchange rate, the development of key performance indicators would be different (Figure 3.15), though not too problematic.

The graph of the key policy rate is not shown here as under the policy of fixed exchange rate a central bank is not trying to affect the interest rates in the economy, which is why the key policy rate becomes useless. It should also be mentioned that the key advantage of the fixed exchange rate monetary policy regime is the relative security it provides for the economic agents who hold assets nominated in the national currency. This is especially true during times of significant macroeconomic instability when there is a great risk of capital outflow from the country.

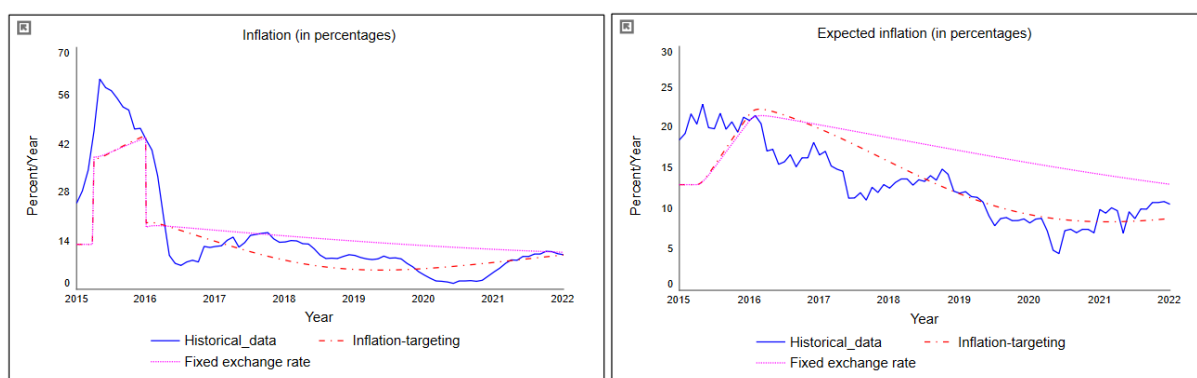


Figure 3.15 – Behavior of the key performance indicators under fixed exchange rate monetary policy regime

Source: developed by the author in Stella Architect

As you can see, inflation and inflation expectations still converge to normal levels relatively fast. Even though all feedback loops that are added by inflation-targeting are turned off in this scenario, the influence of the accumulated over the crisis period gap of trade competitiveness forces the growth rate of domestic prices to slow down (B1 and B2 have a significant influence). Such results suggest that even though the chosen monetary policy regime was relatively efficient in the short and medium term, in the long-run active monetary policy has a relatively small effect on the overall price level. This is consistent with New Keynesian thought in macroeconomics.

Scenario of a combination of inflation-targeting and fixed exchange rate

In Figure 3.16 we explore the combination of the two previously discussed scenarios. This is an especially important scenario as currently (April 12, 2023) NBU operates in a monetary policy setting that corresponds to this scenario. As it can be seen, the deceleration

of inflation and the decrease of inflation expectations happen a little slower than under pure inflation-targeting. The reason for this is that the fixed exchange rate makes exchange rate channel (B5, B6, B7) of the monetary transmission mechanism inactive which is why the increased inflow of foreign capital into the domestic economy that follows the increase of the interest rates in the economy is not affecting the nominal exchange rate and does not help to slow down inflation in short and medium-term.

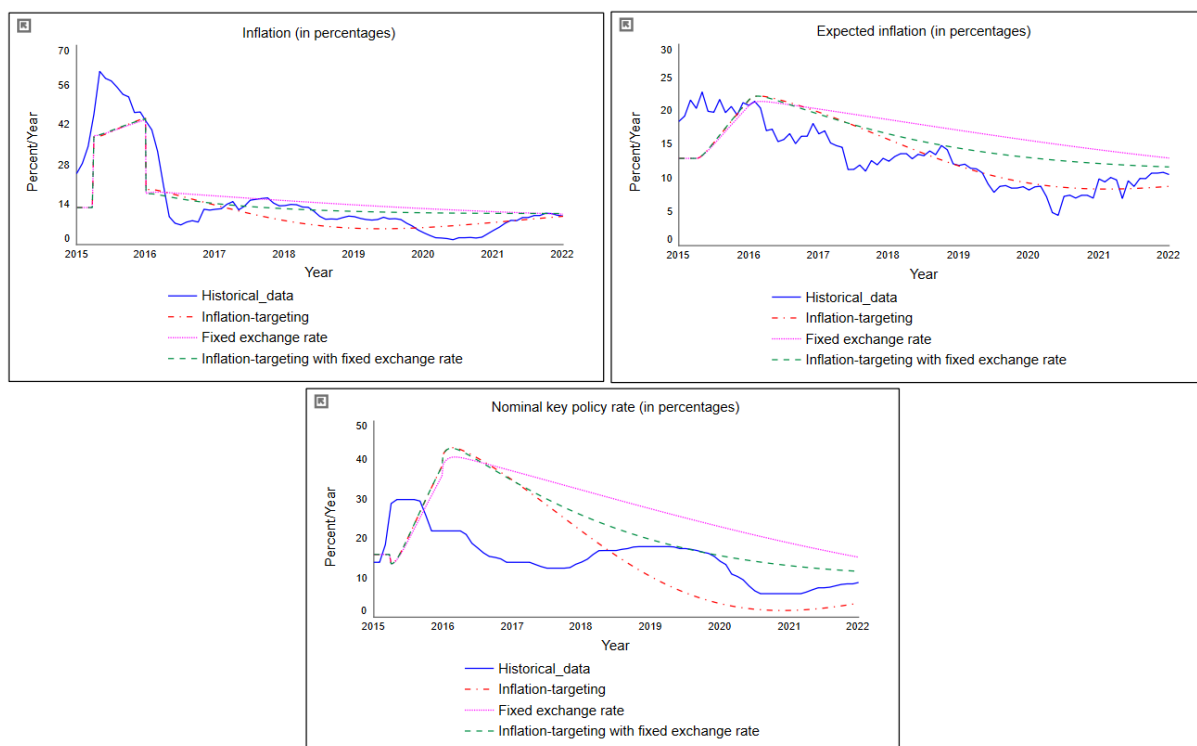


Figure 3.16 – Behavior of key performance indicators under inflation-targeting with fixed exchange rate

Source: developed by the author in Stella Architect

Interestingly, the key policy rate does not decrease as much by the end of the simulation as it did under pure inflation-targeting. This happens because due to the inactivity of the exchange rate channel the trade competitiveness of domestic manufacturers in the international market has not been worsened additionally to the effects of the exogenous shocks (inactive B6), which is why the GDP growth has been higher. Higher GDP growth prevented the central bank from further decreasing its key policy rate when expected inflation reached its normal range. Such results reveal a peculiar advantage of a combination

of the fixed exchange rate with inflation-targeting: if a central bank of a small open economy is not willing to sacrifice economic growth for faster deceleration of inflation, it might use the fixation of the nominal exchange rate to “steal” some economic growth from the main trading partners by making the domestic manufacturers relatively more competitive in the international market.

It should be noted that the simulation settings are given in Appendix E for reproducibility of this research.

Also, the results of the sensitivity analysis indicate that there is significant numerical sensitivity of the key performance indicators to the changes in inflation sensitivity to the relative real exchange rate gap under all three settings of the monetary policy. This parameter represents the degree of involvement of an economy in international trade and defines the speed of influence of foreign prices on domestic ones. Essentially, during the simulations, a high absolute value of this parameter helps inflation rates in domestic and foreign economies to converge to their normal value faster. That is why, even if there is no central bank in an economy, inflation could still be not very volatile if there are no barriers to international trade.

3.3 Policy implications and recommendations

There is one more policy setting that needs to be tested. Even though, IMF (2005) [10] has found that inflation-targeting “appears to have been associated with lower inflation, lower inflation expectations, and lower inflation volatility relative to countries that have not adopted it”, for such positive effects to happen there is a necessity of high degree of independence of monetary policy from fiscal policy [12]. In other words, the central bank’s credibility needs to be relatively high. But in Ukraine, the calibrated value of this parameter for 2015-2021 is equal to only 15%, which means that the population is not very willing to trust its central bank. Figure 3.17 shows what could have happened if the central bank had been 100% credible.

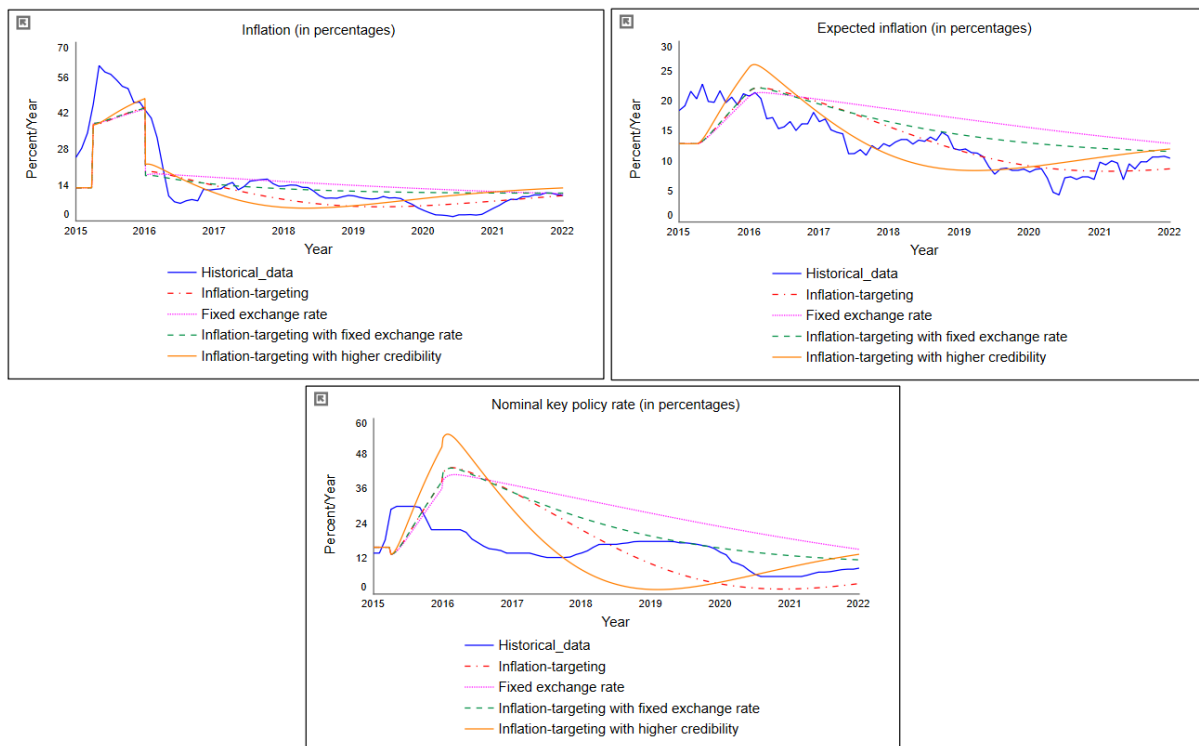


Figure 3.17 – Dynamics of the key performance indicators under inflation-targeting with higher credibility of the central bank

Source: developed by the author in Stella Architect

As can be noticed, inflation and inflation expectations decrease fastest when the central bank is conducting pure inflation-targeting (no fixed exchange rate) and is fully credible. But there is also a problem, by the end of the simulation inflation and inflation expectations have significantly increased due to strengthened R2, even though the central bank has been changing its key policy rate in strict accordance with its public vows. The reason for this is the misunderstanding of the actions of the central bank by the population which also happens too often in real life: the central bank is trying to affect future inflation, while the population is more focused on the presently perceived inflation.

The model has several significant limitations. First, the effects of the dynamics of the trade balance on the foreign exchange markets as well as the foreign exchange expectations were not modeled explicitly. Secondly, the effects of post-crisis economic recovery on the gap of GDP growth were not considered as they had been assumed to be outside of the model

boundary, but for more accurate reproduction of the behavior mode such effects should also be included in the model boundary and modeled as endogenous processes. Thirdly, fiscal policy is not included in the model boundary, but it is a promising field of study, especially from the point of view of the interaction of monetary and fiscal policies. Also, a significant limitation of this project is the fact that normal inflation was assumed to be constant over the whole period of the simulation which is a simplification of reality. Lastly, the results of the sensitivity analysis indicate a necessity for more robust estimations of adjustment time of inflation expectations, central bank credibility, and inflation sensitivity to the changes in the nominal exchange rate.

So, does monetary policy matter? Yes, it does, but primarily in the short and medium term as it helps to decelerate inflation faster. But in the long run, it makes more sense to remove the barriers to the international flows of capital, goods, and services, so that the inflation rates in domestic and foreign economies will converge with no additional obstacles. And that is why the policy of fixed exchange rate is not very helpful.

Was the inflation-targeting regime a useful policy for Ukraine in 2015-2021? It was, but primarily for the purposes of a faster return to normal inflation and inflation expectations. Overall, the marginal effect of such a policy has been found to be relatively small and there is still a lot to be done to strengthen the monetary transmission mechanism. The central bank needs not only to improve its credibility but to communicate to the population that its actions are aimed at future inflation so that economic agents will evaluate the decisions of the central bank more accurately. System dynamics tools might be of great help for such a purpose as they help to communicate to people the delays that a central bank is trying to account for in its policy.

One last point, we should also be cautious about recommendations for the removal of the barriers to international flows of capital, goods, and services as they make the national market much more vulnerable to the volatility of the global markets, which might be especially dangerous for a small open economy with a shallow financial market and a high degree of dollarization like Ukraine as it makes the monetary policy in the domestic economy

much more dependent on the actions and also probable mistakes of the central banks of bigger economies (the Federal Reserve System of the US, ECB, etc.).

Conclusions to Chapter 3

As a result, in this chapter we have developed an explanatory model of a national economy, calibrated it for Ukraine, and used the model to evaluate macroeconomic resilience under three monetary policy regimes: inflation-targeting, fixed exchange rate, a combination of inflation-targeting and fixed exchange rate.

The model consists of 8 sectors and its key feature, essentially the whole idea behind its development, is explicit modelling of interest rate, foreign exchange rate, and inflation expectations channels of the monetary transmission mechanism.

Under pure inflation-targeting inflation and inflation expectation decrease the fastest, but the results at the end of the simulations differ only slightly as most of the balancing effect comes from the feedback loops that operate outside any monetary policy regime. Competition in the international trade forces prices to converge. This conclusion is the greatest insight and the biggest drawback of the model. This is important because it shows how dynamics of the tradable sectors goods stabilize the economy of a national economy without the need of additional interventions. On the other hand, it shows that a lot of feedback relationships are left behind the model boundary. The model does not account for structural changes in an economy, technology and labor productivity differences, non-tradable goods sector dynamics, and country risk premium determinants.

Still, the model incorporates the facts that the foreign exchange channel is the most influential in Ukraine, while interest rate and inflation expectations channels are less developed. We recommend the NBU let the foreign exchange rate float as soon as Ukraine wins the war as it has been found that inflation-targeting without fixed foreign exchange rate leads to a faster deceleration of inflation and more sustainable economic development. We also recommend it to continue developing the asset prices and credit channels of the

monetary transmission mechanism through developing the infrastructure and improving the regulatory conditions for the development of stock, bond, and mortgage markets.

CONCLUSIONS

In this work we have made an overview of inflation-targeting as a monetary policy regime and analyzed the features of Ukrainian economy that impede the attainment of inflation targets. We have also assessed the effectiveness of the interest rate, foreign exchange rate, and inflation expectations channels of the monetary transmission mechanism since 2016, and particularly in 2022 - early 2023, and evaluated the role of inflation-targeting implementation for consumer inflation deceleration in 2015-2020 in Ukraine.

Inflation-targeting is primarily associated with publicly announced inflation goal. It also requires central bank to consider price stability an overriding monetary policy objective. Moreover, a key feature of inflation-targeting is extensive communication and explanation of monetary policy decisions and intentions to the public. Additionally, institutional independence, proper technical infrastructure, healthy financial system (i.e., developed financial market, reliable banking system) and resilient economic structure (i.e., low foreign exchange market sensitivity to international commodities market dynamics, low level of financial dollarization) are key characteristics needed for an economy to be able to implement inflation-targeting and consistently attain its announced goals.

Currently, Ukraine is an inflation-targeting economy with a medium-term target of 5% YoY change in headline CPI. The National Bank of Ukraine has also pegged a foreign exchange rate to the US dollar since the beginning of a full-scale Russian invasion, which is why its monetary policy regime cannot be classified as classical inflation targeting now. Consumer and industrial inflation in Ukraine have been substantially higher than in peer economies over the past decades primarily due to external shocks and dependency on imported energy and food products.

Statistical analysis revealed that the policy rate of the NBU has affected interest rates on loans and deposits to non-financial corporations with maturity in less than 1 year, short-term households' deposits and government bond yields. The importance of these financial products indicated by their high absolute volumes in 2016-2022 shows that the interest rate

channel of the monetary transmission mechanism has substantially improved since 2015. Statistical analysis results also indicate monetary transmission mechanism has weakened since the beginning of the full-scale invasion. Assessment of the inflation expectations channel has shown that inflation expectations of all economic agents stay to a greater extent backward-looking than forward-looking.

Panel regression estimation revealed that that consumer prices are weakly affected by the interest rate policy with 1 percentage point increase in the key policy rate decelerating inflation 12 months later by 0.026 percentage points. At the same time, foreign exchange rate dynamics have a substantial and quick effect: 1% of the foreign exchange rate appreciation results in the deceleration of consumer inflation by 2.59 percentage points in the same month. It should be noted that the coefficient estimations are based on disaggregated consumer price index and do not account for the weights of individual indices in the headline CPI. Thus, the coefficients should be interpreted as an unweighted average effect of respective factors on prices of consumer goods and services rather than on the overall consumer prices.

Additionally, panel regression estimation indicated that industrial prices are more susceptible to the interest rate policy with 1 percentage point increase of the policy rate resulting in industrial inflation deceleration of 0.18 percentage points one month later. Such a fast reaction of industrial price to the monetary policy can be explained by a relatively high policy rate transmission into short-term interest rates of commercial banks on loans and deposits of non-financial corporations. Exchange rate dynamics affect industrial prices significantly with 1% foreign exchange appreciation resulting in roughly 0.66 percentage points industrial inflation deceleration five months later.

Inflation expectations channel proxied by household inflation expectations have been found to be statistically significant for explaining industrial inflation, but not consumer inflation. However, its overall effect on industrial inflation is also quite low: the increase in inflation expectations of the households by 1 percentage point results in industrial inflation accelerating by 0.08 percentage points in the same month.

Consequently, we have developed a system dynamics model to analyze simultaneously the claimed by the literature and empirical research causal macroeconomic relationships, primarily the ones that are associated with the channels of the monetary transmission mechanism. Three monetary policy regimes were tested in the mode: inflation-targeting, fixed foreign exchange rate, inflation-targeting with fixed foreign exchange rate.

Model analysis revealed that under classical inflation-targeting (no fixed exchange rate) inflation and inflation expectation decrease the fastest. At the same time, the effect of monetary policy of any type on inflation deceleration has been found to be relatively insignificant in the medium- and long-term as it is the competition in the international trade that forces the prices in different economies to converge in the model. On the one hand, this conclusion stresses the importance of liberalization of international flows of goods, services, labor, and capital. On the other, it shows that model leaves outside of its boundary significant factors that should be accounted for to make a more comprehensive policy recommendation. In particular, the model does not consider technology and labor productivity differences between trading partners, and the positive structural changes in an economy that are triggered by a more transparent monetary policy (savings in the national currency become more popular, financial market develops faster due to a more predictable interest rate policy). Thus, further research aimed at the incorporation of these factors into the model seems necessary.

Overall, we recommend the NBU to return to the classical inflation-targeting (without fixed foreign exchange rate) as soon as Ukraine wins the war. We also recommend developing the infrastructure and improving the regulatory conditions for the stock, bond, and mortgage markets to strengthen the monetary transmission mechanism.

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Appendix A

Table A1. Industrial inflation in 2016M1 – 2022M2 (based on monthly data on YoY changes)

Indicator \ Statistics	Mean, %	Median, %	Standard Deviation, %	Minimum, %	Maximum, %	Coefficient of variation, %
Industrial Producer Price	19.3	17.9	17.5	-7.5	69.1	90.6
Mining and quarrying	32.2	24.3	41.8	-36.3	159.1	129.6
Manufacturing	13.9	13.7	11.5	-6.0	37.8	82.2
Manufacture of food products, beverages and tobacco products	13.4	12.2	7.9	0.7	32.9	59.3
Manufacture of textiles, apparel, leather and related products	6.5	6.1	3.9	1.7	25.5	59.9
Manufacture of wood and paper products, and printing	9.0	8.3	8.1	-6.3	31.5	90.2
Manufacture of coke, and refined petroleum products	28.2	17.6	41.4	-30.5	117.3	146.9
Manufacture of chemicals and chemical products	14.5	9.5	21.5	-10.6	70.9	148.2
Manufacture of pharmaceuticals, medicinal chemical and botanical products	12.3	11.9	3.6	8.3	31.4	29.6
Manufacture of rubber and plastics products, and other non-metallic mineral products	9.8	10.5	5.8	0.4	28.7	59.7
Manufacture of basic metals and fabricated metal products, except machinery and equipment	20.1	20.4	24.9	-18.8	87.4	124.3
Machine-building	9.1	11.0	7.1	-3.4	25.5	77.8
Manufacture of computer, electronic and optical products	6.3	5.8	4.5	0.1	29.6	71.3
Manufacture of electrical equipment	7.3	8.7	12.0	-16.5	29.5	163.7
Manufacture of machinery and equipment n.e.c.	9.8	10.7	7.2	-0.5	34.9	73.0
Manufacture of transport equipment	10.7	11.4	7.2	-2.1	23.6	67.4
Electricity, gas, steam and air-conditioning supply	29.4	21.0	45.0	-13.3	240.2	153.0

Source: calculated by the author based on data from NBU

Appendix B

Consumer inflation panel regression testing results

Dependent Variable: C_PRICE_INDEX				
Method: Panel Least Squares				
Date: 04/09/23 Time: 15:59				
Sample (adjusted): 2017M01 2022M02				
Periods included: 62				
Cross-sections included: 12				
Total panel (balanced) observations: 744				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-4.562086	1.108221	-4.116585	0.0000
C_PRICE_INDEX(-1)	1.166141	0.035240	33.09112	0.0000
C_PRICE_INDEX(-2)	-0.248068	0.034088	-7.277369	0.0000
POLICY_RATE(-12)	-0.021890	0.012705	-1.723005	0.0853
LOG(NEER)	-5.103015	1.023520	-4.985751	0.0000
Effects Specification				
Cross-section fixed (dummy variables)				
Root MSE	1.495952	R-squared	0.958334	
Mean dependent var	8.226478	Adjusted R-squared	0.957476	
S.D. dependent var	7.333638	S.E. of regression	1.512302	
Akaike info criterion	3.686414	Sum squared resid	1664.978	
Schwarz criterion	3.785597	Log likelihood	-1355.346	
Hannan-Quinn criter.	3.724646	F-statistic	1116.288	
Durbin-Watson stat	2.125004	Prob(F-statistic)	0.000000	

Figure B.1 - Consumer inflation panel estimation specification

Source: calculated by the author in Eviews 12

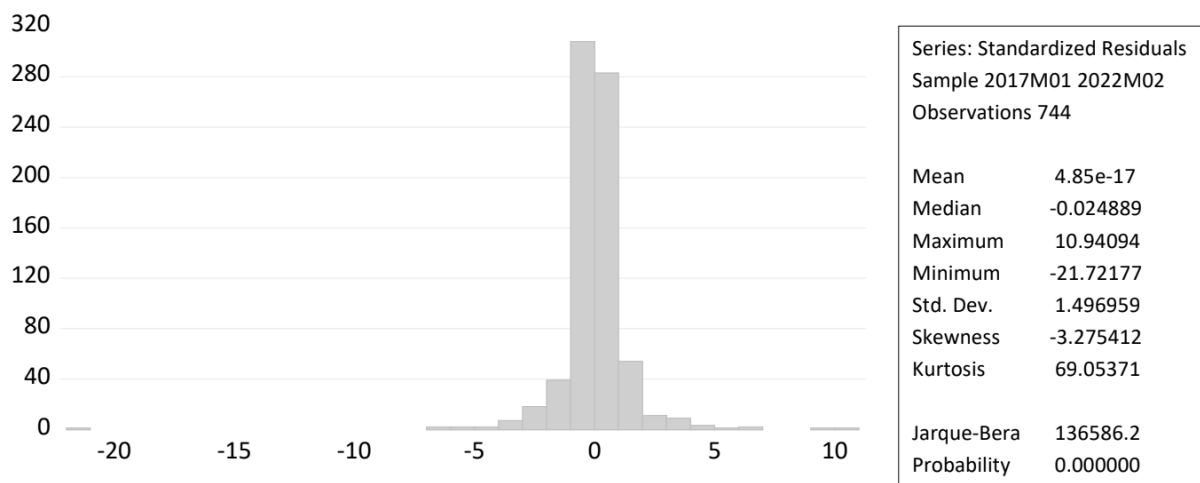


Figure B.2 - Residuals distribution (consumer inflation)

Source: calculated by the author in Eviews 12

Panel Cross-section Heteroskedasticity LR Test

Equation: EQ_4

Specification: C_PRICE_INDEX C C_PRICE_INDEX(-1)

C_PRICE_INDEX(-2) POLICY_RATE(-12) LOG(NEER)

Null hypothesis: Residuals are homoskedastic

	Value	df	Probability
Likelihood ratio	827.2479	12	0.0000

LR test summary:

	Value	df
Restricted LogL	-1370.404	739
Unrestricted LogL	-956.7797	739

Unrestricted Test Equation:

Dependent Variable: C_PRICE_INDEX

Method: Panel EGLS (Cross-section weights)

Date: 04/09/23 Time: 16:04

Sample: 2017M01 2022M02

Periods included: 62

Cross-sections included: 12

Total panel (balanced) observations: 744

Iterate weights to convergence

Convergence achieved after 5 weight iterations

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-2.317913	0.474561	-4.884329	0.0000
C_PRICE_INDEX(-1)	1.301232	0.033316	39.05769	0.0000
C_PRICE_INDEX(-2)	-0.321623	0.033118	-9.711379	0.0000
POLICY_RATE(-12)	-0.022489	0.005545	-4.055740	0.0001
LOG(NEER)	-2.547617	0.437970	-5.816875	0.0000

Weighted Statistics

Root MSE	1.547261	R-squared	0.984839
Mean dependent var	14.52334	Adjusted R-squared	0.984757
S.D. dependent var	11.92015	S.E. of regression	1.552487
Akaike info criterion	2.585429	Sum squared resid	1781.148
Schwarz criterion	2.616424	Log likelihood	-956.7797
Hannan-Quinn criter.	2.597377	F-statistic	12000.90
Durbin-Watson stat	2.051783	Prob(F-statistic)	0.000000

Unweighted Statistics

R-squared	0.955427	Mean dependent var	8.226478
Sum squared resid	1781.147	Durbin-Watson stat	2.289536

Figure B.3 - Panel cross-section heteroskedasticity LR test (consumer inflation)*Source: calculated by the author in Eviews 12*

Panel Period Heteroskedasticity LR Test

Equation: EQ_4

Specification: C_PRICE_INDEX C C_PRICE_INDEX(-1)

C_PRICE_INDEX(-2) POLICY_RATE(-12) LOG(NEER)

Null hypothesis: Residuals are homoskedastic

	Value	df	Probability
Likelihood ratio	548.2236	12	0.0000

LR test summary:

	Value	df
Restricted LogL	-1370.404	739
Unrestricted LogL	-1096.292	739

Unrestricted Test Equation:

Dependent Variable: C_PRICE_INDEX

Method: Panel EGLS (Period weights)

Date: 04/09/23 Time: 16:04

Sample: 2017M01 2022M02

Periods included: 62

Cross-sections included: 12

Total panel (balanced) observations: 744

Iterate weights to convergence

Convergence achieved after 13 weight iterations

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-2.609678	0.694620	-3.756986	0.0002
C_PRICE_INDEX(-1)	1.372975	0.024422	56.21784	0.0000
C_PRICE_INDEX(-2)	-0.399181	0.024171	-16.51502	0.0000
POLICY_RATE(-12)	-0.016605	0.009125	-1.819806	0.0692
LOG(NEER)	-2.812406	0.608805	-4.619551	0.0000

Weighted Statistics

Root MSE	1.555734	R-squared	0.984661
Mean dependent var	13.50539	Adjusted R-squared	0.984578
S.D. dependent var	14.38450	S.E. of regression	1.560988
Akaike info criterion	2.960462	Sum squared resid	1800.710
Schwarz criterion	2.991457	Log likelihood	-1096.292
Hannan-Quinn criter.	2.972409	F-statistic	11859.42
Durbin-Watson stat	1.949604	Prob(F-statistic)	0.000000

Unweighted Statistics

R-squared	0.954937	Mean dependent var	8.226478
Sum squared resid	1800.735	Durbin-Watson stat	2.458898

Figure B.4 - Panel period heteroskedasticity LR test (consumer inflation)*Source: calculated by the author in Eviews 12*

Correlated Random Effects - Hausman Test				
Equation: EQ_4				
Test cross-section random effects				
Test Summary	Chi-Sq. Statistic	Chi-Sq. d.f.	Prob.	
Cross-section random	29.791624	4	0.0000	
** WARNING: estimated cross-section random effects variance is zero.				
Cross-section random effects test comparisons:				
Variable	Fixed	Random	Var(Diff.)	Prob.
C_PRICE_INDEX(-1)	1.166141	1.203193	0.000048	0.0000
C_PRICE_INDEX(-2)	-0.248068	-0.253925	0.000020	0.1924
POLICY_RATE(-12)	-0.021890	-0.021640	0.000000	0.0150
LOG(NEER)	-5.103015	-4.255410	0.028465	0.0000
Cross-section random effects test equation:				
Dependent Variable: C_PRICE_INDEX				
Method: Panel Least Squares				
Date: 04/09/23 Time: 15:56				
Sample (adjusted): 2017M01 2022M02				
Periods included: 62				
Cross-sections included: 12				
Total panel (balanced) observations: 744				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-4.562086	1.108221	-4.116585	0.0000
C_PRICE_INDEX(-1)	1.166141	0.035240	33.09112	0.0000
C_PRICE_INDEX(-2)	-0.248068	0.034088	-7.277369	0.0000
POLICY_RATE(-12)	-0.021890	0.012705	-1.723005	0.0853
LOG(NEER)	-5.103015	1.023520	-4.985751	0.0000
Effects Specification				
Cross-section fixed (dummy variables)				
Root MSE	1.495952	R-squared	0.958334	
Mean dependent var	8.226478	Adjusted R-squared	0.957476	
S.D. dependent var	7.333638	S.E. of regression	1.512302	
Akaike info criterion	3.686414	Sum squared resid	1664.978	
Schwarz criterion	3.785597	Log likelihood	-1355.346	
Hannan-Quinn criter.	3.724646	F-statistic	1116.288	
Durbin-Watson stat	2.125004	Prob(F-statistic)	0.000000	

Figure B.5 - Hausman test (consumer inflation)

Source: calculated by the author in Eviews 12

Redundant Fixed Effects Tests				
Equation: EQ_4				
Test cross-section fixed effects				
Effects Test	Statistic	d.f.	Prob.	
Cross-section F	2.733837	(11,728)	0.0018	
Cross-section Chi-square	30.115324	11	0.0015	
Cross-section fixed effects test equation: Dependent Variable: C_PRICE_INDEX Method: Panel Least Squares Date: 04/09/23 Time: 16:00 Sample (adjusted): 2017M01 2022M02 Periods included: 62 Cross-sections included: 12 Total panel (balanced) observations: 744				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-3.908729	1.114891	-3.505929	0.0005
C_PRICE_INDEX(-1)	1.203193	0.035003	34.37414	0.0000
C_PRICE_INDEX(-2)	-0.253925	0.034223	-7.419620	0.0000
POLICY_RATE(-12)	-0.021640	0.012867	-1.681837	0.0930
LOG(NEER)	-4.255410	1.022462	-4.161923	0.0000
Root MSE	1.526537	R-squared	0.956613	
Mean dependent var	8.226478	Adjusted R-squared	0.956378	
S.D. dependent var	7.333638	S.E. of regression	1.531693	
Akaike info criterion	3.697322	Sum squared resid	1733.755	
Schwarz criterion	3.728316	Log likelihood	-1370.404	
Hannan-Quinn criter.	3.709269	F-statistic	4073.435	
Durbin-Watson stat	2.116827	Prob(F-statistic)	0.000000	

Figure B.6 - Redundant fixed effects tests (consumer inflation)

Source: calculated by the author in Eviews 12

Residual Cross-Section Dependence Test				
Null hypothesis: No cross-section dependence (correlation) in residuals				
Equation: EQ_4				
Periods included: 62				
Cross-sections included: 12				
Total panel observations: 744				
Note: non-zero cross-section means detected in data Cross-section means were removed during computation of correlations				
Test	Statistic	d.f.	Prob.	
Breusch-Pagan LM	74.12731	66	0.2303	
Pesaran scaled LM	0.707391		0.4793	
Pesaran CD	0.137484		0.8906	

Figure B.7 - Residual cross-section dependence test (consumer inflation)

Source: calculated by the author in Eviews 12

Table B.1 Correlation matrix for the consumer prices model

Variables	Consumer price index	Consumer price index (-1)	Consumer price index (-2)	Policy rate (-12)	Log (NEER)
Consumer price index	1.000	0.975	0.938	-0.027	-0.235
Consumer price index (-1)	0.975	1.000	0.976	-0.009	-0.200
Consumer price index (-2)	0.938	0.976	1.000	0.006	-0.166
Policy rate (-12)	-0.027	-0.009	0.006	1.000	0.035
Log (NEER)	-0.235	-0.200	-0.166	0.035	1.000

Source: calculated by the author in Eviews 12

Appendix C

Industrial inflation panel regression testing results

Dependent Variable: I_PRICE_INDEX Method: Panel Least Squares Date: 04/09/23 Time: 16:49 Sample (adjusted): 2016M07 2022M02 Periods included: 68 Cross-sections included: 21 Total panel (balanced) observations: 1428				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-23.77380	7.085022	-3.355501	0.0008
I_PRICE_INDEX(-1)	1.226988	0.026303	46.64833	0.0000
I_PRICE_INDEX(-2)	-0.311136	0.027165	-11.45338	0.0000
POLICY_RATE(-4)	-1.596156	0.326573	-4.887589	0.0000
POLICY_RATE(-6)	1.247488	0.307534	4.056429	0.0001
LOG(NEER(-1))	13.74058	6.343209	2.166188	0.0305
LOG(NEER(-5))	-40.91482	9.035840	-4.528059	0.0000
Root MSE	9.115296	R-squared	0.894503	
Mean dependent var	15.73564	Adjusted R-squared	0.894058	
S.D. dependent var	28.07393	S.E. of regression	9.137720	
Akaike info criterion	7.267589	Sum squared resid	118650.6	
Schwarz criterion	7.293393	Log likelihood	-5182.058	
Hannan-Quinn criter.	7.277225	F-statistic	2008.099	
Durbin-Watson stat	1.986966	Prob(F-statistic)	0.000000	

Figure C.1 - Industrial inflation panel estimation specification

Source: calculated by the author in Eviews 12

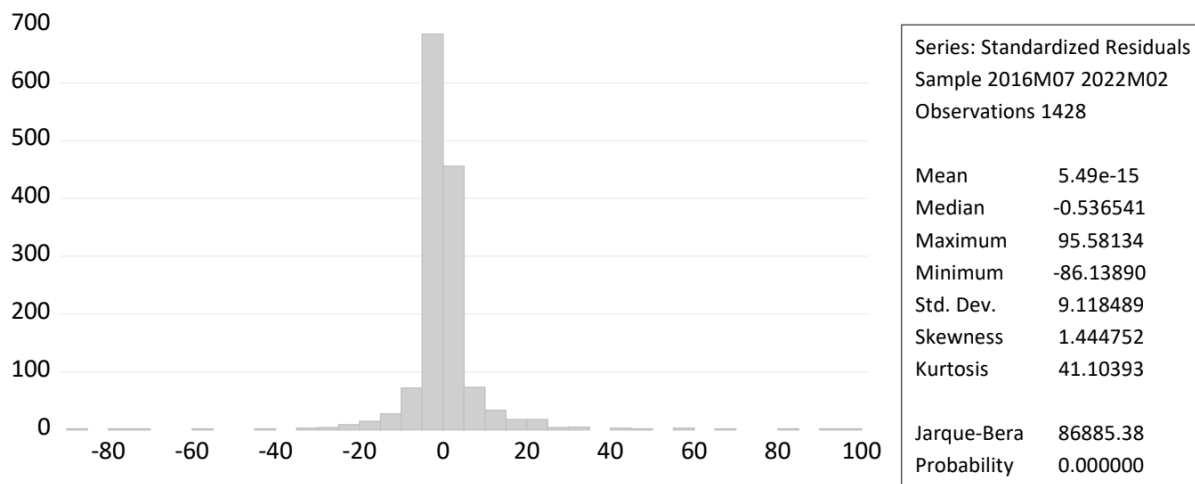


Figure C.2 - Residuals distribution (industrial inflation)

Source: calculated by the author in Eviews 12

Panel Cross-section Heteroskedasticity LR Test

Equation: EQ_2_MAIN

Specification: I_PRICE_INDEX C I_PRICE_INDEX(-1) I_PRICE_INDEX(-2) POLICY_RATE(-4) POLICY_RATE(-6) LOG(NEER(-1)) LOG(NEER(-5))

Null hypothesis: Residuals are homoskedastic

	Value	df	Probability
Likelihood ratio	2842.183	21	0.0000

LR test summary:			
	Value	df	
Restricted LogL	-5182.058	1421	
Unrestricted LogL	-3760.967	1421	

Unrestricted Test Equation:

Dependent Variable: I_PRICE_INDEX

Method: Panel EGLS (Cross-section weights)

Date: 04/09/23 Time: 16:49

Sample: 2016M07 2022M02

Periods included: 68

Cross-sections included: 21

Total panel (balanced) observations: 1428

Iterate weights to convergence

Convergence achieved after 7 weight iterations

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-1.366483	1.363452	-1.002222	0.3164
I_PRICE_INDEX(-1)	1.113492	0.026937	41.33742	0.0000
I_PRICE_INDEX(-2)	-0.134061	0.027727	-4.835084	0.0000
POLICY_RATE(-4)	-0.196852	0.062478	-3.150723	0.0017
POLICY_RATE(-6)	0.091696	0.058595	1.564921	0.1178
LOG(NEER(-1))	1.770407	1.210753	1.462236	0.1439
LOG(NEER(-5))	-4.578937	1.715310	-2.669451	0.0077

Weighted Statistics			
Root MSE	9.430146	R-squared	0.939832
Mean dependent var	46.54014	Adjusted R-squared	0.939578
S.D. dependent var	46.45380	S.E. of regression	9.453345
Akaike info criterion	5.277264	Sum squared resid	126988.7
Schwarz criterion	5.303068	Log likelihood	-3760.967
Hannan-Quinn criter.	5.286901	F-statistic	3699.358
Durbin-Watson stat	1.992350	Prob(F-statistic)	0.000000

Unweighted Statistics			
R-squared	0.887089	Mean dependent var	15.73564
Sum squared resid	126988.9	Durbin-Watson stat	1.680097

Figure C.3 - Panel cross-section heteroskedasticity LR test (industrial inflation)*Source: calculated by the author in Eviews 12*

Panel Period Heteroskedasticity LR Test

Equation: EQ_2_MAIN

Specification: I_PRICE_INDEX C I_PRICE_INDEX(-1) I_PRICE_INDEX(-2) POLICY_RATE(-4) POLICY_RATE(-6) LOG(NEER(-1)) LOG(NEER(-5))

Null hypothesis: Residuals are homoskedastic

	Value	df	Probability
Likelihood ratio	1099.606	21	0.0000

LR test summary:

	Value	df
Restricted LogL	-5182.058	1421
Unrestricted LogL	-4632.255	1421

Unrestricted Test Equation:

Dependent Variable: I_PRICE_INDEX

Method: Panel EGLS (Period weights)

Date: 04/09/23 Time: 16:49

Sample: 2016M07 2022M02

Periods included: 68

Cross-sections included: 21

Total panel (balanced) observations: 1428

Iterate weights to convergence

Convergence achieved after 11 weight iterations

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-11.83938	3.896186	-3.038709	0.0024
I_PRICE_INDEX(-1)	1.128661	0.019016	59.35263	0.0000
I_PRICE_INDEX(-2)	-0.160094	0.019706	-8.124148	0.0000
POLICY_RATE(-4)	-0.959349	0.203900	-4.704989	0.0000
POLICY_RATE(-6)	0.691149	0.199823	3.458808	0.0006
LOG(NEER(-1))	5.573588	3.443471	1.618596	0.1058
LOG(NEER(-5))	-20.13685	4.720329	-4.265984	0.0000

Weighted Statistics

Root MSE	9.293329	R-squared	0.932271
Mean dependent var	19.63589	Adjusted R-squared	0.931985
S.D. dependent var	34.59549	S.E. of regression	9.316190
Akaike info criterion	6.497556	Sum squared resid	123330.6
Schwarz criterion	6.523361	Log likelihood	-4632.255
Hannan-Quinn criter.	6.507193	F-statistic	3259.957
Durbin-Watson stat	1.982356	Prob(F-statistic)	0.000000

Unweighted Statistics

R-squared	0.890342	Mean dependent var	15.73564
Sum squared resid	123330.9	Durbin-Watson stat	1.745729

Figure C.4 - Panel period heteroskedasticity LR test (industrial inflation)*Source: calculated by the author in Eviews 12*

Correlated Random Effects - Hausman Test				
Equation: EQ_2_MAIN				
Test cross-section random effects				
Test Summary	Chi-Sq. Statistic	Chi-Sq. d.f.	Prob.	
Cross-section random	17.011390	6	0.0092	
** WARNING: estimated cross-section random effects variance is zero.				
Cross-section random effects test comparisons:				
Variable	Fixed	Random	Var(Diff.)	Prob.
I_PRICE_INDEX(-1)	1.217236	1.226988	0.000008	0.0005
I_PRICE_INDEX(-2)	-0.316090	-0.311136	0.000010	0.1118
POLICY_RATE(-4)	-1.579918	-1.596156	0.000038	0.0087
POLICY_RATE(-6)	1.212565	1.247488	0.000104	0.0006
LOG(NEER(-1))	13.832081	13.740581	0.000647	0.0003
LOG(NEER(-5))	-42.206938	-40.914817	0.102006	0.0001
Cross-section random effects test equation:				
Dependent Variable: I_PRICE_INDEX				
Method: Panel Least Squares				
Date: 04/09/23 Time: 16:50				
Sample (adjusted): 2016M07 2022M02				
Periods included: 68				
Cross-sections included: 21				
Total panel (balanced) observations: 1428				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-24.58533	7.093336	-3.465975	0.0005
I_PRICE_INDEX(-1)	1.217236	0.026471	45.98373	0.0000
I_PRICE_INDEX(-2)	-0.316090	0.027364	-11.55125	0.0000
POLICY_RATE(-4)	-1.579918	0.326882	-4.833293	0.0000
POLICY_RATE(-6)	1.212565	0.307939	3.937682	0.0001
LOG(NEER(-1))	13.83208	6.348127	2.178923	0.0295
LOG(NEER(-5))	-42.20694	9.048412	-4.664569	0.0000
Effects Specification				
Cross-section fixed (dummy variables)				
Root MSE	9.057866	R-squared	0.895828	
Mean dependent var	15.73564	Adjusted R-squared	0.893895	
S.D. dependent var	28.07393	S.E. of regression	9.144731	
Akaike info criterion	7.282959	Sum squared resid	117160.2	
Schwarz criterion	7.382489	Log likelihood	-5173.033	
Hannan-Quinn criter.	7.320129	F-statistic	463.3827	
Durbin-Watson stat	1.995197	Prob(F-statistic)	0.000000	

Figure C.5 - Hausman test (industrial inflation)

Source: calculated by the author in Eviews 12

Redundant Fixed Effects Tests				
Equation: EQ_2_MAIN				
Test cross-section fixed effects				
Effects Test	Statistic	d.f.	Prob.	
Cross-section F	0.891097	(20,1401)	0.5991	
Cross-section Chi-square	18.050834	20	0.5841	
Cross-section fixed effects test equation: Dependent Variable: I_PRICE_INDEX Method: Panel Least Squares Date: 04/09/23 Time: 16:51 Sample (adjusted): 2016M07 2022M02 Periods included: 68 Cross-sections included: 21 Total panel (balanced) observations: 1428				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-23.77380	7.085022	-3.355501	0.0008
I_PRICE_INDEX(-1)	1.226988	0.026303	46.64833	0.0000
I_PRICE_INDEX(-2)	-0.311136	0.027165	-11.45338	0.0000
POLICY_RATE(-4)	-1.596156	0.326573	-4.887589	0.0000
POLICY_RATE(-6)	1.247488	0.307534	4.056429	0.0001
LOG(NEER(-1))	13.74058	6.343209	2.166188	0.0305
LOG(NEER(-5))	-40.91482	9.035840	-4.528059	0.0000
Root MSE	9.115296	R-squared	0.894503	
Mean dependent var	15.73564	Adjusted R-squared	0.894058	
S.D. dependent var	28.07393	S.E. of regression	9.137720	
Akaike info criterion	7.267589	Sum squared resid	118650.6	
Schwarz criterion	7.293393	Log likelihood	-5182.058	
Hannan-Quinn criter.	7.277225	F-statistic	2008.099	
Durbin-Watson stat	1.986966	Prob(F-statistic)	0.000000	

Figure C.6 - Redundant fixed effects tests (industrial inflation)

Source: calculated by the author in Eviews 12

Residual Cross-Section Dependence Test				
Null hypothesis: No cross-section dependence (correlation) in residuals				
Equation: EQ_2_MAIN				
Periods included: 68				
Cross-sections included: 21				
Total panel observations: 1428				
Note: non-zero cross-section means detected in data				
Cross-section means were removed during computation of correlations				
Test	Statistic	d.f.	Prob.	
Breusch-Pagan LM	1695.871	210	0.0000	
Pesaran scaled LM	72.50306		0.0000	
Pesaran CD	20.16147		0.0000	

Figure C.7 - Residual cross-section dependence test (industrial inflation)

Source: calculated by the author in Eviews 12

Table C.1 Correlation matrix for the industrial prices model

	Industrial price index	Industrial price index (-1)	Industrial price index (-2)	Policy rate (-4)	Policy rate (-6)	Log (NEER (-1))	Log (NEER (-5))
Industrial price index	1.000	0.938	0.847	-0.231	-0.270	-0.144	-0.194
Industrial price index (-1)	0.938	1.000	0.941	-0.194	-0.243	-0.144	-0.201
Industrial price index (-2)	0.847	0.941	1.000	-0.152	-0.209	-0.142	-0.212
Policy rate (-4)	-0.231	-0.194	-0.152	1.000	0.965	0.099	-0.154
Policy rate (-6)	-0.270	-0.243	-0.209	0.965	1.000	0.165	0.034
Log (NEER (-1))	-0.144	-0.144	-0.142	0.099	0.165	1.000	0.628
Log (NEER (-5))	-0.194	-0.201	-0.212	-0.154	0.034	0.628	1.000

Source: calculated by the author in Eviews 12

Appendix D

Model documentation

<p>***** Domestic interest rates sector: *****</p>
<p>Gap_of_real_interest_rate = Real_interest_rate-Normal_real_interest_rate UNITS: (dmnl/Year) DOCUMENT: - This variable reflects an absolute deviation of the real interest rate from its normal level - There is no division by normal real interest rate because usually it is the effect of the absolute difference between the normal level or interest rates (or its long-term trend) and actual one that affects the decisions of economic agents about savings and investments. In other words, it is easier to understand the difference between 5% per year and 2% per year as a 3% per year gap, than to say that interest rates are 2.5 times higher than usual.</p>
<p>Nominal_interest_rate = Real_interest_rate+Expected_inflation UNITS: (dmnl/Year) DOCUMENT: - This variable reflects the level of nominal interest rate in an economy. Nominal interest rate can be decomposed into 2 parts: real interest rate and expected inflation.</p>
<p>Normal_real_interest_rate = 0.03 UNITS: (dmnl/Year) DOCUMENT: - This parameter shows how many percents per year (but here it is shown as a fraction per year to simplify calculations) an investment should generate (after taking into account expected inflation) in order to satisfy an average investor in normal times (steady state of a economy, equilibrium, etc.).</p>
<p>Real_interest_rate(t) = Real_interest_rate(t - dt) + (Net_change_in_real_interest_rate) * dt INIT Real_interest_rate = Normal_real_interest_rate UNITS: (dmnl/Year) DOCUMENT: - Real short-term interest rate level in the economy. This level reflects real monetary conditions for borrowing. - This variable shows how many percents per year (but here it is shown as a fraction per year to simplify calculations) an investment should generate (after taking into account expected inflation) in order to satisfy an average investor. - In the beginning of the simulation this variable is set equal to its normal level, because in equilibrium or steady state of an economy real interest rate should tend to its normal level. - If a central bank does not have an active interest rate policy, the determinants of the interest rate would include foreign level of interest rates, the average propensity to save in the domestic economy (the supply of capital), the number of projects in the economy that are able to generate cash flows sufficient to cover the total costs of borrowing (the actual demand for capital), the level of development of the financial market (different risk premiums, transaction costs) and other country-specific factors.</p>
<p>INFLOWS: Net_change_in_real_interest_rate = Policy_2_switch:_inflation_targeting* (Real_key_policy_rate-Real_interest_rate)/Real_interest_rate_adjustment_time UNITS: (dmnl/Year)/Year DOCUMENT: - If a central bank does not have an active interest rate policy and does not set a key policy rate that would be perceived by economic agents as an indicator of real monetary conditions (price of borrowing, price of lending, loan availability in an economy), then real interest rate should equal to its normal level. Thus, if "policy 2 switch" is off, then the net change in real interest rate should be equal to 0 all the time.</p>

Real_interest_rate_adjustment_time = 1/2

UNITS: Year

DOCUMENT:

- This parameter reflects how long on average does it take for real interest rate in economy to adjust to changes in real key policy rate. Because of the design of this model (real interest rate is the only stock in the sequence "real key policy rate - real interest rate - gap of GDP growth - inflation"), this variable also reflects the time it takes real interest rate changes (in other words, real monetary conditions changes) to affect the aggregate demand, the gap of GDP growth, and inflation. That is why, this variable can also be viewed as the lag from monetary policy actions to inflation. The value chosen aligns with literature review and author's estimates for Ukraine.

GDP growth sector:

Gap_of_GDP_growth =

GDP_growth_sensitivity_to_the_relative_gap_of_real_exchange_rate*Relative_real_exchange_rate_gap +

GDP_growth_sensitivity_to_the_gap_of_real_interest_rate*Gap_of_real_interest_rate +

GDP_shock*GDP_shock_switch

UNITS: (dmnl/Year)

DOCUMENT:

- This is the number of percentage points increase of GDP per year compared with the "normal" yearly increase of GDP

- Gap of GDP growth shows the difference between the actual GDP increase and the one that would reflect the change in the potential of the economy (or the increase in the trend of the GDP). So, in normal situation it should be zero as the economy would be expected to grow exactly at the pace of growth of its potential. Economy can't grow faster or slower than the rate of growth of its potential in the long term, but in the short-term period there could be deviations from such a trend, which would affect the price level.

- Gap of GDP growth is not normalized, because its normal level is 0 and it is already percentage per year.

- This can also be considered a representation of a velocity of GDP growth (minus the normal velocity). There is no delay in the formation of the gap of GDP growth for the following reason: the sensitivity coefficients that are used for calculation of the gap of GDP growth implicitly take into account the delays in the changes of the growth rate. This happens because they are taken from an econometrics model, which uses only instantaneous relationships. And during optimization procedures for such a model, the estimated values of the coefficients tend to be smaller than they would have been if there were a possibility to consider the delays explicitly.

GDP_growth_sensitivity_to_the_gap_of_real_interest_rate = -0.035

UNITS: (dmnl/Year)/(dmnl/Year)

DOCUMENT:

- This parameter shows by how many percentage points in annual terms does a positive 1% per year gap of real interest rate decrease the rate of GDP growth.

- The sign is negative, because if there are higher rates in the economy, it will be more expensive for firms to borrow money and investments will decrease, which is why GDP will decrease.

GDP_growth_sensitivity_to_the_relative_gap_of_real_exchange_rate = -0.065

UNITS: (dmnl/Year)

DOCUMENT:

- This parameter shows by how many percentage points in annual terms does a positive 1% relative gap of real exchange rate decrease the rate of GDP growth.

- The sign is negative, because if there is a positive relative real exchange rate gap it means that foreign producers temporary have higher price competitiveness than domestic producers, that is why net export decreases, and GDP growth slows down.

Interest rate policy sector:

<p>Effect_of_inflation_gap_on_real_key_policy_rate = $\text{Inflation_gap_perceived_by_the_central_bank} * \text{Monetary_policy_sensitivity_to_the_inflation_gap}$ UNITS: (dmnl/Year) DOCUMENT: - This variable shows a reaction of a central bank to the inflation gap over time. It is assumed that the effect is linear.</p>
<p>Effect_of_the_gap_of_GDP_growth_on_real_key_policy_rate = $\text{Gap_of_GDP_growth} * \text{Monetary_policy_sensitivity_to_the_gap_of_GDP_growth}$ UNITS: dmnl/Year DOCUMENT: - This variable shows a reaction of a central bank to the gap of GDP growth over time. It is assumed that the effect is linear.</p>
<p>Inflation_gap_perceived_by_the_central_bank = Expected_inflation-Normal_inflation UNITS: (dmnl/Year) DOCUMENT: - This variable shows the absolute difference between the expected inflation and the normal inflation. - If a central bank is using its interest rate policy to affect inflation, then a central bank usually accounts for a difference between inflation expectations for medium-term and medium-term inflation target.</p>
<p>Monetary_policy_sensitivity_to_the_gap_of_GDP_growth = 0.4 UNITS: (dmnl/Year)/(dmnl/Year) DOCUMENT: - This parameter shows by how many percentage points in annual terms a central bank needs to increase its real key policy rate to close the gap of GDP growth of 1% per year in the medium-term. That is a part of a decision rule used at a central bank. - The sign is positive, because most of the central banks are responsible by their national legislation for smoothing business cycles in their countries, so that economic growth would be less volatile. Thus, when there is a temporary positive gap of GDP growth, the central bank increases its real key policy rate to tighten real monetary conditions, which will lead to slower economic growth.</p>
<p>Monetary_policy_sensitivity_to_the_inflation_gap = 2 UNITS: (dmnl/Year)/(dmnl/Year) DOCUMENT: - This parameter shows by how many percentage points in annual terms a central bank needs to increase its real key policy rate to close the perceived inflation gap of 1% per year in the medium-term. That is a part of a decision rule used at a central bank. - The sign is positive, because if inflation is higher than its normal value, than the central bank must increase its real key policy rate to make real monetary conditions for an economy tighter.</p>
<p>"Nominal_key_policy_rate_(in_percentages)" = $(\text{Real_key_policy_rate} + \text{Expected_inflation}) * \text{Percents_per_fraction}$ UNITS: Percent/Year DOCUMENT: - The nominal interest rate at which the central bank carries out its main operations (borrows money to the commercial banks and takes deposits from the commercial banks if there is high liquidity surplus in the banking system). It is expressed as percentages per year for presentation purposes.</p>
<p>Normal_inflation = 0.13 UNITS: (dmnl/Year) DOCUMENT: - This parameter shows the annual percentage (but here it is converted to a fraction) increase in prices in an economy in normal times (steady state of a economy, equilibrium, etc.).</p>

Percents_per_fraction = 100

UNITS: Percent/dmnl

DOCUMENT:

- This variable is needed for conversion of fractional rates into percentage rate. And percentage rates are primarily used for presentation purposes.

Real_key_policy_rate = Normal_real_interest_rate +Effect_of_inflation_gap_on_real_key_policy_rate
+Effect_of_the_gap_of_GDP_growth_on_real_key_policy_rate

UNITS: (dmnl/Year)

DOCUMENT:

- This variable shows the real interest rate at which the central bank carries out its main operations.
- In normal times (steady state of an economy, equilibrium, etc.) there is no gaps of inflation and GDP growth, that is why in this case the real key policy rate equal to normal real interest rate (it is also called neutral real interest rate).
- In reality, the central banks set a nominal key policy rate (so that we would have to add expected inflation to the real key policy rate), but here we are making a simplification that inflation expectations are the same for each economic agent, and because it is real interest rates that affect the real monetary conditions, there is no need for additional calculations.

Domestic prices sector:

Effect_of_exchange_rate_changes_on_inflation =

Nominal_exchange_rate_change_for_the_last_year*Inflation_sensitivity_to_the_changes_of_the_nominal_exchange_rate

UNITS: (dmnl/Year)

DOCUMENT:

- This variable shows an effect of the changes in nominal exchange rate on inflation over time. It is assumed that the effect is linear.

Effect_of_the_gap_of_GDP_growth_on_inflation =

Gap_of_GDP_growth*Inflation_sensitivity_to_the_gap_of_GDP_growth

UNITS: (dmnl/Year)

DOCUMENT:

- This variable shows an effect of the gap of GDP growth on inflation over time. It is assumed that the effect is linear.

Effect_of_the_relative_gap_of_real_exchange_rate_on_inflation =

Inflation_sensitivity_to_the_relative_real_exchange_rate_gap*Relative_real_exchange_rate_gap

UNITS: (dmnl/Year)

DOCUMENT:

- This variable shows an effect of the relative gap of real exchange rate on inflation over time. It is assumed that the effect is linear.

Inflation = Expected_inflation +Effect_of_the_gap_of_GDP_growth_on_inflation

+Effect_of_the_relative_gap_of_real_exchange_rate_on_inflation

+Effect_of_exchange_rate_changes_on_inflation + Inflation_shock*Inflation_shock_switch

UNITS: (dmnl/Year)

DOCUMENT:

- This variable shows the annual percentage (but here it is converted to a fraction) increase in prices in an economy. In other words, this can be interpreted as a velocity of change in price level.
- All of the drivers of inflation are assumed to be independent of each other.
- There is no delay in the calculation of inflation for the following reason: the sensitivity coefficients that are used for the calculations of the effect of 3 different factor on inflation implicitly take into account the delays in the

changes of the growth rate. This happens because they are taken from an econometrics model, which uses only instantaneous relationships. And during optimization procedures for such a model, the estimated values of the coefficients tend to be smaller than they would have been if there were a possibility to take into account the delays explicitly.

"Inflation_(in_percentages)" = Inflation*Percents_per_fraction

UNITS: Percent/Year

DOCUMENT:

- The inflation rate but expressed as percentages per year for presentation purposes.

Inflation_sensitivity_to_the_changes_of_the_nominal_exchange_rate = -0.05

UNITS: (dmnl/Year)/(dmnl/Year)

DOCUMENT:

- This parameter shows by how many percentage points in annual terms does a positive 1% of the nominal exchange rate appreciation for the last year decrease the actual inflation rate.

- The sign is negative, because if the nominal exchange rate depreciates, then the domestic prices on imported products might increase, because foreign producers might want to keep the same profit margin.

Inflation_sensitivity_to_the_gap_of_GDP_growth = 0.18

UNITS: (dmnl/Year)/(dmnl/Year)

DOCUMENT:

- This parameter shows by how many percentage points in annual terms does a positive 1% per year gap of GDP growth increase the actual inflation rate.

- The sign is positive, because if the economy is growing faster than its potential then the prices should go up to reflect the increased competition for resources.

Inflation_sensitivity_to_the_relative_real_exchange_rate_gap = -0.06

UNITS: (dmnl/Year)

DOCUMENT:

- This parameter shows by how many percentage points in annual terms does a positive 1% of relative gap of real exchange rate decrease the actual inflation rate.

- The sign is negative, because if there is a positive real exchange rate gap it means that there is a temporary higher price competitiveness of foreign producers comparing to domestic ones. That is why, it would be expected that the prices on imported goods and services will grow slower.

- Ukrainian economy is highly dependent on import, that is why this component should be added to reflect the marginal costs of importers, which will be translated into prices on imported products.

Initial_price_level_in_domestic_market = 1

UNITS: Units of national currency

DOCUMENT:

- The initial price of a reference group of products measured in the units of national currency. A reference group of products is the same in both economies and for simplicity I am assuming that in the beginning of the simulation the relative price level equals to 1.

Price_index_for_domestic_market = Price_level_in_domestic_market/Initial_price_level_in_domestic_market

UNITS: dmnl

DOCUMENT:

- A measure of the total inflation in domestic economy since the beginning of the simulation. This variable is used primarily for the reasons of calculations of the real exchange rate index. And also, the price indices are available for every economy in the world.

Price_level_in_domestic_market(t) = Price_level_in_domestic_market(t - dt) +
(Change_of_price_level_in_domestic_market) * dt

INIT Price_level_in_domestic_market = Initial_price_level_in_domestic_market

UNITS: Units of national currency

DOCUMENT:

- The price of a reference group of products measured in the units of national currency.

<p>INFLOWS: $\text{Change_of_price_level_in_domestic_market} = \text{Price_level_in_domestic_market} * \text{Inflation}$ UNITS: Units of national currency/Year DOCUMENT: - Inflation is a velocity of price level change and that is why the inflow to price level is its past value multiplied with inflation rate.</p>
<p>***** Foreign prices sector: *****</p>
<p>$\text{Inflation_in_main_trading_partner} = \text{Normal_inflation}$ UNITS: (dmnl/Year) DOCUMENT: - This parameter shows the annual percentage (but here it is converted to a fraction) increase in prices in the economy of main trading partner.</p>
<p>$\text{Initial_price_level_in_main_trading_partner} = 1$ UNITS: Units of foreign currency DOCUMENT: - The initial price of a reference group of products measured in the units of foreign currency. A reference group of products is the same in both economies and for simplicity we are assuming that in the beginning of the simulation the relative price level equals to 1.</p>
<p>$\text{Price_index_for_main_trading_partner} = \frac{\text{Price_level_in_main_trading_partner}}{\text{Initial_price_level_in_main_trading_partner}}$ UNITS: dmnl DOCUMENT: - A measure of the total inflation in main trading partner since the beginning of the simulation. This variable is used primarily for the reasons of calculations of the real exchange rate index. Also, the price indices are available for every economy in the world.</p>
<p>$\text{Price_level_in_main_trading_partner}(t) = \text{Price_level_in_main_trading_partner}(t - dt) + (\text{Change_of_price_level_in_main_trading_partner}) * dt$ INIT $\text{Price_level_in_main_trading_partner} = \text{Initial_price_level_in_main_trading_partner}$ UNITS: Units of foreign currency DOCUMENT: - The price of a reference group of products measured in the units of foreign currency.</p>
<p>INFLOWS: $\text{Change_of_price_level_in_main_trading_partner} = \text{Inflation_in_main_trading_partner} * \text{Price_level_in_main_trading_partner}$ UNITS: Units of foreign currency/Year DOCUMENT: - Inflation is a velocity of price level change and that is why the inflow to price level is its past value multiplied with inflation rate.</p>
<p>***** Trade competitiveness sector: *****</p>
<p>$\text{Real_exchange_rate_index} = \frac{\text{Nominal_exchange_rate_index}}{\text{Relative_inflation_index}}$ UNITS: dmnl DOCUMENT: - This variable shows a relative trade competitiveness of foreign producers against domestic producers. - Because of the assumption that there are only two countries in the world of this model, this stock can also be considered a real effective exchange rate (REER).</p>

<p>Reference_real_exchange_rate_index = 1 UNITS: dmn1 DOCUMENT: - That is a real exchange rate in the beginning of the simulation and because initial values of all 3 indexes required for the calculations of the real exchange rate index equal to 1 initially, the value of this parameter also equals to 1.</p>
<p>Relative_inflation_index = Price_index_for_main_trading_partner/Price_index_for_domestic_market UNITS: dmn1 DOCUMENT: - A comparison of total inflation since the beginning of the simulation in main trading partner against domestic economy.</p>
<p>Relative_real_exchange_rate_gap = (Real_exchange_rate_index - Reference_real_exchange_rate_index)/Reference_real_exchange_rate_index UNITS: dmn1 DOCUMENT: - Normalized deviation of trade competitiveness from its initial state. This gap represents actual trade conditions in the international market. If there is a positive gap, this means that foreign producers currently have an advantage in foreign trade, which would lead to a decrease in net export of the national economy (more import and less export for domestic market) and at the same time this would lead to a deceleration in domestic inflation as the marginal costs for importers are lower.</p>
<p>***** Foreign exchange market sector: *****</p>
<p>Current_normal_nominal_interest_rate_in_the_domestic_market = Normal_nominal_interest_rates_in_the_domestic_market + Nominal_exchange_rate_shock*Nominal_exchange_rate_shock_switch UNITS: (dmn1/Year) DOCUMENT: - The level of nominal interest rates at which investors will be indifferent between investing abroad and investing in the domestic economy</p>
<p>Elasticity_of_nominal_exchange_rate_to_the_gap_of_nominal_interest_rate = 0.25 UNITS: dmn1 DOCUMENT: - This parameter reflects by how many percents should a nominal exchange rate appreciate to close 1% of relative gap of nominal interest rate.</p>
<p>Indicated_nominal_exchange_rate = Nominal_exchange_rate* (1 + Elasticity_of_nominal_exchange_rate_to_the_gap_of_nominal_interest_rate*Relative_gap_of_nominal_interest_rate) UNITS: Units of foreign currency/Units of national currency DOCUMENT: - It is assumed that the current value of the nominal exchange rate is an anchor for the foreign exchange market, which is adjusted by the effect of differences between the required nominal interest rate and the actual nominal interest rate.</p>
<p>Initial_nominal_exchange_rate = Initial_price_level_in_main_trading_partner/Initial_price_level_in_domestic_market UNITS: Units of foreign currency/Units of national currency DOCUMENT: - The initial price of national currency measured in units of foreign currency - It is assumed that purchasing power parity defines the nominal exchange rate in equilibrium in this model.</p>

$$\text{Nominal_exchange_rate}(t) = \text{Nominal_exchange_rate}(t - dt) +$$

$$(\text{Change_in_nominal_exchange_rate_due_to_international_flows_of_capital} -$$

$$\text{Foreign_exchange_interventions_effect_on_nominal_exchange_rate}) * dt$$

INIT Nominal_exchange_rate = Initial_nominal_exchange_rate

UNITS: Units of foreign currency/Units of national currency

DOCUMENT:

- The price of national currency measured in units of foreign currency.

INFLOWS:

$$\text{Change_in_nominal_exchange_rate_due_to_international_flows_of_capital} =$$

$$(\text{Indicated_nominal_exchange_rate} - \text{Nominal_exchange_rate}) / \text{Nominal_exchange_rate_adjustment_time}$$

UNITS: Units of foreign currency/Units of national currency/Year

DOCUMENT:

- Because of the difference between the level of the nominal exchange rate that is needed in order to reflect the relative gap of nominal interest rate and the actual level of the nominal exchange rate, there would be international flows of capital (e.g., if the nominal interest rate in economy is higher than its required level investors will be willing to buy national currency, which is why the demand for the national currency will increase and the national currency will appreciate).

OUTFLOWS:

$$\text{Foreign_exchange_interventions_effect_on_nominal_exchange_rate} =$$

Policy_1_switch: fixed_exchange_rate*

$$\text{Change_in_nominal_exchange_rate_due_to_international_flows_of_capital} + (1 -$$

$$\text{Policy_1_switch: fixed_exchange_rate})$$

Normal_fraction_for_coverage_of_exchange_rate_volatility_with_foreign_exchange_interventions

$$\text{Change_in_nominal_exchange_rate_due_to_international_flows_of_capital}$$

UNITS: Units of foreign currency/Units of national currency/Year

DOCUMENT:

- This is an effect of foreign exchange interventions that is meant to cover the effects of international flows of capital on the nominal exchange rate. A central bank in a developing economy is usually interested in the stability of the nominal exchange rate of its currency, because nominal exchange rate affects the revenues of the country's export and also plays important role in building confidence of the population in the national currency. This is especially the case of Ukraine where there is a long history of fixed exchange rate regime (people relied heavily on the assumption that the exchange rate will not change for years and made their plans according to this assumption).

- When there is no policy of keeping the nominal exchange rate at a constant level, the effect of the foreign exchange interventions is just the normal coverage of exchange rate volatility multiplied with the effect on the nominal exchange rate due to international flows of capital. But if there is a policy of keeping the exchange rate at a constant level, then the effect on the nominal exchange rate from due to international flows of capital is neutralized completely by the foreign exchange interventions by the central bank.

$$\text{Nominal_exchange_rate_adjustment_time} = 1$$

UNITS: Year

DOCUMENT:

- This parameter reflects the time it takes the international flows of capital to cover the gap of nominal interest rates.

$$\text{Nominal_exchange_rate_change_for_the_last_year} =$$

$$(\text{Change_in_nominal_exchange_rate_due_to_international_flows_of_capital}$$

$$+ \text{Foreign_exchange_interventions_effect_on_nominal_exchange_rate}) / \text{Nominal_exchange_rate}$$

UNITS: (dmnl/Year)

DOCUMENT:

- This variable shows the relative change of the nominal exchange rate for the last year.

$$\text{Nominal_exchange_rate_index} = \text{Nominal_exchange_rate} / \text{Initial_nominal_exchange_rate}$$

UNITS: dmnl

DOCUMENT:

<p>- This variable shows the dynamics of the nominal exchange rate compared to its initial level over time.</p>
<p>Normal_fraction_for_coverage_of_exchange_rate_volatility_with_foreign_exchange_interventions = 0.15 UNITS: dmnl DOCUMENT: - This is a fraction of the total effect on the nominal exchange rate from the foreign investors that is neutralized by the interventions of the central bank on the foreign exchange market. - According to the paper about quarterly projection model (Grui & Vdovychenko, 2019) for Ukraine, this value should be equal to 0.15. This value in the paper is based on the econometrics estimation on quarterly time-series data for Ukraine for 2000-2018.</p>
<p>Normal_nominal_interest_rates_in_the_domestic_market = Normal_inflation+Normal_real_interest_rate UNITS: (dmnl/Year) DOCUMENT: - The level of nominal interest rates at which investors will be indifferent between investing abroad and investing in the domestic economy (in normal times).</p>
<p>Relative_gap_of_nominal_interest_rate = (Nominal_interest_rate- Current_normal_nominal_interest_rate_in_the_domestic_market)/Current_normal_nominal_interest_rate_in_the _domestic_market UNITS: dmnl DOCUMENT: - Normalized deviation of an actual level of the nominal interest rate in an economy from the currently required by investors level of nominal interest rate in the domestic market.</p>
<p>***** Inflation expectations formation sector: *****</p>
<p>Central_bank_credibility = 0.15 UNITS: dmnl DOCUMENT: - This parameter represent not only the credibility of the central bank, but also the general level of knowledge of economic agents; but it is called central bank credibility because if this variable is set equal to 0, than inflation expectation are completely backward-looking and the central bank can not affect inflation expectations in any way and has to relay on other channels of monetary transmission to change the actual inflation; at the same time, if this variable is set equal to 1, than the expectations channel of monetary transmission has its highest effect and helps central bank a lot in the process of achieving the inflation target.</p>
<p>Effect_of_monetary_policy_gap_on_rational_inflation_expectations = Monetary_policy_gap*Sensitivity_of_rational_inflation_expectation_to_monetary_policy_gap UNITS: (dmnl/Year) DOCUMENT: - This variable shows an effect of the monetary policy gap on rational inflation expectations over time. It is assumed that the effect is linear.</p>
<p>Effect_of_perceived_inflation_gap_on_expected_key_policy_rate = Perceived_inflation_gap*Monetary_policy_sensitivity_to_the_inflation_gap UNITS: (dmnl/Year) DOCUMENT: - It is assumed that the population knows the monetary policy rule for setting the real key policy rate and can apply this rule to estimate by many percentage points in annual terms the real key policy rate should exceed its normal level to close the gap between the perceived inflation and normal inflation in medium-term.</p>

<p>Effect_of_the_gap_of_GDP_growth_on_expected_key_policy_rate = Gap_of_GDP_growth*Monetary_policy_sensitivity_to_the_gap_of_GDP_growth UNITS: (dmnl/Year) DOCUMENT: - It is assumed that the population knows the monetary policy rule for setting the real key policy rate and can apply this rule to estimate by many percentage points in annual terms the real key policy rate should exceed its normal level to close the gap between the actual gap of GDP growth and its normal level. - It is also assumed that the population perceive the gap of GDP growth instantly, because they make their judgments about the current state of economy based on their income and employment.</p>
<p>Expected_inflation(t) = Expected_inflation(t - dt) + (Updating_expected_inflation) * dt INIT Expected_inflation = Normal_inflation UNITS: (dmnl/Year) DOCUMENT: - Inflation expected for the next 12 months. This is a stock of perceptions (or information) and that is why it is modeled as a first-order control (with an inflow of updates).</p>
<p>INFLOWS: Updating_expected_inflation = (Indicated_inflation_expectations - Expected_inflation)/Time_to_adjust_inflation_expectations UNITS: Per Year/Year DOCUMENT: - Inflation expectations are usually quite persistent, which is why it takes time to update them, so that they will reflect the changes in macroeconomic environment.</p>
<p>"Expected_inflation_(in_percentages)" = Expected_inflation*Percents_per_fraction UNITS: Percent/Year DOCUMENT: - The expected inflation rate but expressed as percentages per year for presentation purposes.</p>
<p>Expected_real_key_policy_rate = Normal_real_interest_rate +Effect_of_perceived_inflation_gap_on_expected_key_policy_rate +Effect_of_the_gap_of_GDP_growth_on_expected_key_policy_rate UNITS: (dmnl/Year) DOCUMENT: - The expected real key policy rate is anchored to normal real interest rate and there are linear adjustments to reflect the perceived inflation gap and the gap of GDP growth.</p>
<p>Indicated_inflation_expectations = (Perceived_inflation*(1-Central_bank_credibility) + (Rational_inflation_expectations*Central_bank_credibility)) *Policy_2_switch:_inflation_targeting + Perceived_inflation* (1-Policy_2_switch:_inflation_targeting) UNITS: (dmnl/Year) DOCUMENT: - The weighted average of backward-looking inflation expectations (perceived past inflation) and forward-looking inflation expectations (which is based on the central bank credibility and the level of understanding of macroeconomics by the population). - If the central bank does not have a communicate policy as a part of inflation-targeting monetary policy regime, then it is assumed that inflation expectations are completely backward-looking.</p>
<p>Monetary_policy_gap = Expected_real_key_policy_rate-Real_key_policy_rate UNITS: (dmnl/Year) DOCUMENT: - This variable shows the extent to which the actions of the central bank meet the expectations of the population in terms of the absolute difference between the level of real key policy rate expected by the population and its actual level.</p>

<p> $\text{Perceived_inflation}(t) = \text{Perceived_inflation}(t - dt) + (\text{Change_in_perceived_inflation}) * dt$ INIT Perceived_inflation = Normal_inflation UNITS: (dmnl/Year) DOCUMENT: - Annual percentage increase in prices in an economy calculated by the national statistics office (e.g. State Statistics Service of Ukraine) and perceived by the population. This is a stock of perceptions (or information) and that is why it is modeled as a first-order control (with an inflow of updates). </p>
<p> INFLOWS: $\text{Change_in_perceived_inflation} = (\text{Inflation} - \text{Perceived_inflation}) / \text{Time_to_perceive_inflation}$ UNITS: Per Year/Year DOCUMENT: - Actual inflation is the goal for perceived inflation, but there is a delay in the perception, which is why the first-order inflation delay is used here. </p>
<p> $\text{Perceived_inflation_gap} = \text{Perceived_inflation} - \text{Normal_inflation}$ UNITS: (dmnl/Year) DOCUMENT: - The difference between the perceived inflation by the economic agents and the inflation target. - This variable reflects the perceived (by the population) performance of the central bank in inflation targeting. </p>
<p> $\text{Rational_inflation_expectations} = \text{Normal_inflation}$ + $\text{Effect_of_monetary_policy_gap_on_rational_inflation_expectations}$ UNITS: (dmnl/Year) DOCUMENT: - This variable shows the rate of inflation for the next 12 month that will be expected by the population in the situation when the population understand monetary policy and trust the central bank. - In this case, the expected inflation would be equal to the inflation target (that is set by the central bank) plus the effect of the discrepancy between the expected real key policy rate and the actual one. </p>
<p> $\text{Sensitivity_of_rational_inflation_expectation_to_monetary_policy_gap} = 1$ UNITS: (dmnl/Year)/(dmnl/Year) DOCUMENT: - This parameter reflects by how many percentage points in annual terms future-oriented (or rational) inflation expectations will increase because of 1 percentage point in annual terms of positive gap between the expected and actual real key policy rate. - The sign is positive, because if the expected key policy rate is higher than the actual one, then economic agents will think that monetary policy is not tight enough to return economy to the targeted inflation level (or not tight enough to return the gap of GDP growth to its normal level), and they will expect higher inflation. - We assume that this parameter equals to 1 as it is the most straightforward approach: if the required rate is higher than the actual by 1 percentage point the inflation will be assumed to be higher in the future than the promised by the central bank one by 1 percentage point. </p>
<p> $\text{Time_to_adjust_inflation_expectations} = 2$ UNITS: Year DOCUMENT: - Time it takes to update inflation expectations. I assumed that it takes around 2 years to change expectations. The actual value is unlikely to be shorter as it usually takes quite a lot of time to change expectations in the whole economy. And it is also unlikely to be much longer as Ukraine is a developing economy where the state of economy can change drastically in a matter of several quarters, and the people are quite used to such quick shocks (since the year 1991 when Ukraine became independent state, they have seen hyperinflation, several revolutions, and war). </p>
<p> $\text{Time_to_perceive_inflation} = 1/12$ UNITS: Year DOCUMENT: - This parameter reflects the time it takes to calculate the price indices and to disseminate the results. - Usually there is a 10-20 day delay before information about inflation for the last month is calculated, plus additional 10-20 days before most of the economic agents will have the updated information. </p>

<p>*****</p> <p>Policy switches sector:</p> <p>*****</p>
<p>Policy_1_switch:_fixed_exchange_rate = 0</p> <p>UNITS: dmn1</p> <p>DOCUMENT:</p> <p>- This policy means that a central bank will use its international reserves to absorb all the discrepancies between the demand and supply of foreign currency in the foreign exchange market to keep the nominal exchange rate at a constant level.</p>
<p>Policy_2_switch:_inflation_targeting = 1</p> <p>UNITS: dmn1</p> <p>DOCUMENT:</p> <p>- This policy means that the central bank will change its key policy rate, which will affect real monetary conditions, aggregate demand, GDP growth and inflation. Also, it means that the central bank clearly communicates how it conducts monetary policy, explains to the population the chosen inflation target, and shows that its actions are aimed at achieving inflation target.</p>
<p>*****</p> <p>Shocks sector:</p> <p>*****</p>
<p>GDP_shock = -STEP(0.06, 2015.25) + STEP(0.06, 2016)</p> <p>UNITS: (dmn1/Year)</p> <p>DOCUMENT:</p> <p>- This is a representation of some of the direct effects of war on GDP in the short run (occupation of the territory, destruction of capital, a emigration of large proportion of the population).</p>
<p>GDP_shock_switch = 1</p> <p>UNITS: dmn1</p> <p>DOCUMENT: This is a switch for GDP shock.</p>
<p>Inflation_shock = STEP(0.25, 2015.25) - STEP(0.25, 2016)</p> <p>UNITS: (dmn1/Year)</p> <p>DOCUMENT:</p> <p>- This is a representation of some of the direct effects of war on inflation in the short run (disrupted supply chains, destruction of enterprises that manufactured a large proportion of supply for some of the markets).</p>
<p>Inflation_shock_switch = 1</p> <p>UNITS: dmn1</p> <p>DOCUMENT: This is a switch for inflation shock.</p>
<p>Nominal_exchange_rate_shock = STEP(0.2, 2015.25) - STEP(0.2, 2016)</p> <p>UNITS: (dmn1/Year)</p> <p>DOCUMENT:</p> <p>- This is a representation of some of the direct effects of war on the required nominal interest rate and international flows of capital. A war increases risks in a country, which is why investors will be willing to invest in the country at war only if they will receive higher interest (risk premium). This increase in the required nominal interest rate leads to an increase of demand for foreign currency in foreign exchange market, which causes depreciation of national currency.</p>
<p>Nominal_exchange_rate_shock_switch = 1</p> <p>UNITS: dmn1</p> <p>DOCUMENT: This is a switch for nominal exchange rate shock.</p>

Appendix E

Simulation Experiment Report

This simulation experiment report follows the minimum simulation reporting requirements proposed by H. Rahmandad and J. Sterman [64].

Modelling Software: Stella Architect 3.1

Integration method: Runge-Kutta 4th Order Method

DT = 1/128

Time Unites: Year

Simulation Start Time: 2015

Simulation End Time: 2022

Equilibrium

These values initialize the model in equilibrium condition:

Inflation shock switch = 0

GDP shock switch = 0

Nominal exchange rate shock switch = 0

Baseline Scenario – Inflation-targeting monetary policy regime

This scenario reproduces the reference mode. The initial values are as follows:

Shocks sector

Inflation shock switch = 1

GDP shock switch = 1

Nominal exchange rate shock switch = 1

Policy switches sector

Policy 1 switch: fixed exchange rate = 0

Policy 2 switch: inflation targeting = 1

Inflation expectations formation sector

Time to perceive inflation = 1/12

Time to adjust inflation expectations = 2

Sensitivity of rational inflation expectations to monetary policy gap = 1

Central bank credibility = 0.15

Domestic prices sector

Inflation sensitivity to the gap of GDP growth = 0.18

Inflation sensitivity to the relative real exchange rate gap = -0.06

Inflation sensitivity to the changes of the nominal exchange rate = -0.05

Initial price level in domestic market = 1

Foreign prices sector

Initial price level in main trading partner = 1

Trade competitiveness sector

Reference real exchange rate index = 1

Foreign exchange market sector

Elasticity of nominal exchange rate to the gap of nominal interest rate = 0.25

Nominal exchange rate adjustment time = 1

Normal fraction for coverage of exchange rate volatility with foreign exchange interventions = 0.15

Domestic interest rates sector

Real interest rate adjustment time = 0.5

Normal real interest rate = 0.03

Interest rate policy sector

Normal inflation = 0.13

Monetary policy sensitivity to the gap of GDP growth = 0.4

Monetary policy sensitivity to the inflation gap = 2

Percents per fraction = 100

GDP growth sector

GDP growth sensitivity to the relative gap of real exchange rate = -0.065

GDP growth sensitivity to the gap of real interest rate = -0.035

Fixed exchange rate monetary policy regime scenario

This is a hypothetical scenario in which the central bank of Ukraine has found additional sources for replenishment of its international reserves in 2015 and has decided to adhere to its conventional policy of fixed exchange rate. All parameter and initial values are the same as in the baseline run except for the following:

Policy 1 switch: fixed exchange rate = 1

Policy 2 switch: inflation targeting = 0

Scenario of a combination of inflation-targeting and fixed exchange rate

This a hypothetical scenario in which the central bank of Ukraine has not only found the additional sources for replenishment of its international reserves in 2015 and continued to keep the exchange rate constant, but also decided to introduce the inflation-targeting monetary policy tools (active key policy rate management, public communication of the inflation target to the economic agents, and public vow to use the central bank's

instruments to achieve the target in the medium-term). Essentially, this is what the central bank has been doing in the real world since the 24th of February 2022 when the full-scale war has started. All parameters and initial values are the same as in the baseline run except for the following:

Policy 1 switch: fixed exchange rate = 1

Policy 2 switch: inflation targeting = 1

Scenario of increased central bank credibility

In this scenario, it is assumed that the central bank has been much more credible over the period of 2015-2021. All parameters and initial values are the same as in the baseline run except for the following:

Central bank credibility = 1.00