

The impact of exchange rate policy on the level of trade competitiveness in Ukraine

By

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First, I want to thank every defender who is fighting for the independence and sovereignty of Ukraine. You defend the democratic values of all civilized society. And I sincerely thank you, knowing how incredibly high the price of this struggle is. For me, you are Heroes and an example of strength, and courage!

Thanks to my supervisor, Professor David Wheat. Your wise comments and advice helped me in writing this research. Thanks to the System Dynamics Group and the University of Bergen for the opportunities!

Thanks to my family, partner, and friends for their support and inspiration. I also thank myself for going through this path to the end, despite all the circumstances and difficulties.

Go forth and conquer!

Abstract

The impact of the exchange rate on the trade positions of national producers and on the development of domestic production is one of the critical issues for developing countries. Before the start of the full-scale invasion in Ukraine, fluctuations in the exchange rate negatively affected the position of national producers. After the start of hostilities in 2022, the real sector of the economy suffered great losses and destruction. According to official data, the number of losses for 2022 reached about 30% of GDP (NBU, 2023c). In the conditions of the post-war period, improving the exchange rate policy, which will contribute to strengthening the position of national producers, is one of the important directions of economic recovery. This research is aimed at finding optimal or improving current exchange rate policies to increase the level of competitiveness of national producers.

The paper proposes three main policies that will contribute to the strengthening of the exchange rate and the development of the real sector of the economy. These include the share of international investments, improving the expectations of economic entities and reinvestment to increase the production capacity of industries. The relevance of the proposed policies is high during the war, but the main attention was directed to the post-war period. Because of the transition from a fixed currency regime to a flexible one.

The research results demonstrate the importance of exchange rate revaluation, improvement of public expectations regarding exchange rate fluctuations, attraction of international investment and increase in the reinvested profit in the production capacity of industries for improving the competitiveness of national producers, which is essential in post-war economic recovery.

Key words: exchange rate, competitiveness, trade, model, industries, producers, currency, imports, policy.

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Abbreviations

1	Balance of Payments	BOP
2	Current Account	CA
3	Exchange rate	ER
4	The National Bank of Ukraine	NBU
5	Ukrainian national currency	UAH
6	State Statistics Service of Ukraine	SSSU
7	Terms of Trade	TOT
8	Aggregate Demand	AD
9	Foreign Currency	FC
10	Gross Domestic Product	GDP

Chapter 1. Introduction

The country's trade position on the international market describes not only the level of development of domestic production but also reveals the degree of interaction with partner countries, ensuring the redistribution of economic and political influence. There is no single definition of the concept of "trade competitiveness" or its similar concepts such as "international competitiveness", and "international trade" in the scientific literature. One of the oldest definitions is the description of the concept of competitiveness as the "ability to produce" and "ability to sell" (Balassa, 1962) goods and services. Nowadays, this definition has been expanded and supplemented with such concepts as a country's "ability to earn" and "ability to attract" (Petersen, 2021). This means that the production and sale of goods are not sufficient conditions to describe the competitiveness of the country. Because it is important not only to sell the product but also to make a profit from its sale and attract investment to the country.

The international trade competitiveness of the national producers is essential from many perspectives for the country. One of them is the efficient allocation of scarce resources (Vijayasri, 2013). Another no less important factor is that international trade leads to the acceleration of the economic development of developing countries through the import of high-tech products. In general, trade positively and significantly affects GDP per capita growth and income growth (Busse & Koeniger, 2012). Such an impact on the income of the population might lead to increasing of standard living and make it possible to maximize consumer satisfaction.

One of the main factors affecting the level of trade competitiveness is the currency exchange rate. The exchange rate shows the country's currency's price relative to other currencies' prices (Vogler et al., 2019). However, the definition based on tradable and non-tradable goods in the international trade exchange

rate indicates the country's competitiveness (Kipici & Kesriyeli, 2000). A primary relationship between two variables (exchange rate and trade) describes an opposite interaction. With the growth of exchange rate fluctuations, the level of international trade decreases due to the growth of instability in the domestic market, which worsens the conditions of national producers. However, there are many counterarguments to this statement. For instance, the impact of the exchange rate can be minimized by hedging companies' currency and other risks (Ethier, 1973).

Therefore, it is important to investigate the impact of exchange rate changes on the country's trade opportunities, as well as to apply coordinated exchange rate and trade policies (Yol & Baharumshah, 2005). An important task is the research of optimal exchange rate policies that will contribute to increasing the competitiveness of national manufacturers.

1.1 Problem Statement

There are two main changes in the value of the domestic currency – reduction and increase. If the value of the national currency decreases under demand-supply forces with a flexible exchange rate regime, then the value depreciates. If the price of domestic currency declines, but under a fixed exchange rate regime, then the currency devaluates. A similar logic in terms is used when the value of the currency increases. Such «terminological consistency» is important to avoid erroneous use of concepts (Smith, 2017). From 1996 to 2014, the exchange rate regime in Ukraine was fixed, from 2014 to March 2022 - floating, and from the next month after the start of a full-scale war (24.02.2022) in Ukraine - fixed.

During this time, the Ukrainian national currency was most affected by devaluation. The largest increase in devaluation occurred in 2014 and amounted to almost 200 percent (195%) (Batrakova T.I., 2016). In December 2013, the dollar was equal to 8 UAH, and in November 2015 - 23.6 UAH. With the

beginning of the full-scale invasion of Russia into Ukraine, the Central Bank of Ukraine was forced to devalue the Ukrainian hryvnia by 25% to support the economy and strengthen trade competition in the market (NBU, 2022).

The main goal of the research paper is the implementation of improved exchange rate policies that will strengthen the position of national producers and contribute to increase the level of competitiveness.

There are several theories of the impact of devaluation on the country's trade balance. For quite a long time, the theory was spread that the devaluation of the exchange rate has a positive effect on the trade balance, provided that the sum of the elasticities of import and export prices is greater than one (Bahmani et al., 2013). However, other scientists argue that devaluation is not able to improve the trade balance and the position of national producers due to the weak financial sector, the rawness of the economy, and other factors (Oleinikov & Serova, 2019).

The author of this paper is inclined to the second theory and aims to verify and prove this statement. Because the relationship between exchange rate fluctuations and the trade balance has different effects depending on the characteristics of the country's economy. In Ukraine, the dynamics of the trade balance have been negative since 2005 (Macrotrends, 2023), despite the high rates of exchange rate devaluation. Thus, the main problem is that the dynamics of fluctuations of the Ukrainian national currency do not strengthen the position of national producers in the long term and have a negative impact on their position on the international market.

The concept of “competitiveness” in the work is considered from two sides - the level of production capacity of the three main branches of the economy – manufacturing, agriculture, and mining (the higher the production capacity of enterprises, the more domestically produced goods on the market, and accordingly, the higher the competitive position of manufacturers) and the share of imports compared to domestically produced goods.

1.2 Research Objectives and Questions

Given the negative dynamics of the trade balance and the moderate devaluation of the exchange rate, the priority objectives are:

- Determine the impact of exchange rate fluctuations on the country's trade positions, namely the imports and production capacities of the main industries (manufacturing, agriculture, mining);
- To define the main problems of exchange rate fluctuations on trade competitiveness;
- Analyse the reference mode of the exchange rate and main trade indicators;
- Determine the balance between domestic production and imported value-added goods and services to define how dependent national producers are on imported products;
- Investigate the interrelationship of the influence of exchange rate policy on the trade position of the national producers;
- Define the optimal level of the exchange rate that will contribute to strengthening the development of the national commodity market;
- Develop recommendations for a long-term exchange rate policy.

According to the objectives, the main research questions are:

1. ***What is the optimal exchange rate policy that will improve the position of national producers and increase their competitiveness?*** (main research question)
2. What is the interaction between domestic producer positions and exchange rate policy?
3. How to increase the competitiveness of national producers by reducing the share of imported products?

4. How the foreign exchange policy affects the country's trade position and which policy is optimal for increasing competitiveness of domestic producers?

The use of system dynamics methods to study exchange rate behavior is not new. For example, some authors considered the exchange rate system as part of the monetary sector (Faryna, 2014), and some modeled the impact of macroeconomic factors on the exchange rate separately (Khan, 2020). However, the novelty of this research lies in the fact that the developed model considers not only the currency market sector (exchange rate change), but also the commodity market sector of the economy (domestic production and trade), and the relationship between these sectors. According to the conducted searches, this topic was not fully disclosed before.

1.3 Problem behaviour analysis

The dynamic of the exchange rate of the hryvnia (UAH) from 1997 to 2022 is depicted in Figure 1.1.

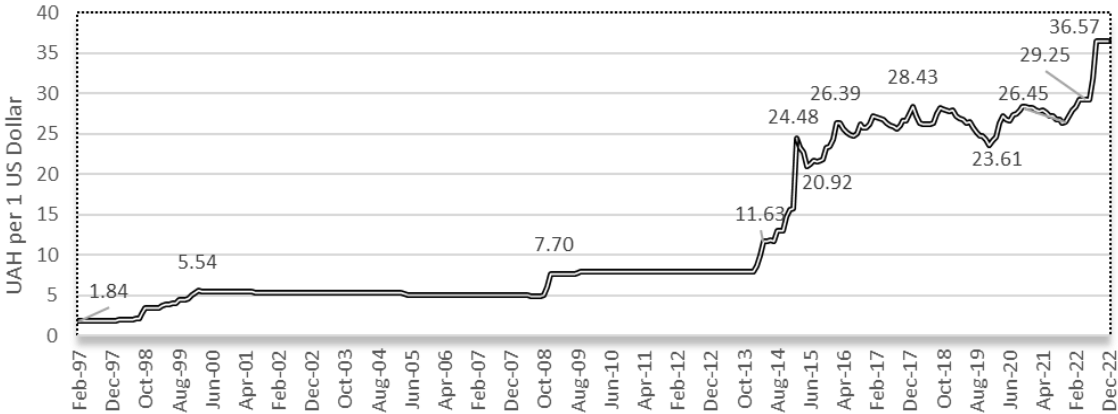


Figure 1.1. The reference mode of the exchange rate UAH/USD (average for the period) (NBU, 2023d).

The largest fluctuations in the value exchange rate occurred in 1998-1999, 2008-2009, 2014-2015, 2019-2020, and 2021-2022.

The first devaluation of the hryvnia took place in 1998-1999. The main reasons were the impact of the Asian financial crisis, the fall in GDP, the trade balance deficit, and the growth of foreign debt. Additionally, the expansionary fiscal and monetary policies of the government had a negative impact on the economy. That led to instability that created uncertainty for investors and put pressure on the exchange rate. Simultaneously, the devaluation stimulated the export of goods producers, which led to an increase in the volume of sales of foreign currency and supply on the market (Bereslavska, 2015). As a result, the volume of foreign currency reserves of the NBU increased.

From 2000-2004 Ukraine achieved macroeconomic stability. During that period was sharp economic growth, and low rates of inflation. At the same time, political instability plays an important role during that time. There were tensions between the president and parliament, which put downward pressure on the hryvnia. Additional uncertainty was created by the transition to a market-based economy. This was also facilitated by the fact that the position of the dollar in the domestic market was somewhat weakened by its devaluation in international markets (Basilevska & Voitko, 2013).

In 2008-2009, the dynamics of the hryvnia exchange rate experienced significant fluctuations. The main factors of currency devaluation:

- Global financial crisis and its negative impact on the inflow of foreign funds from abroad to the banking system;
- Drop in world metal prices in August 2008 by 15-20%. As a result the export revenue significantly decreased, while the import value grow;
- Intensification of the capital outflow due to negative expectations about the devaluation of the national currency;

In terms of exchange rate policy, since 2014, the national currency of Ukraine has been significantly undervalued. This was caused by three simultaneous crises: economic – caused by the annexation of Crimea and the war in Donbas (Stepanenko & Pylynskyi, 2015); currency - because the fixed

exchange rate had to be abandoned due to the deterioration of the foreign trade balance and the growth of the budget deficit, and banking (Adamyk, 2016) - because the oligarchic banking system led to an increase in overdue debts and a panicked outflow of deposits. Instead, towards the end of the period (2019-2021), the gradual growth of the exchange rate to the equilibrium leis is observed.

At the beginning of the war in Ukraine (24.02.2022) the NBU fixed the exchange rate at the level of 29,25 UAH per 1 USD and then increased the value up to 36.57 on July 21, 2022. A fixed currency regime has its advantages and disadvantages, one of which is the high cost of usage foreign exchange reserves.

However, such a policy of the central bank is a forced and necessary step to maintain nominal stability in the conditions of war. The fixed exchange rate policy is complemented by high-interest rates and currency restrictions. The dynamics of trade balance indicators will be considered further (Figure 1.2).

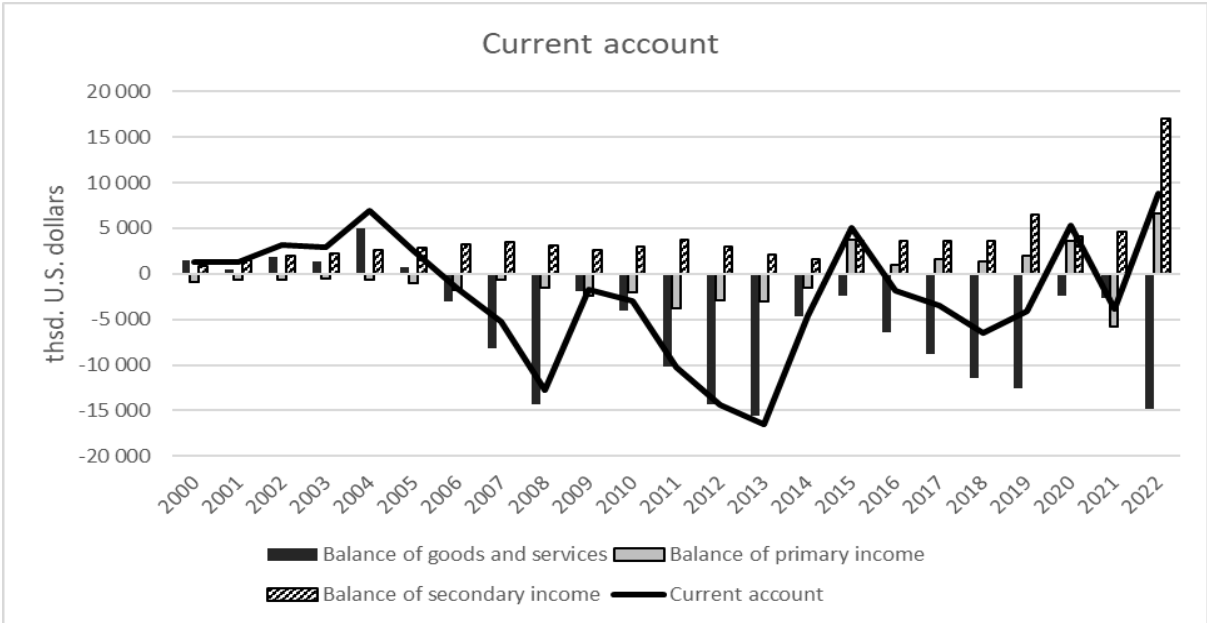


Figure 1.2. The key items of the current account of Ukraine (NBU, 2023a).

One of the important trade indicator is the current account balance. This is one of three accounts of the balance of payments (BOP). The BOP shows the fraction between funds received by the country from abroad and payments abroad for a certain period. It consists of the current account, which represents all transactions in terms of trade of goods and services, transfers, and investments; the capital account, which includes the capital inflow and outflow, foreign aid, and remittance; and the financial account, which shows the direct investment, portfolio investment, reserve asset. The current account consists of three balances: the balance of goods and services, and the balance of primary and secondary income.

The export-import dynamics reflect the constant predominance of exports over imports until 2004. Since then, the balance of goods and services is constantly falling. The country's negative trade balance has some risks for the economy, such as the devaluation of the currency, dependence on the supplier country, increase of external debt, and others. The lowest value was in 2008 which was triggered by the financial global crisis. That period was the first time when the net export was negative (-17 million USD). However, after 2008 occurred sharp recovery of the economy. Another significant decline in the balance of goods and services started in 2010 and was the deepest in 2013 (-15,6 million USD).

The main reasons for that were the combination of different shocks such as geopolitical (revolution and occupation of the East region of Ukraine), banking crisis, deterioration of trade, and reduction of the capacity of producers. After the period of decline in trade activity, the economy sharply recrudesced. Simultaneously, the balance of the secondary income remained positive.

Due to the full-scale war in Ukraine, the balance of goods and services was – 14,8 million U.S. dollars. The main factor is the full-scale invasion in 2022. For instance, the inability to produce goods in the temporarily occupied territories, disruption of logistics and transport connections between regions,

blocking ports as the main trade routes, migration and forced relocation of workers, loss of stocks, warehouses, and equipment, restrictions on electricity consumption, loss of access to internal natural resources and so on.

1.4 Research Outline

Chapter I presents the topic of the research, the main objectives and questions that will be answered, a dynamic behaviour description of the problem. The Chapter II is devoted to research methodology. Chapter III describes the structure of the model, its main sectors, including its limitations and assumptions. Chapter IV-V explains data validation and main policies. Chapter VI presents the conclusions to the work and answers to the research questions, as well as suggestions for further research.

Chapter 2. Methodology

This chapter of the scientific paper is devoted to the disclosure of methods, including a detailed description of the method of System Dynamics, methods of data collection and processing, a review of scientific literature, and research ethics. Further, each of them will be considered in detail.

2.1 Observation and research topic definition

The first stage of scientific research was literature review, formulation of the scientific topic, the objective of the research. During the research of the literature, the topic and purpose of the study were adjusted according to the available studies. This made it possible to modify and specify the research topic more accurately. The final version of the research topic is “The impact of exchange rate policy on the level of trade competitiveness in Ukraine”. Trade competitiveness is represented as the changes of export-import volumes in the economy. In addition to this, in the model the import value is endogenous, and export is exogenous because of different mechanisms of influence on the formation of currency exchange rate policy and what is more important it is this classification allows to give answers to the main research questions.

In accordance with the objectives, another such methods of scientific research as the description (empirical method) of theoretical foundations, as well as statistical analysis, generalization, classification were applied.

The main information sources of the study consist of legal acts, scientific articles, regulations of the National Bank of Ukraine and the Ministry of Finance of Ukraine, statistical data from the State Statistics Service of Ukraine, the World Bank, reports of the National Commissions of the Financial Services Market and official open resources from the Internet. These and other sources will be depicted in more detail in this section.

The important methods that were also used in the work are data processing and modelling method. Let`s begin with the last one.

2.2 System Dynamics Method

System Dynamics method was used to represent the relationships between the real production sector, which includes international trade, and the exchange rate sector. The origins of system dynamics began with the reproduction and simulation of supply chain problems and were originally known as “Industrial Dynamics” (Dangerfield, 2014). The founder of system dynamics methodology, Jay Wright Forrester, developed a new tool that had a new approach to solving strategic problems of a corporation to define policy problems (Forrester, 1958). Today, the methods of system dynamics are widely used to display the complex system and solve the main management policies problems in various fields of economics and science.

The main advantage of this method is the deepening of the understanding of the complex system, which makes it possible to identify the shortcomings of different policies (Sterman, 2000). At the same time, with the usage of a combination of the four simplest elements, five basic structures of system dynamics method are formed, namely, accumulative relationship, instantaneous cause-and-effect relationship, local loops feedback, main feedback loops, nonlinearity (Sterman, 2002). Feedback loops describe three basic types of system behavior - exponential growth (reinforcing loop), exponential decay (balancing loop), and equilibrium (combination of the two types of loops). However, to display complex economic systems, which can be characterized by a large amplitude of oscillations, it is advisable to use a combination of different feedback loops (Faryna, 2016). Simultaneously, the minimum necessary condition to modelling the complex economic system is the presence of at least one balancing feedback loop.

The method of system dynamics allows effectively display the relationships between the exchange rate and the main factors of influence using feedback links and modelling the nonlinear behavior of variables. The process of building a model is an iterative process and includes such basic steps as defining a dynamic problem to be solved, developing hypotheses of the behavior of variables, representing relationships that are theoretically justified and practically representative using the basic structures of system dynamics. The final stages are testing the built model, checking its compliance with the research objectives, and evaluating the effectiveness of the policy and different scenarios. The final stage is the development of recommendations and thorough conclusions, in accordance with the received results.

CLD (Causal Loop diagrams) plays an important role in the modelling, with the help of which it is possible to display the main causal mechanism of the complex system. This is a good start to the modelling (Haraldsson & Sverdrup, 2013). However, the phase of building of the CLD requires a comprehensive understanding of the whole system and the connections between parameters.

The main software used for system dynamics modelling is Stella Architect.

2.3 Data Collection

Data processing and collection is one of the most important and time-consuming processes. The relevance and correctness of the scientific research depends on the quality of the processed materials and sources. Initially, a large amount of scientific literature was developed. The main resources are SSRN, Scopus, Electronic Kyiv-Mohyla Academy Institutional Repository and scientific repositories of other universities, Google Scholar. The information search of the literature consisted in the application of various combinations of Boolean queries, for example, the key words were "exchange rate", "trade balance", "devaluation", "terms of trade", currency policy. From among the

proposed list, only those sources that have the greatest relevance to the given request and the purpose of scientific research were carefully selected.

In addition to scientific literature, other sources were also scientific reports of the main financial institutions, the government and ministries that are responsible for the implementation of foreign exchange, trade, and monetary policy. For example, the document of the National Bank of Ukraine (NBU) - Inflation Report was examined, which shows a detailed analysis of the current macro situation on the market with a retrospective analysis and expected forecasts. This is an official document that is published every quarter in order to ensure the publicity and transparency of the monetary policy of the National Bank of Ukraine (NBU, 2023b).

Publications of the State Statistics Service of Ukraine (SSSU) are another important source of information. Statistical publications contain detailed information on different categories, such as national accounts (SSSU, 2023a), enterprise activity, foreign economic activity, trade balance, prices, and others. The main government sources that were processed are legislative documents that correspond to the topic.

The collection and processing of statistical data and parameters was based on the following sources - SSSU, the Ministry of Finance, the National Bank of Ukraine, as well as foreign sources - data from the World Bank, Trade Map, Numbeo, Trading Economics, OEC World, CEIC Data, Trade Competitiveness Map, Moody's Analysis (economic indicators).

The process of data collection and processing consisted in the systematization, classification and grouping of data from the specified sources. The information presented in the mentioned above sources is general and require additional processing for further analysis and use in modelling. The main tool that was used for data processing after their initial search is Excel.

Other sources of data collection were news resources and electronic journals. These were articles from official Internet media, news, and blogs.

Examples of such sources are BBC, Bloomberg, Investing.com, Forbes, VoxUkraine, The New Voice of Ukraine. The main criteria for choosing a source are the date of publication and the person's expertise in the field related to the topic. However, defining the credibility of media sources is much harder than other information sources (Keshavarz, 2021). That is why, each e-magazine was chosen carefully.

Interviews of respondents and collection of data from them, which would be used in the model, were not carried out. However, the model's logic and structure were verified with external experts.

2.4 Literature Review

The built model reveals the basis relationship between the factors that influence the formation of the exchange rate, one of the most important of which is the export and import volume of the economy and explains the inverse influence of the exchange rate on the country's trade positions. The interaction between the factors will be considered in more detail further.

Exchange rate

The exchange rate is the price of foreign currency in relation to the national one. The exchange rate is defined under demand-supply forces for foreign currency (Kuznyetsova et al., 2017), which in turn are formed under the influence of many factors such as the trade activity of the country, protection of the national producers, the stability of the economy or economic growth, level of income per capita, the impact of external shocks, and the internal motivation of consumers to sell or buy currency. There are two directions of changes in currency values – increasing and decreasing. The main difference between the concepts of devaluation (revaluation) and depreciation (appreciation) has already been mentioned.

At the same time, there are a lot of exchange rate currency regimes (Ghosh et al., 2003). That depends on the internal peculiarities of the policy of the financial institutions, which is provided according to the national economic conditions and development of the country in different sectors. Nevertheless, the main basic exchange rate regimes are fixed, floating, managed to float, pegged.

In Ukraine, up to and including 2014, the exchange rate regime was fixed, and since 2015 – managed float. Fixation of the exchange rate caused many problems, including reduction of international reserves, loss of competitiveness of domestic producers (Ilychok & Trevoho, 2016), devaluation of the national currency, high level of inflation, etc. In fact, the exchange rate peg reflected the illusion of stability. The flexible exchange rate regime in Ukraine was maintained until the start of a full-scale war. After February 24, 2022, the NBU fixed the hryvnia-to-dollar rate at UAH 2,2549; and the hryvnia-to-euro rate at UAH 33,1707.

Trade position of the country

The strong international trade position of the country leads to expanding the exchange of goods and services which are not available domestically. The commodity market becomes more competitive when local products are attractive to foreign consumers and vice versa. The higher the trade competitiveness, the cheaper home products (due to the price competitiveness). Many macro indicators describe the trade competitiveness of the country, for example, such variables as the balance of payments, current account, and the country's balance of trade and terms of trade. The balance of trade represents the difference between goods and services, export and import. If export exceeds import, then the trade balance is positive - the country receives more import goods units for one unit of its export goods - if not, the balance is negative. For each country is essential to stimulate a positive trade balance because in that case, the

international trade position of the country strengthens, and the earnings increases due to high sales on the world market. In case of a deficit (when imports exceed export) the country can use also borrowing from other countries. Such a country is forced to go into more debt to pay for its consumption instead of investing in its future growth. However, this concept is complex. Therefore, under the influence of other important macrofactors, the role of exchange rate in trade facilities might be reduced (Liew et al., 2003).

The impact of the exchange rate on the trade position affecting foreign currency demand and supply

If the exchange rate depreciates and the price of the national currency decreases, the national goods and services become cheaper in comparison with foreign goods and services and more attractive and affordable to foreign buyers as they can buy more with their own currency. The demand for national goods increases which leads to rising export volumes in the country. When export volume grows, the demand for national currency rockets, and as a result, the local currency appreciates.

2.5 Research Ethics

All ethical principles, such as transparency, guarantees of anonymity and confidentiality, honesty, and impartiality, as well as other norms that don't lead to negative consequences for researchers and members of society, were observed. Also, in order to avoid any ethical quarrels, during the research the advice described in the book "The Student's Guide to Research Ethics" (Stein-Parbury, 2006) was followed. All literature sources are cited according to one of the latest citation formats – APA 7th Edition, using the software package – EndNote 20.

Chapter 3. Model Development

The model building process consisted of creating a large number of models and constantly iterating the existing ones. In order to best reflect the problem of scientific research, taking into account the complexity of the chosen economic system.

The model consists of the following three main parts - the exchange rate sector, the real economy sector, and the price change sector. A complex system of the model ensures the achievement of the goal of scientific research - to reflect and investigate the impact of the foreign exchange policy on the country's trade position and its feedback links.

In this chapter, the sectors of the model will be considered in detail. To begin with the presentation of the logic of the main relationships between the variables, which are displayed using the CLD.

3.1 CLD presentation

The CLD represents the main logic and links in the model, including the feedback structure of the system (Santos et al., 2002). This section introduces the main balancing and reinforcing loops. Each of them will be considered further in a detail.

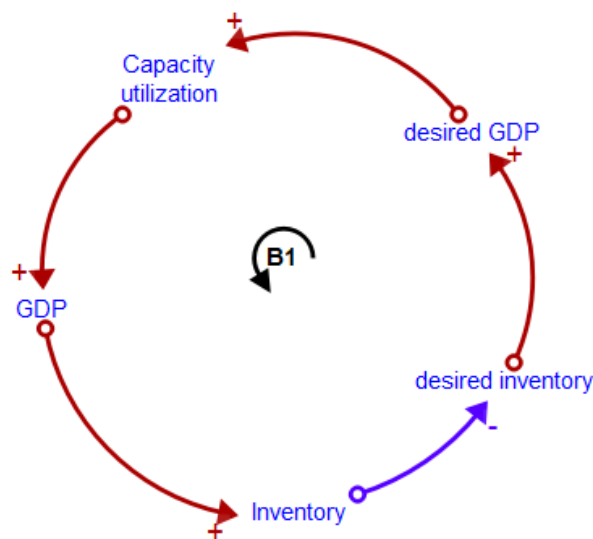


Figure 3.1. CLD of production in the real sector of the economy

To begin with B1 (Figure 3.1), the capacity utilization rate shows how efficiently and to what extent the economy uses its resources. In other words, it is the ratio between the output obtained at the current level of resources and the potential output that can be achieved if the production capacity is used to the maximum (CFI, 2019). Larger production capacities contribute to the increase in production volumes, which in turn lead to the accumulation of inventory. It is worth reminding that three main branches of the real sector of the economy are added to the model – manufacturing (the largest of them), agriculture and the mining industry. Therefore, inventories (like other variables) relate only to these industries. A high level of inventory accumulation reduces the desired future needs in inventory due to high financial costs of its maintenance, obsolescence, spoilage, and other losses. The identified inventory volume stimulates production.

It is also worth noting that the exchange rate is expressed in the number of hryvnias (national currency in Ukraine) per dollar USA unit (UAH/USD).

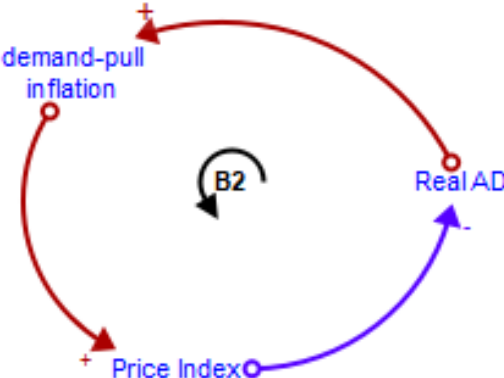


Figure 3.2. The impact of the Price Index on the Real AD (CLD)

The concept of “demand-pull inflation” (B2 – Figure 3.2) arises under conditions of growth in aggregate demand, but with a limited level of supply (its fall or constant level). In the model, this type of inflation is reflected as a ratio of Aggregate Demand to GDP and shows whether supply can or cannot meet growing demand (Curry & Lock, 2022). This type of inflation and cost-push inflation, which shows an increase in the price level due to an increase in production costs (materials, wages, salaries, etc.) are the components of the

general level of inflation. Therefore, with the growth of each of them, the overall level of prices in the country increases. As a result, the real aggregate demand decreases due to rising prices.

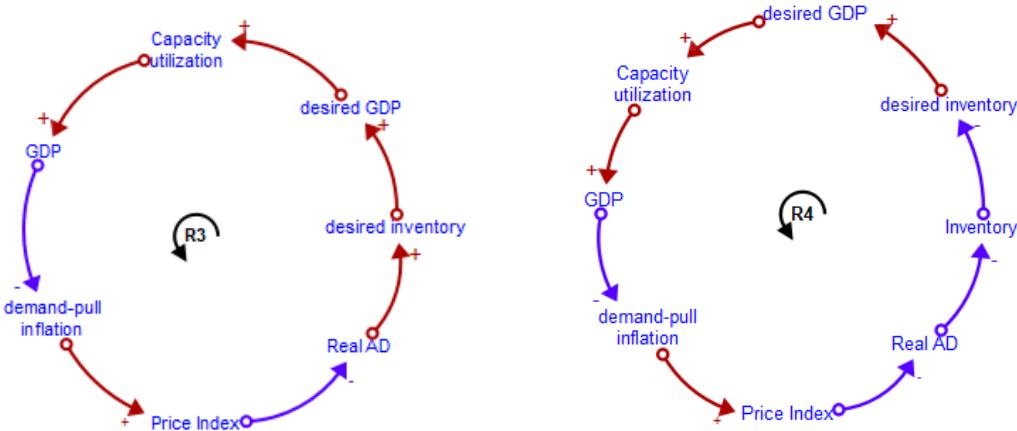


Figure 3.3. The impact of inflation on the production capacity of industries (CLD)

Next, will be considered two loops simultaneously R3 and R4 (Figure 3.3). R3 – GDP -demand-pull inflation – Price Index – Real AD – desired GDP – capacity utilization – GDP. R4 - GDP -demand-pull inflation – Price Index – Real AD – inventory – desired inventory – desired GDP – capacity utilization – GDP. These loops are based on the two previous ones. However, both are reinforcing.

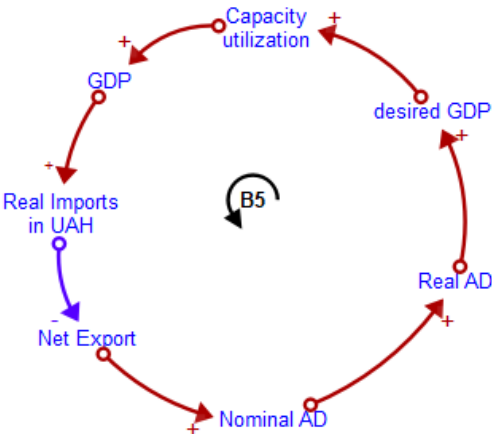


Figure 3.4. The interrelationship between GDP and imports (CLD)

Loop B5 is a balancing loop (Figure 3.4). An rising in GDP increases the country's import capacity. Simultaneously, imports volumes have a negative effect on net exports, which is defined as the difference between exports and

imports. Net export is a component of Aggregate Demand. Therefore, the increase in net exports has a positive effect on real aggregate demand, which stimulates production and improving capacity utilization.

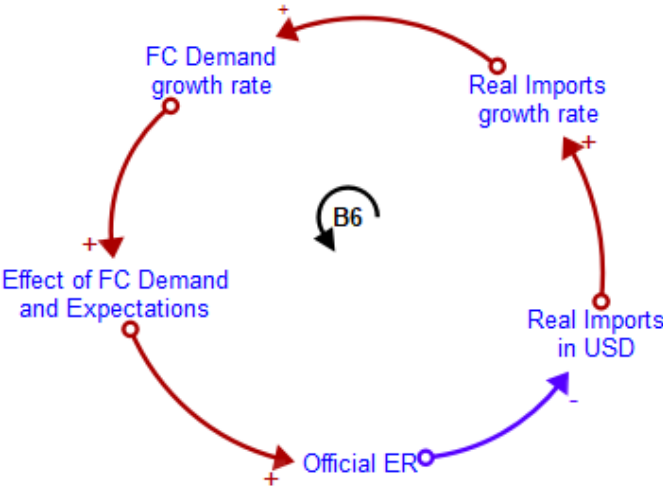


Figure 3.5. The relationship between import volumes, demand for foreign currency, and the exchange rate (CLD)

Import and its growth rate creates demand for foreign currency (B6 – Figure 3.5). The greater the volume of imports, the greater the demand for foreign currency. If the demand for foreign currency increases, then the demand for the national currency decreases relatively. Accordingly, the exchange rate of the national currency falls, the currency devalues. Therefore, when the demand for foreign currency increases, the exchange rate of foreign currency increases. When the exchange rate increases, import prices also grow *ceteris paribus*. The increase in import prices reduces the incentives to import, and therefore the volume of imports decreases.

Relative price is the ratio of changes in prices on the domestic market in the national currency and on the foreign market in US dollars, adjusted for the exchange rate. The calculation of the relative price is the inverse of the expression of the real effective exchange rate (REER) (Schmitz et al., 2011), which reflects the level of competitiveness of national producers in the market.

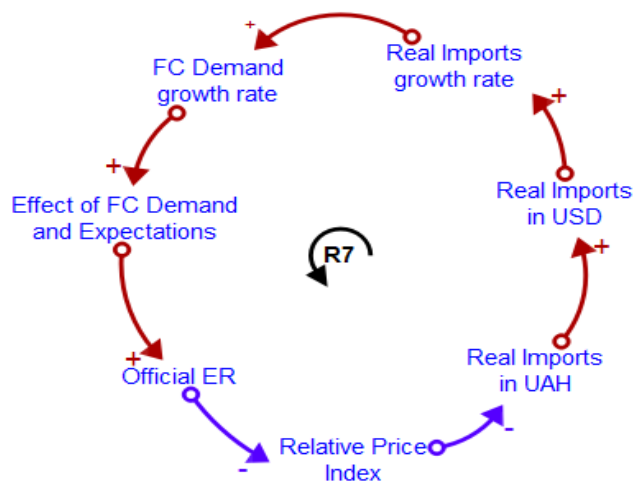


Figure 3.6. Interaction of currency changes (exchange rate and demand for foreign currency) and import volumes (CLD)

Thus, the growth of the national exchange rate means appreciation of the currency (R7 – Figure 3.6). During the appreciation, the foreign currency rate decreases, but the relative price of goods increases. This change means that the price of goods and services in Ukraine becomes higher relative to the price level in the rest of the world.

One of the consequences of that changes in the relative price is an increase in import prices. Importing goods becomes more expensive than domestically produced goods. As a result, import volumes are decreasing. Therefore, the relationship is inverse.

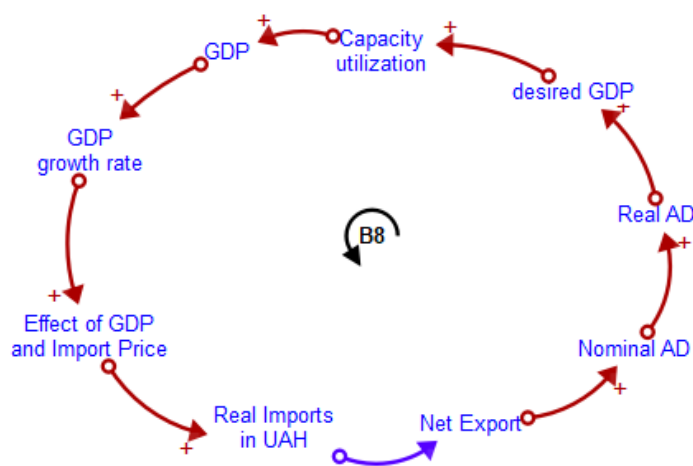


Figure 3.7. The main links of production capacities and imports for industries (CLD)

The last loop (B8 – Figure 3.7) describes the relationship between GDP and imports. The growth of production capacity increases the opportunities for imports. However, if there is an increase in imports, the volume of aggregate demand will reduce due to a decrease in net exports. Thus, an excessive increase in imported goods restrains the development of domestic production.

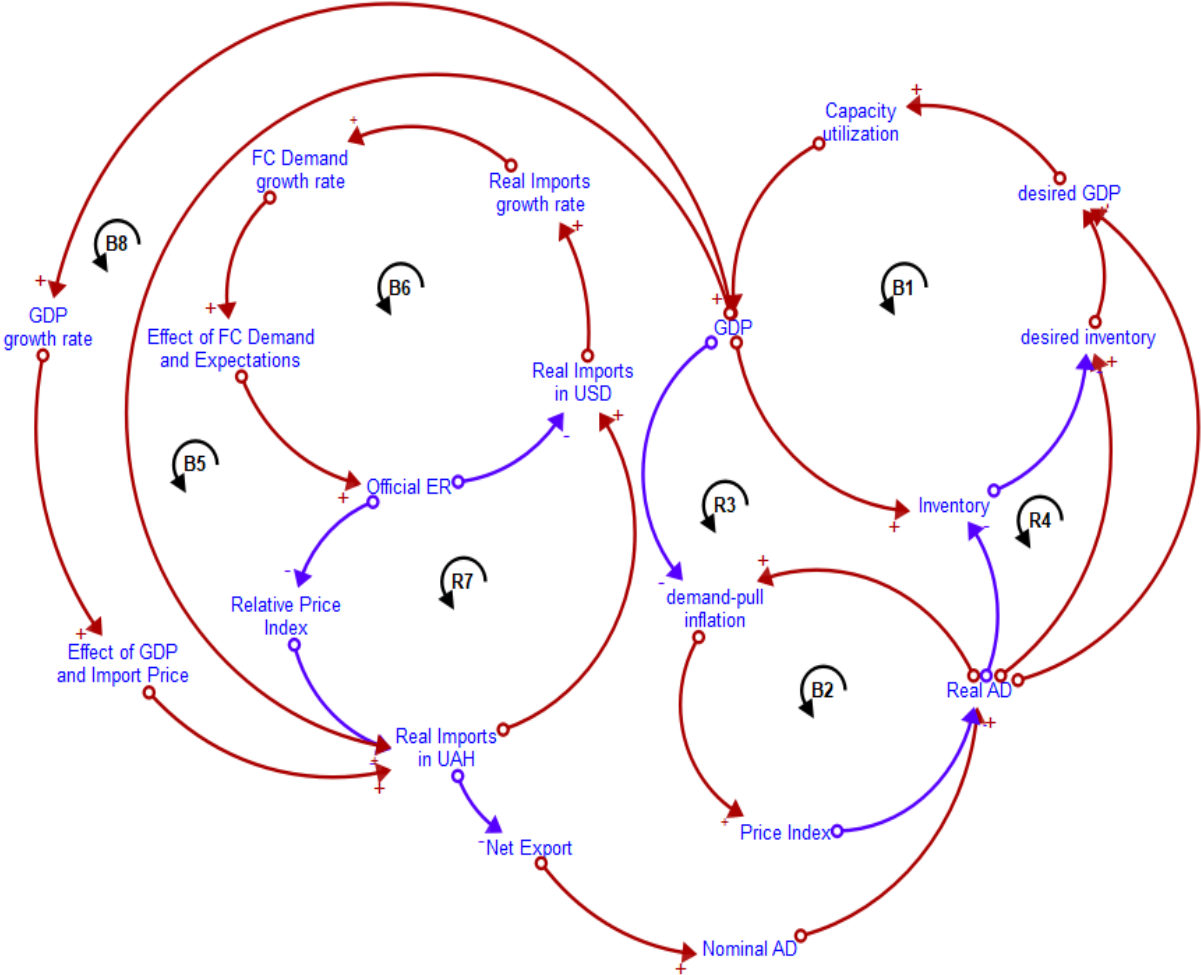


Figure 3.8. The main CLD of the model

The combination of all links is presented in Figure 3.8. It reflects the mutual influence of the main sectors of the model - exchange rate, production, imports, and price changes. An important task was to determine the impact of currency fluctuations on changes in the volume of imports and domestic production. An additional influencing factor is the inflation, which affects the volume of domestic production and, accordingly, the competitiveness of national producers in the market.

3.2 Description of the main sectors of the model

The model consists of four main sectors - the exchange rate sector, the sector of real economy, which includes foreign trade, import sector and the price sector. In addition to this, the model was extended and includes three main industries of the national economy - the manufacturing industry, which is one of the largest, the mining and agricultural industries.

The peculiarity of Ukraine's economy is its large reserves of raw materials. According to the volume of grain exports, the country is among the 5 leaders in the world (according to the data of the pre-war period). In addition, Ukraine contains large deposits of combustible minerals, which were also exported to other countries (before the war). Deposits of many natural minerals set a benchmark for the trade of resources and shifted the focus from the development of powerful domestic production. Thus, the share of manufactured goods with high added value has been decreasing since 2000. However, such development and distribution of industries makes the economy vulnerable to exchange rate fluctuations and market prices for raw materials. Therefore, a strategic goal is the implementation of new policies for the development of internal real sectors of the economy. This issue is especially relevant in the post-war period. When reconstruction plans are being developed to restore and rebuild the industries of the economy, which were destroyed because of Russia's invasion in Ukraine. To begin with the presentation of exchange rate sector.

3.2.1 Description of the Exchange rate Sector

In Ukraine, the foreign currency exchange rate is formed under the influence of demand and supply for foreign currency on the interbank market. The Central Bank of Ukraine can regulate the exchange rate with tools such as currency interventions. The sector reflects the demand for foreign currency,

which arises under the influence of changes in import volumes (import growth rates). The greater the volume of imports, the greater the demand for currency. Since the export component was included as an exogenous variable, the supply of foreign currency is not represented in this sector (Figure 3.9).

In addition, terms of trade (ratio of export and import prices) were included in the formation of demand for foreign currency. However, the influence of this indicator is not significant in comparison with the change of import prices. The terms of trade and the change in import volumes represent the inflows and outflows of foreign currency. That is why, these two variables are the main parameters which were used to model the demand for foreign currency.

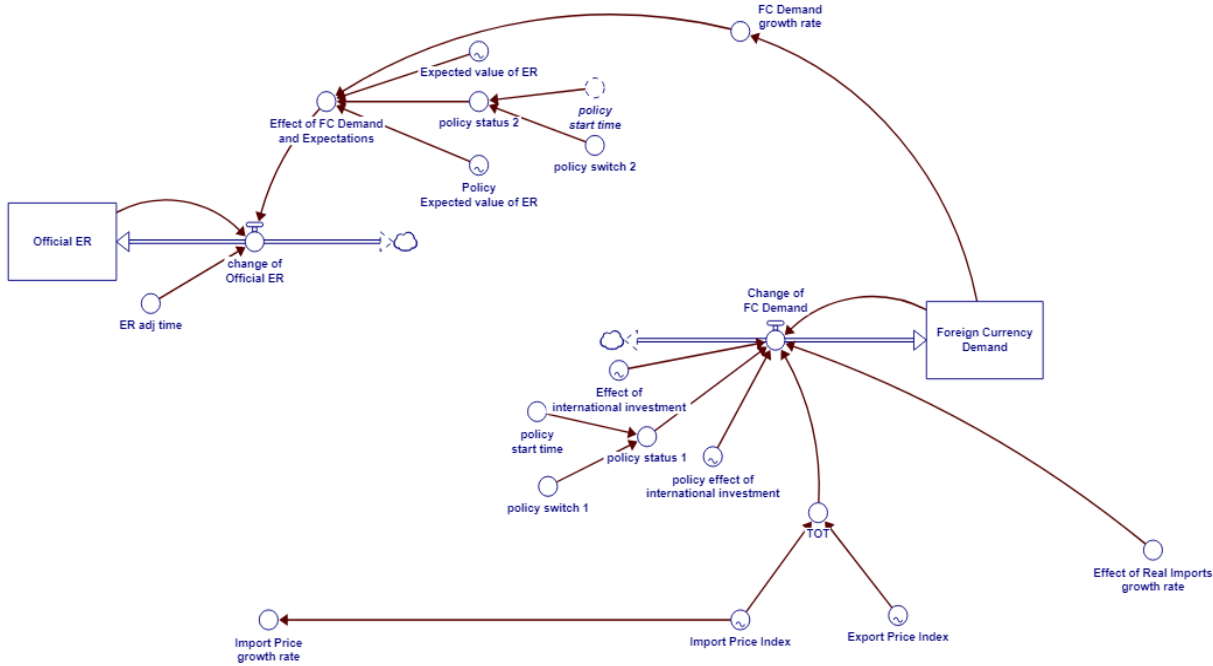


Figure 3.9. Exchange rate sector

The dynamics of the exchange rate is formed under the influence of the following main factors - the direct impact of demand for foreign currency (the supply was not included) and expectations.

Expectations of the population (expected value of the ER) are one of the powerful factors that strongly influence exchange rate fluctuations. One of the examples is crisis in the market due to political, geopolitical, economic and other factors, during which exchange rate expectations increase. The population begins to actively buy more stable foreign currency, increasing the demand for it. As a result, the exchange rate increases and further deepens the crisis in the market. Therefore, the expectations of the population are an important factor influencing the dynamics of the exchange rate. In order to reduce the impact of the negative expectations of the population, the Central Bank actively implements and adheres to the policy of transparency and communication - reporting on the results of the current policy and intentions for the future.

The expectation variable is given by the graphical function in the model. It reflects a change in the population's willingness to purchase foreign currency. In the equilibrium state, the value of the function becomes 1. During the crisis years (for example, 2014, 2020, 2022), there is an increase in future expectations regarding the exchange rate, so the function increases. On the contrary, under a balanced and prudent monetary policy, economic growth, expectations are decreasing.

International investment also affect the demand for foreign currency. From the investor's point of view, the main motivation of investing is to borrow funds in the country where the interest rate is low and to invest the funds in a security whose yield depends on the interest rate. Thus, the higher the rate, the higher the return for the investor. Therefore, raising the rate can contribute to the inflow of foreign currency, increasing the investment attractiveness.

With an increase in foreign investments, the demand for the national currency increases, as the currency is converted into the national one for the purpose of investment. When demand increases, the rate of the national currency increases, and accordingly the exchange rate appreciates.

3.2.2 Description of Import Sector

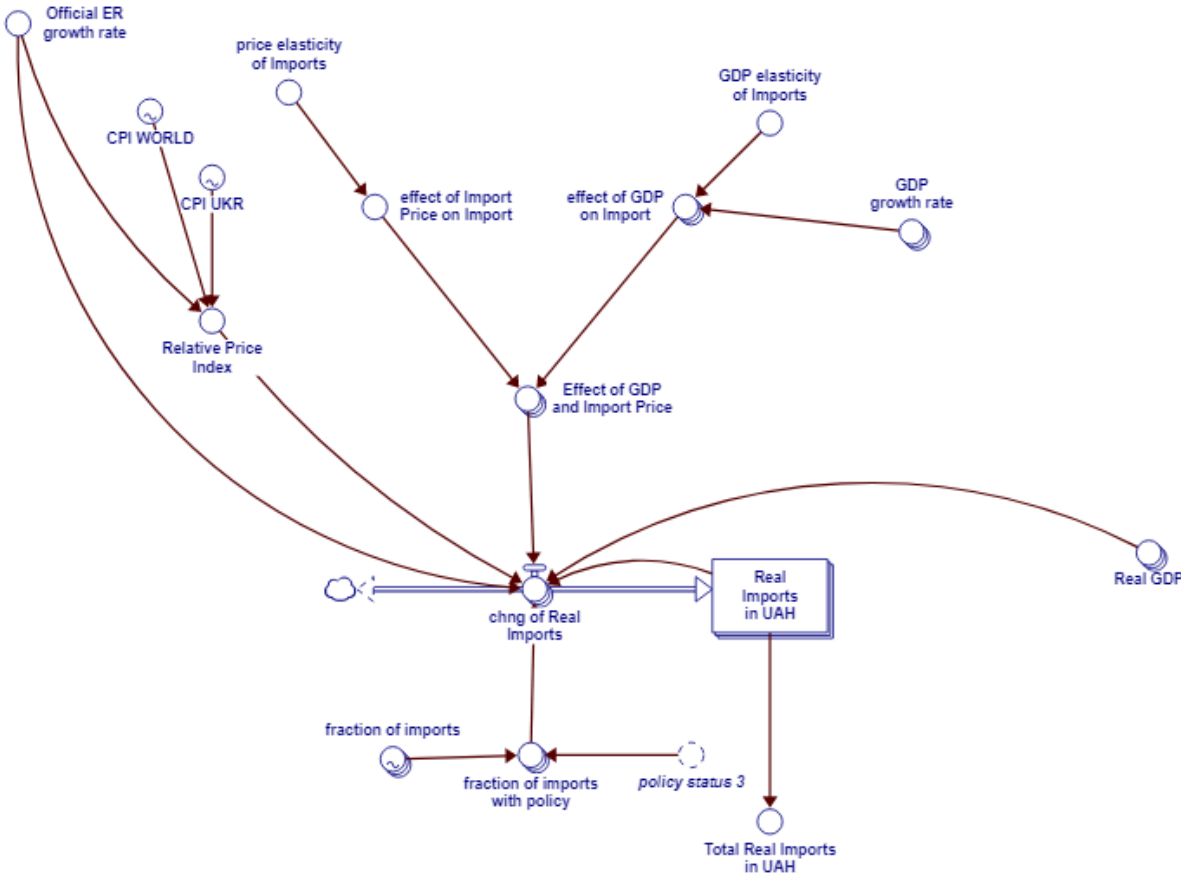


Figure 3.10. Import sector

The real import volumes is influenced by such main factors as relative prices, import prices and changes in GDP (Figure 3.10). Relative prices show the competitiveness of domestic goods and services. For example, an increase in relative prices can occur due to an increase in domestic prices or a decrease in the exchange rate. The high level of inflation makes domestic production more expensive, and the appreciation of the exchange rate contributes to the increase in imports. An increase in imports has a negative effect on domestic producers, who will have less incentive to develop production and improve capacity utilization rate.

As mentioned earlier, the increase in import prices has a negative effect on import volumes, while the increase in GDP has a positive effect.

3.2.3 Description of the Price Index Sector

The price sector is depicted in the Figure 3.11.

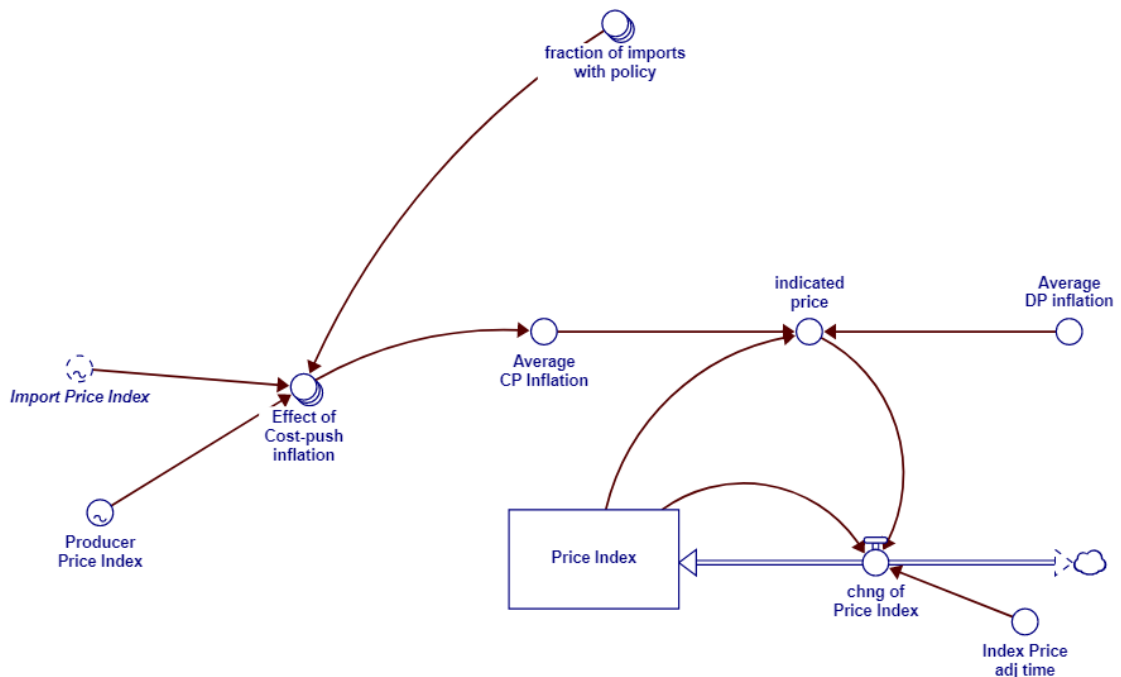


Figure 3.11. Price Index Sector

The price sector includes two components of inflation – cost-push inflation and demand-pull inflation. Let's consider the first one. The higher the production costs (raw materials, wages, price of components...), the higher the prices of domestically produced goods and services. One of the peculiarities of Ukrainian industries is the high share of imported goods in comparison with the own manufactured. An increase in the price of imported goods increases the prices of domestic production. Therefore, the cost-push inflation indicator includes the changes in the prices of domestically produced goods and imported goods. Also, the price index consists of the demand-pull inflation component. If the demand for goods and services increases, and the supply is unchanged or decreases, then domestic market prices increase.

Therefore, the Indicated price depends on the two factors - on the stimulation of demand (demand-pull inflation) and the impulse of expenses (cost-push inflation) (Dadashova & Faryna, 2015). The pull effect occurs due to the excess of aggregate demand over GDP, and the push effect is formed due to changes in the cost of production.

3.2.4 Description of the Real Sector of the Economy

The Figure 3.12 shows the Real sector of the economy.

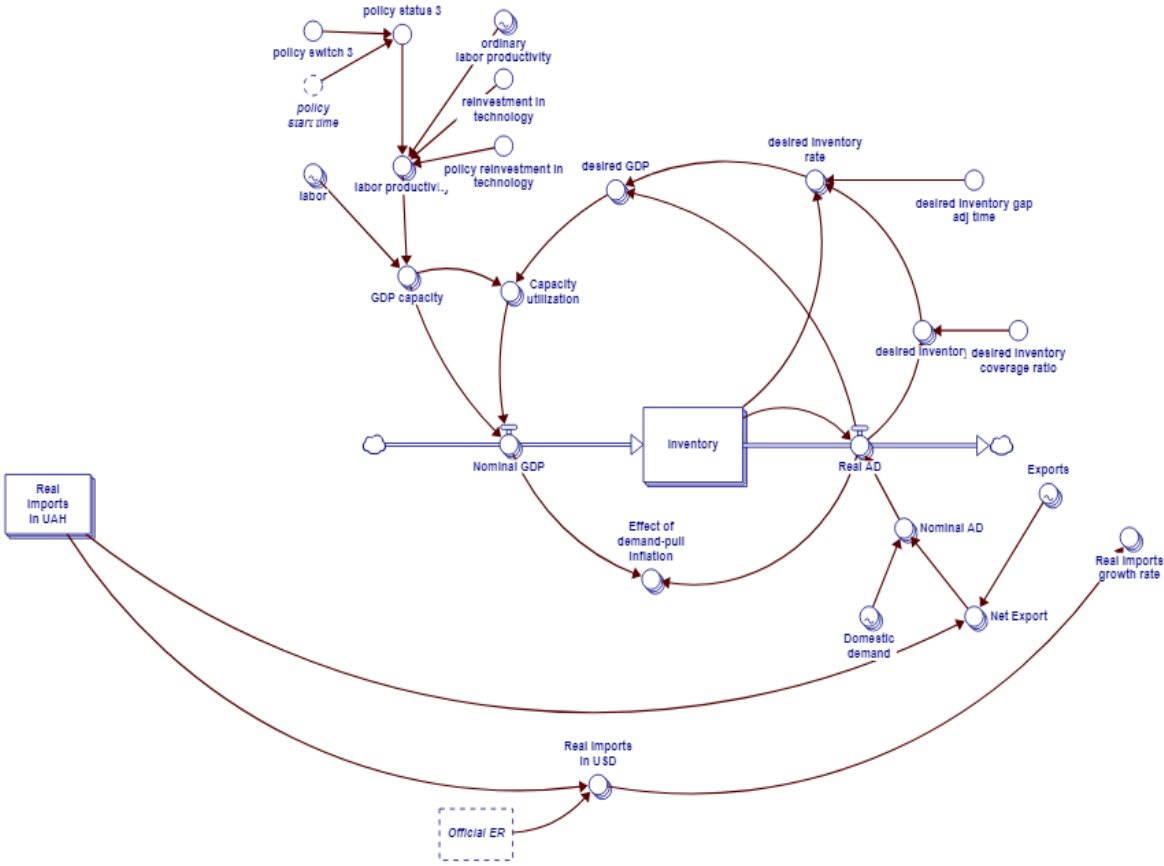


Figure 3.12. The real sector of the economy for three industries

First of all, it is worth noting that the real sector of the economy is represented by three industries - manufacturing, agriculture and mining. Accordingly, the volumes of aggregate demand, GDP, imports and other

variables are calculated for these industries separately. The collection and processing of data was done by industry.

The manufacturing and commodity markets represent a system of exchange relations between business entities regarding the purchase and sale of goods and services in accordance with the laws of supply and demand. The object of the manufacturing market is a good that has a defined material form, as well as a service, idea, product, or material that has qualitative and quantitative characteristics. Subjects of the commodity market are both legal entities and individuals engaged in the production, or purchase of goods. The role of the state in relations between buyers and sellers usually acquires intermediary functions. For example, in such matters as quality and safety criteria of the provided goods and services.

The main conditions for the functioning of the manufacturing and commodity market are (Rumyantsev & Kovalenko, 2006):

- ensuring the competitiveness of product manufacturers;
- the free cross-industry movement of goods;
- formation of pricing depending on supply and demand;
- independence of business entities in their expressions of will, and independence in making business decisions;
- possession by the participants of market relations of complete and unbiased information about supply and demand, phases of economic development, price level.

The trade competitiveness and strong position of the national manufacturing and commodity producers play an essential role in the spurring of economic growth, intensive increasing of the sector of real production, and creation of new jobs. The development of the markets and support of the key domestic features of producers should be a priority for developed and especially emerging countries. If the country has a strong trade position in the world

market, then its international competitiveness is high, which is a positive side for foreign and domestic markets.

Since imports are a component of the domestic aggregate demand of the country, it is important to accurately reflect the simplified model of the Real sector of the economy. Domestic demand stimulates the production of national producers to satisfy this demand. At the same time, the volume of produced goods and services affects the volume of imports, just as imports affect the demand for production.

3.3 Adequacy of Model Boundary

The built model has certain boundaries. Firstly, the system includes only three main industries – manufacturing, mining, and agriculture, not considering, for example, construction and other industries of the economy. Secondly, the model reflects the main sectors of the Ukrainian market and does not consider the specifics of foreign markets. However, it includes the dynamics of the exchange rate and inflation of the main trading partner of Ukraine. The change of the main trading partners before and after the war in terms of export and import volumes is presented in Table 3.1-3.2. It is also worth noting that such boundaries of the model make it possible to achieve the main goal of scientific research (Forrester & Senge, 1979). The entire modelling process was based on the literature review and official data sources.

Table 3.1. Main trading partners of Ukraine by share of exports (Minfin, 2022)

2021	2022
China (11,8%)	Poland (15,4%)
Poland (7,7%)	Romania (8,2%)
Turkey (6,1%)	Turkey (6,6%)
Italy (5,1%)	China (5,3%)
RF (5,0%)	Germany (5,2%)

Table 3.2. Main trading partners of Ukraine by share of imports (Minfin, 2022)

2021	2022
China (15%)	China (15,1%)
RF (9,1%)	Poland (9,9%)
Germany (8,2%)	Germany (8,3%)
Poland (6,8%)	Turkey (5,2%)
Belarus (6,6%)	USA (4,2%)

Before the war (before 2022), the main trade partners (in terms of export and import) of Ukraine were such countries as China, Poland, Turkey and the Russian Federation, Belarus. With the beginning of the full-scale invasion, the countries of the European Union, the United States, China, and Turkey became the main partners. This indicates a radical reorientation of trade relations in the international market.

3.4 Model Assumptions

The main assumptions of the model are as follows.

1. Cost-push inflation is based only on the change of prices for domestically produced goods and imported goods.
2. Export is exogenous variable because imports create demand for foreign currency.
3. Model focuses on the interaction of the Ukrainian national currency (hryvnia – UAH) and the USD as the currency of the United States of America. Other currencies are not included in the model.
4. The production capacities of the real sector are not used to the maximum, but only by 85% (Berdynskykh, 2019). This assumption was based on pre-war Ukrainian data, since during the war this indicator is much lower.
5. Since the model reflects three main directions, it is assumed that the change in import growth rate is weighted average value between industries.

Chapter 4. Model Simulation and Validation

4.1 Simulation results of the model

4.1.1 Exchange rate Sector

The dynamics of the exchange rate and demand for foreign currency is shown in Figure 4.1.

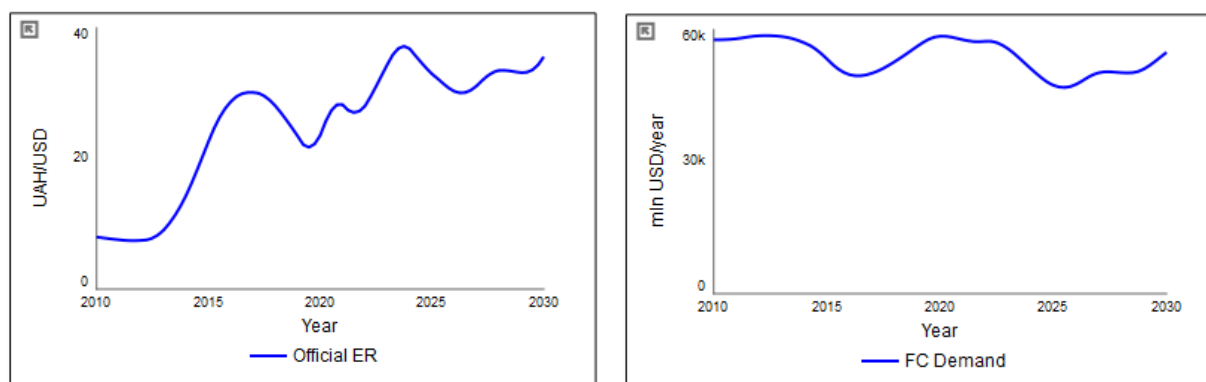


Figure 4.1. The model behavior of the Real Exchange rate (A) and Foreign Currency Demand (B)

Exchange rate (Figure 4.1 A) and foreign currency demand (Figure 4.1 B) fluctuations reflect the impact of crises at different period. The growth of the exchange rate began in 2014, when a change in currency regimes took place. By 2019, it was possible to improve currency regulation and stabilize currency expectations. As a result, the appreciation of the exchange rate took place in 2019. The Covid-19 crisis has negative consequences for the stability of national currency. However, one of the most influential factors that caused the greatest decline in economic growth was a full-scale invasion of Russia in Ukraine in 2022. The exchange rate quickly and significantly devalued as a response to shocks in various sectors of the economy.

According to the base scenario, the future dynamics of the exchange rate will increase after 2022, and then gradually decrease - appreciates. In general, the dynamics of the exchange rate has an oscillating cyclical trend, which is affected by the phase of economic growth, seasonal trade volumes, crisis situations and others. In addition, it is worth noting that the simulation of the

exchange rate in the work considers the scenario of a flexible currency regime and the impact of its fluctuations on the country's trade positions. Despite the fact that in Ukraine since the full-scale invasion, the exchange rate has been fixed. The purpose of this work is to consider the different scenarios for the dynamics of a flexible exchange rate and its impact on the country's trade position under the conditions of the transition from a fixed currency regime to a flexible one in the post-war period. And to determine the best policy that will promote the development of domestic production and increase the competitive advantage in the market.

4.1.2 Import and Real GDP Sectors

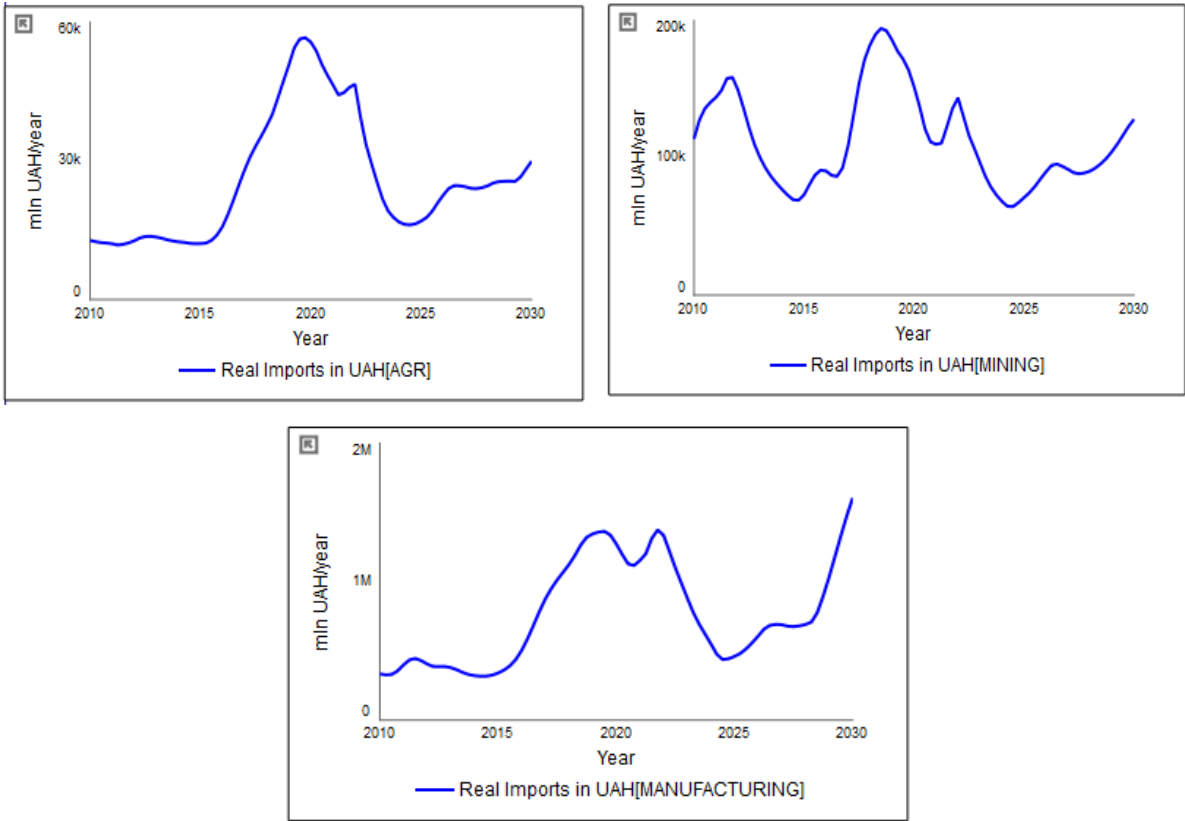


Figure 4.2. The model behavior of the Real Imports of Agriculture (A), Mining (B), Manufacturing (C)

The dynamics of import volumes of the three industries have common features (Figure 4.2). For example, the expansion of the main production

capacity of industries occurred until 2022. For the future period, according to the basic scenario, a fall and a gradual recovery are predicted.

One of the features of Ukrainian industries is the high fraction of imported goods. The share of these products is the highest in the manufacturing sector. For example, the Ukrainian manufacturing sector produced only 30% of machines, equipment, computers, and other high-tech goods (SSSU, 2023b). The remaining 70% was imported from abroad. Therefore, when comparing the volume of imports and the GDP of production, it can be stated that domestically produced goods make up a small part of the total volume.

In the mining sector, fuel products are imported the most, despite the high share of own deposits of combustible resources. Raw materials are exported, and goods with high added value are imported. A similar situation is observed for the agricultural industry.

Further, will be considered the dynamics of real GDP and GDP capacity (Figure 4.3).

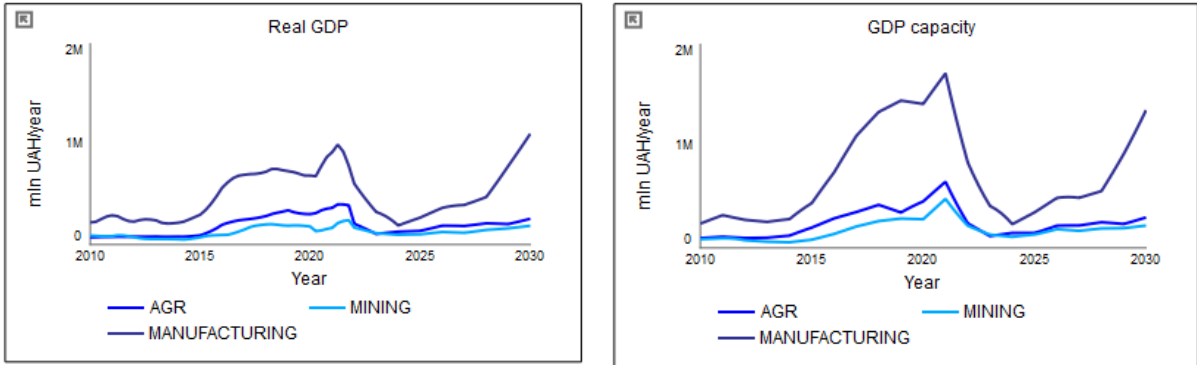


Figure 4.3. The model behavior of the Real GDP (A) and GDP capacity (B)

It is predicted that the volume of GDP capacity and as result the GDP will significantly decrease in the war and post-war period. The main reasons for such dynamics are occupation of territories, disruption of supply chains, limited access to electricity and labour migration. Despite the internal movement of production capacities, manufacturing volumes remain the lowest for the entire period. One of the biggest losses is the loss of the mining industry. Since many deposits are located in the Eastern region of Ukraine, which is temporarily under

occupation. The negative consequences for the agricultural industry are limiting the cultivation of crops and blocking sea routes, which were mainly used to sell agricultural products.

4.2 Key findings of simulation results

The simulation results of the historical behaviour of the variable reflect the main crisis periods that have occurred since 2010.

The exchange rate sector depicts devaluation processes of the national currency rate, and fluctuations in demand for foreign currency caused by various factors. The biggest and most significant crises occurred in 2014 and 2022. The dynamics of imports and real GDP also reproduces the impact of these crises.

The future dynamics of the main indicators will depend on the duration of the full-scale invasion. According to the base scenario (assuming the end of the war in 2023), there will be a significant decline in the production capacity of the economy in all industries. The main reasons for this are the disruption of supply chains, the destruction of production and infrastructure facilities in the temporarily occupied territory, labour migration of the population, and limited access to electricity. However, provided the end of the war, the development of strategic reconstruction plans and international investments, there will be a gradual recovery of Ukrainian production. This basic scenario is reflected in the dynamics of the forecast values of the analysed variables.

4.3 Tests of model validation

This section of the work is dedicated to validation the built model using various tests such as calibration, sensitivity analysis, parameter test and others.

4.3.1 Model Calibration

One of the main tasks of calibration is to approximate the dynamics of the series reproduced in the model to its historical data. The main model variables such as the exchange rate, import volumes and GDP were calibrated. The purpose of calibration is model validation and reproduction of historical data dynamics. Since the modelling is an iterative process, calibration was carried out at each stage of system building.

4.3.2 Unit Test

All units of variables are precisely defined and correspond to the scientific literature and real data.

4.3.3 Integration Error Test

Euler integration method was used in the model. Methods such as Runga-Kutta 2 and Runga-Kutta 4 were also analysed. When choosing other methods, minor changes in the numerical values of the variables were observed. However, there were no significant deviations. Therefore, the main Euler method was chosen.

4.3.4 Behaviour Replication Test

One of the important factors of the model is the reproduction of the behaviour of the historical values of variables. The obtained results are shown in Figure 4.4.

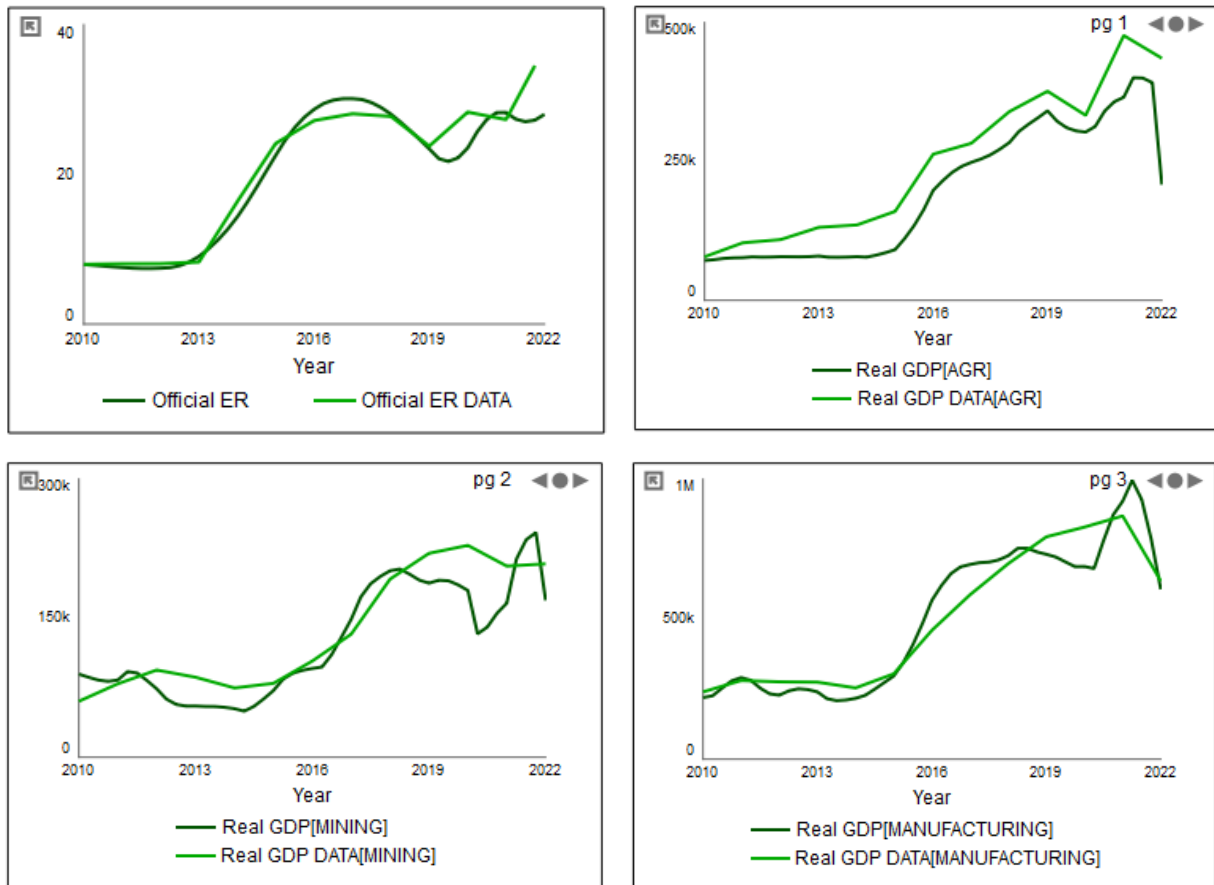


Figure 4.4. The behavioural dynamic of main variables simulated by the model and its historical data

The dynamics of simulated results are most accurately reproduced in exchange rate, the manufacturing and mining sectors, although there is a minor deviation, and less precisely - in the agricultural industry. Factors that affect this are the time lag and discrepancy in official data from different sources (probably due to different statistical data processing methodologies). The reasons of deviation from historical values for exchange rate are the omission of modelling the supply of foreign currency, since according to one of the assumptions of the model, exports are an exogenous variable. Also, other macro indicators, such as currency interventions, can distort the dynamics. However, this is already a direction for further research.

For the statistical measurement of the deviation, the mean square error (MSE) was calculated based on the methodology presented in the article

(Langarudi & Radzicki, 2013). The obtained results by main series are shown in Table 4.1.

Table 4.1. Inequality statistics of the main variables

	U	Um	Us	Uc
Exchange rate	0.096164	0.042006	0.007978	0.950016
Import AGR	0.359249	0.609735	0.006661	0.383604
Import Mining	0.186922	0.335206	0.145240	0.519554
Import Manufacturing	0.160958	0.528260	0.023736	0.448004
Real GDP AGR	0.237784	0.773903	0.048099	0.177998
Real GDP Mining	0.210712	0.234492	0.089481	0.676027
Real GDP Manufacturing	0.144683	0.002950	0.015595	0.981456

The obtained correlation results allow to conclude that most of the values of U_c are greater than 0.5. If the values of U_c are close to 1, this indicates that the model accurately reproduces historical data. In the table 1, the largest value was obtained for the Real GDP manufacturing industry, and the smallest - for agriculture. It is also worth noting that for the exchange rate U_c is also high, which is a good result.

To sum up, according to the statistics of the main variables, the model reproduces their historical dynamics.

4.3.5 Structural Model Test

The structure of the model reflects the main cause-and-effect relationships in accordance with the literature review and official data. In addition to this, all component models are logically connected and scientifically based. To determine whether this structure is correct, the data triangulation method was applied, which consists of the use of various methods of data collection - the study of scientific literature, the analysis of social media posts, and publications of state institutions.

4.3.6 Parameter Test

The main task of this test is to check parameters for their compliance with real values, official data, or literature. The parameters must be scientifically correct, based on academic literary sources or official data. All the specified criteria were observed during the building of the model. For example, the parameters of GDP and Price elasticity was chosen in accordance with the literature, and all data were taken from the official sources of the State Statistics Service of Ukraine and the National Bank of Ukraine.

4.3.7 Extreme Condition Test

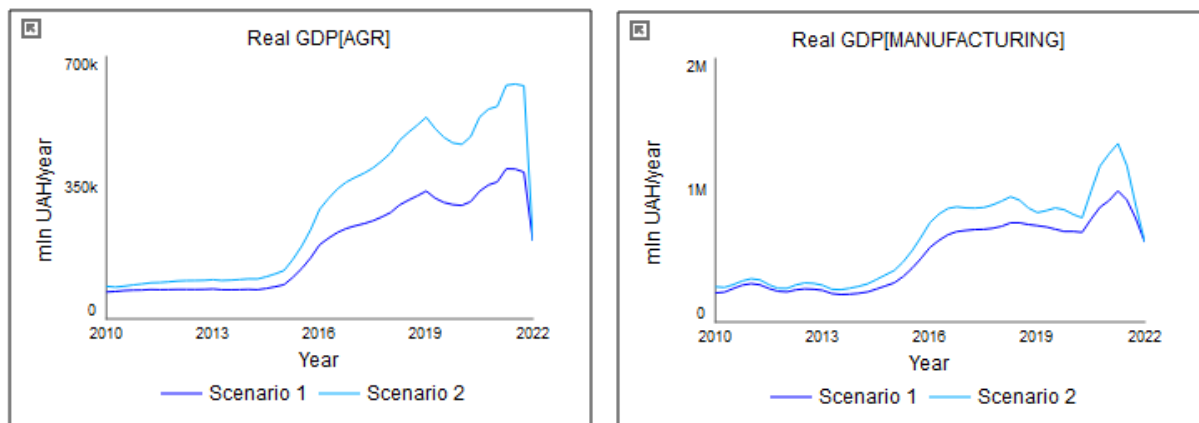


Figure 4.5. Extreme test for Desired inventory coverage parameter

The extreme condition test allows to test the maximum and minimum values of the parameters. This is important to check the logic and correctness of the model even with extreme parameter values. All parameters were tested in the model. Let`s consider an example of the parameter of desired inventory coverage. The results of the maximum values are shown in the Figure 4.5 for the real GDP of the agricultural and manufacturing industries.

4.3.8 Sensitivity Analysis

Sensitivity analysis allows to assess the reliability of the model's simulated results and check the uncertain variables. Correct reproduction of the behaviour of the main variables is one of the important tasks of system dynamics. Sensitivity analysis provides a diagnosis of the impact of parameter uncertainty on behavioural relationships (Hekimoglu & Barlas, 2010).

Variables of all blocks of the model were examined for sensitivity to changes in parameters. All of them are given in the model. The main summary of the sensitivity test would be considered further.

To begin with the parameter of desired inventory coverage. That indicator shows the current level of inventory that is in production and what period of time the inventory can cover. The main details of the sensitivity test for the inventory coverage ratio are given in Table 4.2.

Table 4.2. Sensitivity test for changes in the inventory coverage parameter

Parameter	Desired inventory coverage ratio
Type of distribution	Uniform, 0.5-1

Indicators such as the exchange rate, demand for currency, GDP and imports are sensitive to changes in this parameter. Changing inventory coverage has its advantages and disadvantages. The advantages are the flexibility of meeting demand, ensuring uninterrupted production. The main disadvantages are high inventory holding costs, risks of obsolescence, and reduced liquidity. Therefore, if the indicator is high, then the value of GDP and, accordingly, imports increase. Because an increase in production capacity provides an opportunity to increase the level of inventories. If imports increase, the demand for foreign currency grows accordingly. It, in turn, increases the deviation of the exchange rate, increasing the rate of foreign currency. The results of the sensitivity test are depicted in the Figure 4.6.

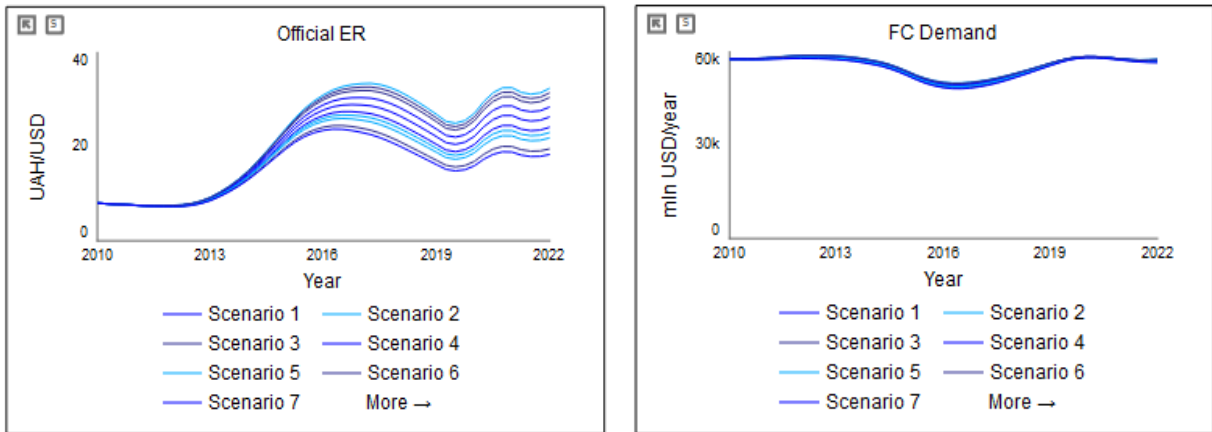


Figure 4.6. Results of the sensitivity test for Official exchange rate and foreign currency demand

In the Figure 4.7 are shown the behaviour of the real imports and GDP. However, for visual presentation, the graphics include only examples of the agricultural industry. Imports and GDP of other sectors of the economy are also sensitive to changes in inventory coverage ratio. That graphs are displayed in the model.

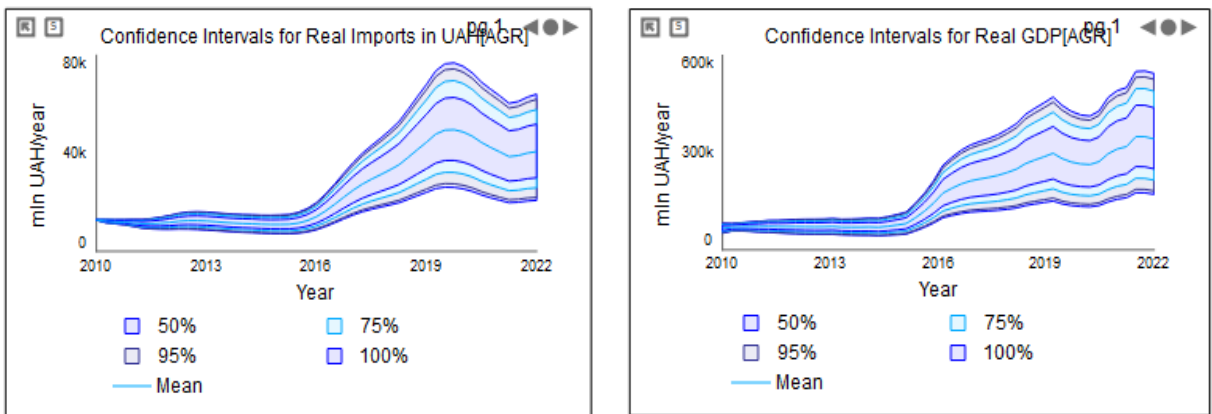


Figure 4.7. Results of the sensitivity test for Real Imports and Real GDP

The sensitivity of the exchange rate, imports and GDP is low or absent to the parameters such as GDP elasticity or import price elasticity. This means that the given uncertainty of these parameters does not significantly affect the dynamics of the main indicators.

However, another sensitivity test is devoted to the time parameters of the model (Table 4.3), which play an important role in the formation of the exchange rate, the inflation index, and the inventory gap.

Table 4.3. Sensitivity test for changes in adjustment time

Parameters	ER adj time, Index Price adj time, Desired inventory gap adj time
Type of distribution	Uniform, 0.28-0.52, 0.63-1.17, 0.735-1.365

The results of the sensitivity test for time parameters are shown in Figure 4.8. One of the most sensitive variables is the exchange rate variable. As mentioned earlier, the exchange rate is set on the interbank market, where currency is bought and sold. Such auctions take place every day, except for weekends.

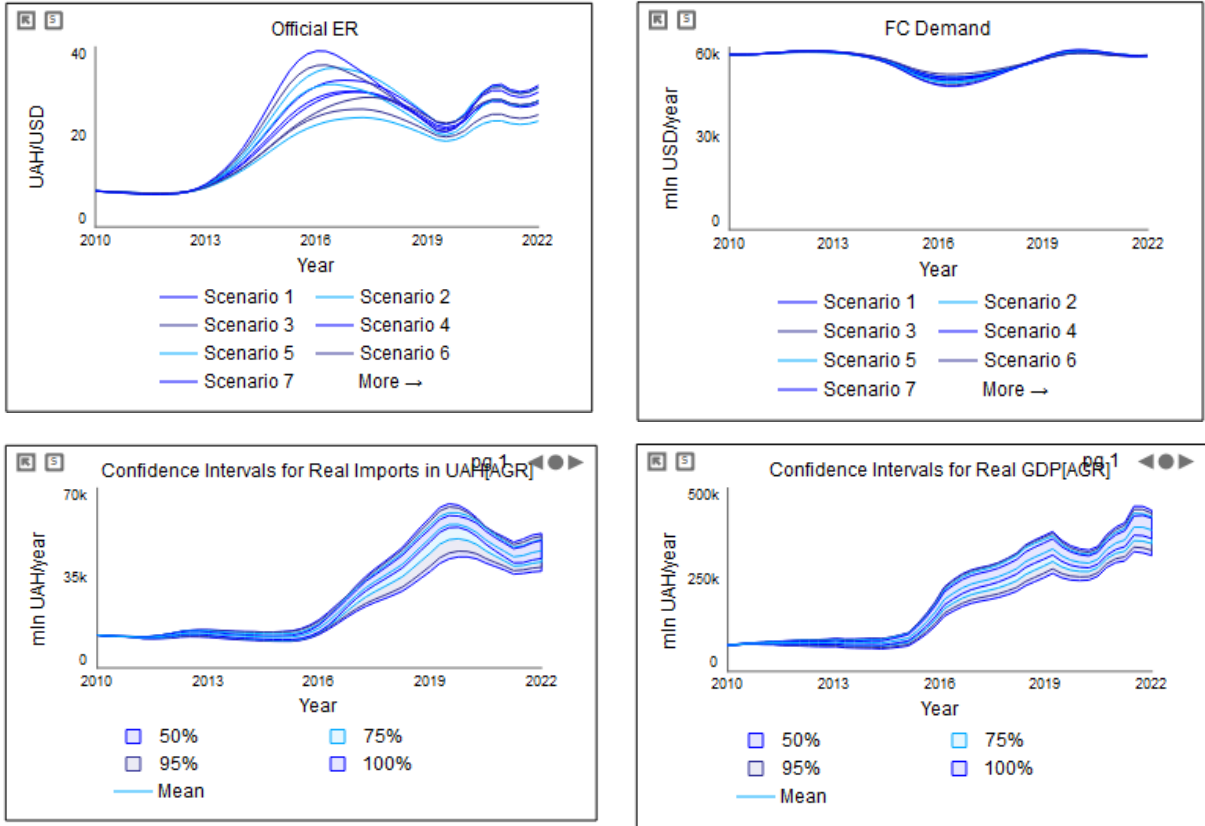


Figure 4.8. Results of the sensitivity test for time parameters

Deviation from the schedule can negatively affect the determination of the course in the market. Therefore, the longer the exchange rate formation period, the greater the fluctuations and deviations of the exchange rate itself will be observed in the market.

A similar logic is observed for the price index and real imports and GDP. In addition, it is worth noting that the demand for foreign currency is the least sensitive to changes in time parameters.

Chapter 5. Policy Analysis

Three main policies have been added to the model, which, according to research and empirical evidence, have an impact on the exchange rate and can positively influence the stimulation of domestic production. Let's recall that these policies consider scenarios of possible fluctuations in the exchange rate in the event of a transition from a fixed to a free-floating currency regime.

The importance of the transition from a fixed exchange rate to a flexible one is also substantiated by the American professor of Ukrainian origin - Yuri Horodnichenko. He argues that the exchange rate should be flexible, but fluctuations should occur within a defined and permissible narrow range (Gorodnichenko, 2022). Thus, the exchange rate will change (rise or fall) under the influence of market forces, but within the corridor and at a rate determined by the Central Bank.

Therefore, the main task of the policy is to promote the strengthening of the exchange rate, which might have a positive effect on the trade competitiveness of domestic producers. Such policies include improving expectations and increasing international investment. The connection between the exchange rate and the trade and exchange position, as well as domestic production is inverse. That means that it describes not only the influence of the exchange rate on producers, but also the mutual influence of production capacities on the strengthening or weakening of the national currency. Therefore, one of the policies will concern the development and restoration of domestic production, namely investments in technological support of production processes.

Further, will be analyzed the effectiveness of policies and the obtained result in more detail.

5.1 Analysis of exchange rate policies

In the absence of policies, according to the base scenario of the model, the exchange rate will reach the level of UAH 35.59 to the US dollar by the end of 2030. However, with the implementation of the policy of improved expectations and international investments in the economy, the national exchange rate of the hryvnia will strengthen. The dynamics of various scenarios of exchange rate behavior are shown in Figure 5.1.

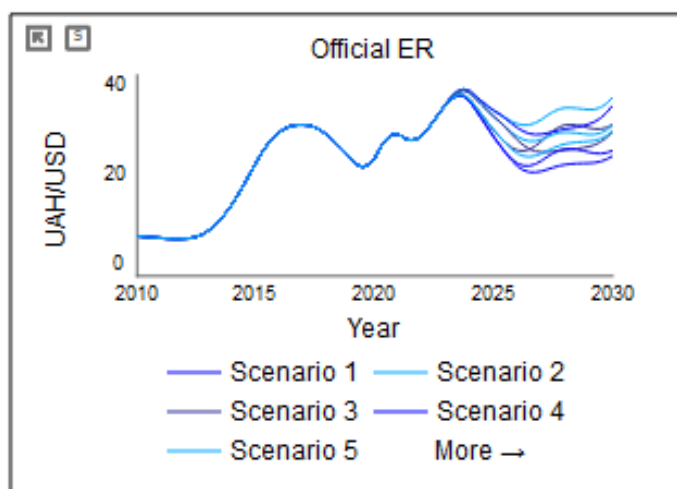


Figure 5.1. The future dynamics of exchange rate with different combination of implemented policies

Improving the expectations of the population will contribute to the strengthening of the exchange rate (scenario 2). However, this change is not significant compared to the baseline scenario. Such factors as the end of the war, the return of the workforce, the recovery and reconstruction of the economy, and the transparent and defined monetary policy of the central bank will contribute to the improvement of expectations. Of course, expectations have an impact on exchange rate fluctuations, but this is not the main tool for determining the stability of a national currency.

The logic of the policy equation of the expected value of the Exchange rate is the following. During a war, the expectations of economic agents are high, which negatively affects the exchange rate, leading to its devaluation.

However, in the post-war period, due to investment attraction, labor force return, balanced monetary policy, the expectations of the population should improve. Accordingly, the dynamics of the expected value of Exchange rate variable is decreasing when applying the policy.

A more important policy that can strengthen the exchange rate is the increase in international investment. The policy is based on an increase in the share of international investments in the post-war period.

The role of international financial aid from abroad during the crisis period is essential for any country. Such financial support ensures the solvency of the country, and its ability to fulfill obligations on time, and compensates part of the economic losses incurred due to different shocks that led to the crisis. Since the beginning of the full-scale war in Ukraine, many countries, and regions provided significant financial, humanitarian, and military aid, without which Ukraine could not conduct defensive action, carry about citizens, and maintain the economy.

Figure 5.2 depicts all three types of foreign support – military, humanitarian, and financial according to from which country or region it was received.

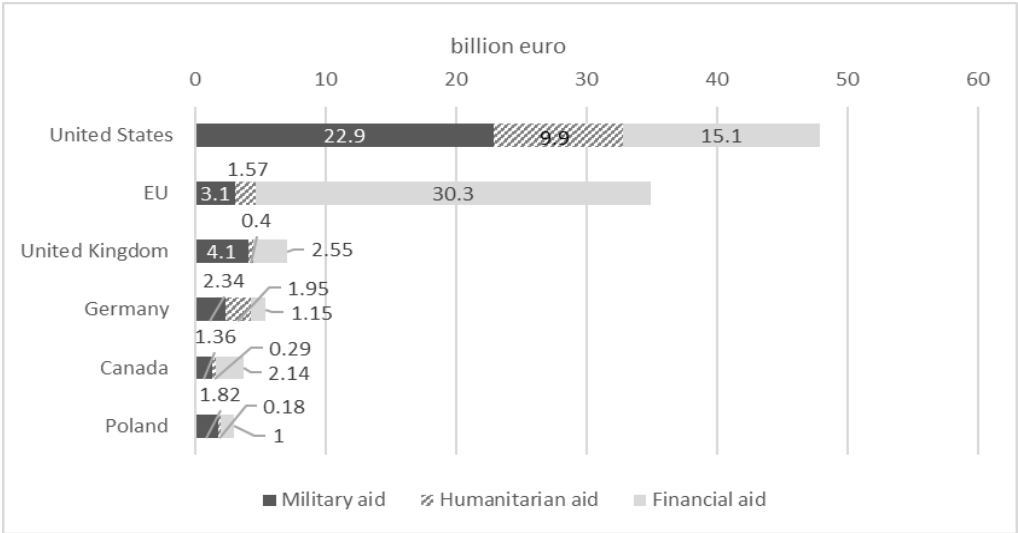


Figure 5.2. Top-6 countries with the highest fraction of government assistance to Ukraine since the beginning of the full-scale war to November 2022 (KIEL, 2023)

The largest investor with the highest contribution and support is the United States. The total amount of support equals 48 billion euros. A significant sum (34.97 billion euros) of assistance was received from European Union Institution. The 7.05 billion euros contributed by the United Kingdom. The support from Germany is 5.44, from Canada – 3.79, and from Poland – 3 billion euros. In addition to this, from Figure 5.2 can be seen that all countries except EU Institutions provide more assistance which is aimed at the military sector. This reflects a primary necessity of Ukraine to defend its borders. However, the essential part of support is financial foreign aid, which prevents the occurrence of default and maintains reserves at the necessary level, which is sufficient for the performance of the country`s obligation and covers three months of imports.

Possible combinations of all policies are listed in Table 5.1. The combination of two policies ensures an appreciation of the exchange rate to UAH 28.81 per US dollar.

Table 5.1. Combination of all policies and the results of exchange rate

	International Investment Policy	Expectations Policy	Reinvestment in technology Policy	Exchange rate results
Scenario 1	0	0	0	35.59
Scenario 2	0	1	0	33.98
Scenario 3	1	0	0	30.15
Scenario 4	0	0	1	30.07
Scenario 5	1	1	0	28.81
Scenario 6	0	1	1	28.74
Scenario 7	1	0	1	24.98
Scenario 8	1	1	1	23.90

Future international financial investments will contribute to the strengthening of the exchange rate. Because it will create demand for the

national currency. At the same time, the level of the interest rate is important, on the basis of which profitability for a foreign investor will be based. A higher interest rate provides a higher yield on a security (for example, a governmental bond). Therefore, in the model, the calculation of international investments is based on the policy rate of the Central Bank.

5.2 Analysis of real sector policy

According to the studies of the Ukrainian industries, it can be concluded that in the three selected sectors there is a high share of imported goods compared to domestic production. Therefore, the third policy is aimed precisely at the reinvestment of the profits of the companies of the three areas of industry in technological support, which will increase the production capacity.

For countries with large raw material reserves, there is a danger of a "raw material trap" or "Dutch disease". The concept of "Dutch disease" means the dependence of the economy on the export of one or two types of raw materials, which form the main income of the country. Instead, the development of own production is low, and therefore domestic demand is ensured at the expense of imported goods and services. The term originated in 1977 to describe the backwardness of the manufacturing and processing sectors of the economy in the Netherlands following the discovery in 1959 of a large natural gas field in Groningen (Brahmbhatt et al., 2010).

Therefore, the third policy (reinvestment in technology) is based precisely on the growth of domestic production in industries, increasing the share of reinvested profits of companies. The results of this policy and the previous two are shown in graphs 5.3 -5.5.

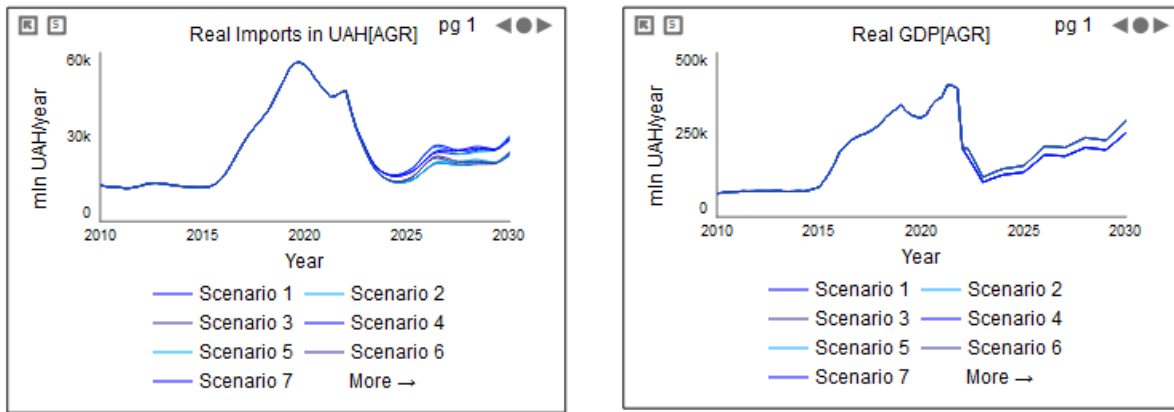


Figure 5.3. The future dynamics of Real Imports and Real GDP in the agricultural industry

The recovery of the agricultural sector will depend not only on the improvement of the applied technologies, but also on the speed of demining of the area of agricultural land, the restoration of infrastructure and the attraction of the workforce. That is why the growth from reinvestment in the technological improvement of the industry slightly increases the volume of GDP. However, it is worth noting that the GDP of the sector is a complex system that includes many interrelated components. Therefore, investments play a significant role in the recovery of this industry.

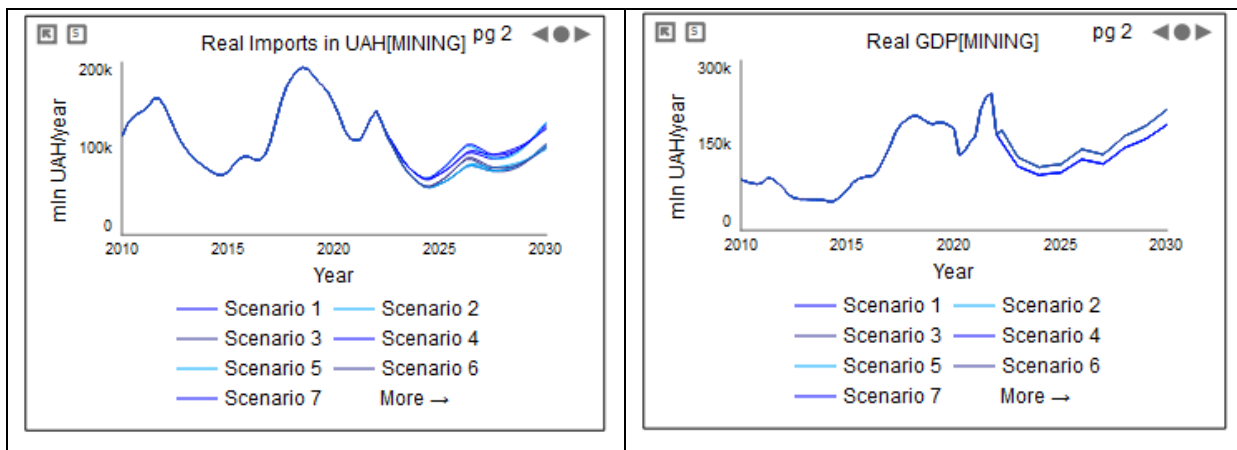


Figure 5.4. The future dynamics of Real Imports and Real GDP in the mining industry

A feature of the mining industry is their concentration in the regions where the greatest hostilities took place, and which experienced the greatest destruction. Therefore, to restore the sector, it is necessary to build the entire infrastructure from scratch. Then gradually introduce increased reinvestment in production capacity. That is why the dynamics of the recovery of the sector is long-term and gradual.

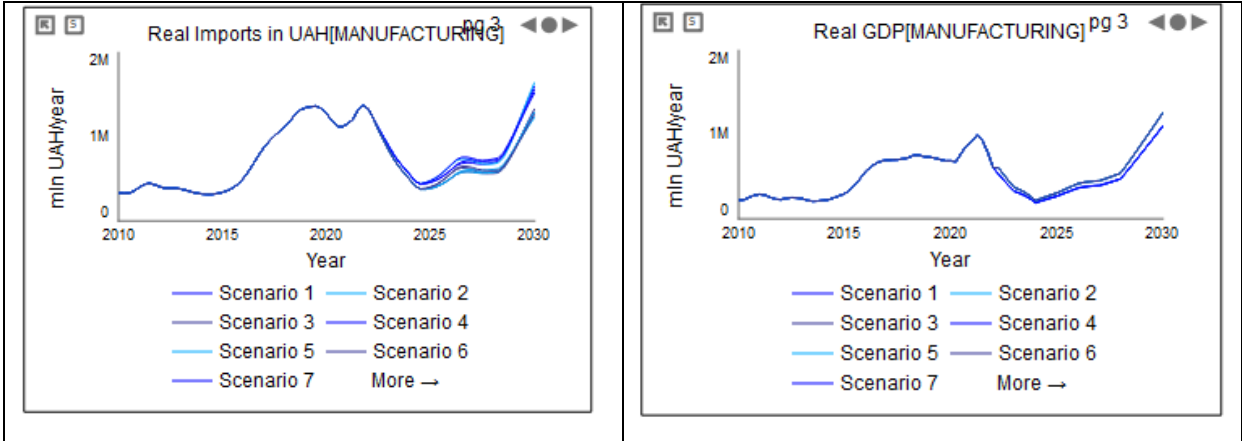


Figure 5.5. The future dynamics of Real Imports and Real GDP in the manufacturing industry

The country's manufacturing capacity also suffered heavy losses from the full-scale invasion and will require big investment to rebuild. However, in an optimistic scenario - under the conditions of the end of the war and gradual reconstruction, the policy of increasing reinvestment will contribute to the increase of production capacities and the development of the sector. An important condition is an increase in the share of domestically produced goods and services. At the same time, the focus should be on niche products. In the post-war period, the defense complex will develop rapidly. However, it is also important to focus on the production of cars, engines, locomotives, aircraft, vehicles, and light industries. Therefore, the policy of growing the share of reinvestment can increase the volume of GDP.

5.3 Implementation Obstacles

The considered policies make it possible to achieve a result, but at the same time there are many obstacles that can become an obstacle to the implementation of policies or their effectiveness.

Firstly, even if the war ends in the near future, the priority direction of gradual recovery will be the reconstruction of housing, demining, etc. Improving expectations is not a priority for government policy. Therefore, the implementation of this policy will take more time.

Secondly, the massive destruction and occupation of the territory caused a lot of damage in various industries and sectors of the economy. Of course, the restoration of the real sector is an important area of reconstruction, but the more critical areas are the rebuilding of infrastructure, logistics, and housing. Therefore, the redistribution of the involved investments will be carried out in accordance with the urgency and importance of the tasks. This means that the share of investments in the recovery of production of industries in the coming years will be smaller than in other directions, inhibiting the recovery and development of the real sector.

Thirdly, in order to restore the production capacities of the industries, a lot of additional work is needed to return agricultural land, mineral deposits and land to the pre-war period. Most of the territories were mined, flooded, burned or completely destroyed. This in turn again slows down the implementation of policies.

Chapter 6. Conclusion

6.1 The key findings and summary

The main goal of the scientific research was to identify the mutual influence and relationships between the fluctuations in the exchange rate and the trade position of the country. Trade competitiveness meant the country's domestic production capacity in three main sectors and the dynamics of trade with the outside world, which was based on a study of import volumes.

This study should answer the main research question - *"What is the optimal exchange rate policy that will improve the position of national producers and increase their competitiveness?"* on the condition that in the post-war period there will be a change in currency regimes - from fixed to flexible.

Based on the results of the modelling and the obtained results, it can be concluded that in order to increase the incentives for the recovery and development of the domestic sector of production, it is necessary to ensure the appreciation of the exchange rate. This is possible due to three main policies, which were discussed in detail in the work, namely - improving the expectations of economic subjects, attracting international investments and reinvesting in the production capacities of industries.

The appreciation of the national currency increases incentives for importers. This causes competition in the domestic market, as imported goods are cheaper compared to domestically produced goods. In order to be competitive in the market, domestic producers have to also reduce the price of their own goods. One of the ways to reduce the price of domestically produced goods is to increase the productivity of own production through the

improvement of technological support. In other words, in order for the domestic manufacturer to remain competitive on the market, it is necessary to invest in innovative production technologies.

In addition, an important task for producers is to focus on the manufacturing of goods for final consumption, rather than intermediate ones. The feedback of the increase in production on the exchange rate is that only the reorientation of the country from the export of raw materials to development and investment in domestic production will be able to strengthen the exchange rate of the national currency. On the contrary, as long as the country's economic position depends mainly on the export of raw materials and natural resources, the strength of the national currency will weaken.

A potential solution is investment and development of domestic production. This issue is especially relevant in the post-war period, when large manufacturing entities were destroyed and need capital reconstruction. Therefore, it is important that the government develop plans for the recovery and reconstruction of the real sector of the economy, based on investments in innovative manufacturing and strategies for the development of niche industries, such as the production of vehicles, engines, household appliances, computers, etc. The agro-industrial and mining sectors also require large capital investments for reconstruction, as well as a reorientation from the exclusive sale of raw materials to their domestic production. The factor that will contribute to the strengthening of the national currency is the attraction of foreign investments. It will also improve the expectations of the population.

6.2 Limitations of the research

The main limitations of the work were time limitation. As part of the researching, requests were made to the employees of the National Bank of Ukraine to verify the scientific hypotheses of the model. However, due to lack of time and busy schedule, most of them postponed consultations for the period when the work should be written. Therefore, time constraints did not allow deepening the work of interviews of experts with extensive practical experience.

Another limitation is the inconsistency of datasets from official sources. A common practice of Ukrainian statistical data collection is the introduction of a new methodology of data calculation and processing. This makes it impossible to work with an array of data, as it must first be reduced to one dimension. This also created certain limitations of the research.

6.3 Further research

There are several directions for further research and deepening of scientific results. Firstly, more branches of the real sector of the economy can be added for an in-depth comparison.

Secondly, the model does not include the component of foreign currency supply, as export is an exogenous variable. A possible further research may be the expansion of the model and the construction of the export component, which will form the block of foreign currency supply.

Thirdly, we can add the real sectors of other foreign countries - the main trading partners of Ukraine.

Finally, it is worth noting that there are many factors that affect the exchange rate. These include currency interventions, amounts of international reserves, interest rates, and others. Therefore, the scientific research can be expanded by the impact of additional macro indicators on the exchange rate.

References

Adamyk, B. (2016). Problems and perspectives of banking regulation in Ukraine during the economic crisis of 2014-2016. *Czech Journal of Social Sciences, Business and Economics*, 5, 18-27. <https://doi.org/10.24984/cjssbe.2016.5.3.2>

Bahmani, M., Harvey, H., & Hegerty, S. W. (2013). Empirical tests of the Marshall-Lerner condition: a literature review. *Journal of Economic Studies*, 40(3), 411-443. <https://doi.org/10.1108/01443581311283989>

Balassa, B. A. (1962). Recent developments in the competitiveness of American industry and prospects for the future.

Basilevska, & Voitko. (2013). Currency-course analysis on basis of macroeconomic indexes: Dynamic aspect.

Batrakova T.I., S. A. O. (2016). Причини виникнення девальвації гривні та шляхи її подолання.

Berdynskykh, O. (2019). Capacity utilization rate of industrial companies <https://gmk.center/en/infographic/capacity-utilization-rate-of-industrial-companies-in-ukraine-is-growing/>

Bereslavska. (2015). Devaluation shocks and their consequences for Ukraine's economy. *Economy and Forecasting*.

Brahmbhatt, M., Canuto, O., & Vostroknutova, E. (2010). Dealing with Dutch Disease. *World Bank - Economic Premise*, 1-7.

Busse, M., & Koeniger, J. (2012). Trade and Economic Growth: A Re-Examination of the Empirical Evidence. *SSRN Electronic Journal*. <https://doi.org/10.2139/ssrn.2009939>

CFI. (2019). Capacity Utilization. <https://corporatefinanceinstitute.com/resources/economics/capacity-utilization/>

Curry, B., & Lock, C. (2022). Demand-Pull Inflation. <https://www.forbes.com/advisor/investing/demand-pull-inflation/>

Dadashova, P., & Faryna, O. (2015). Концептуальні підходи до побудови макромоделі економіки України методами Системної Динаміки. <https://ekmair.ukma.edu.ua/server/api/core/bitstreams/834721d5-edc8-443e-a1f9-4c2630a3c0e5/content>

Dangerfield, B. (2014). Systems Thinking and System Dynamics: a primer. In (pp. 29-51).

Ethier, W. (1973). International Trade and the Forward Exchange Market. *American Economic Review*. <https://www.jstor.org/stable/1914383>

Faryna. (2016). Dynamic models of assessing the stability of the financial system of Ukraine: dissertation for obtaining the scientific degree of candidate of economic sciences. <https://ekmair.ukma.edu.ua/handle/123456789/9075>

Faryna, O. I. (2014). A System Dynamics Model of Ukraine's Monetary Sector. <https://proceedings.systemdynamics.org/2014/proceed/papers/P1452.pdf>

Forrester, J., & Senge, P. (1979). Tests for Building Confidence in System Dynamics Models. *System Dynamics Group, Cambridge*, 40. <http://static.clexchange.org/ftp/documents/roadmaps/RM10/D-2926-7.pdf>

Forrester, J. W. (1958). Industrial dynamics: a major breakthrough for decision makers. *Harvard business review*, 36(4), 37-66.

Ghosh, A., Gulde, A.-M., & Wolf, H. (2003). Exchange Rate Regimes: Choices and Consequences. <https://doi.org/10.7551/mitpress/2898.001.0001>

Gorodnichenko, Y. (2022). No fear of floating for the hryvnia. *Vox Ukraine*. <https://voxukraine.org/en/no-fear-of-floating-for-the-hryvnia>

Haraldsson, H. V., & Sverdrup, H. (2013). Finding simplicity in complexity in biogeochemical modelling. *Environmental modelling: Finding simplicity in complexity*, 277-289.

Hekimoglu, M., & Barlas, Y. (2010). Sensitivity Analysis of System Dynamics Models by Behavior Pattern Measures.

Ilychok, B., & Trevoho, I. (2016). Exchange Rate of Ukrainian Currency – Trends and Potential Changes. *Economics, Entrepreneurship, Management*, 3, 31-38. <https://doi.org/10.23939/eem2016.02.031>

Keshavarz, H. (2021). Evaluating credibility of social media information: current challenges, research directions and practical criteria. *Information Discovery and Delivery*, 49(4), 269-279. <https://doi.org/10.1108/IDD-03-2020-0033>

Khan, A. (2020). A System Dynamics Model Of Exchange Rate Determination And Forecasting. *SEISENSE Journal of Management*, 3, 44-55. <https://doi.org/10.33215/sjom.v3i4.367>

KIEL, I. (2023). Ukraine Support Tracker. Institute for the world economy <https://www.ifw-kiel.de/topics/war-against-ukraine/ukraine-support-tracker/?cookieLevel=not-set>

Kipici, A. N., & Kesriyeli, M. (2000). The real exchange rate definitions and calculations. Working Papers 0001, Research and Monetary Policy Department, Central Bank of the Republic of Turkey.

Kuznyetsova, A., Misiats, N., & Klishchuk, O. (2017). The equilibrium model of demand and supply at the Ukrainian Interbank Foreign Exchange Market: disclosure of problematic aspects. *Banks and Bank Systems*, 12, 31-43. [https://doi.org/10.21511/bbs.12\(4\).2017.03](https://doi.org/10.21511/bbs.12(4).2017.03)

Langarudi, S., & Radzicki, M. (2013). Resurrecting a Forgotten Model: Updating Mashayekhi's Model of Iranian Economic Development. https://doi.org/10.1007/978-1-4614-8606-0_11

Liew, V., Lim, K.-P., & Hussain, H. (2003). Exchange Rate and Trade Balance Relationship: The Experience of ASEAN Countries.

Macrotrends. (2023). Ukraine Trade Balance 1989-2023. <https://www.macrotrends.net/countries/UKR/ukraine/trade-balance-deficit>>Ukraine Trade Balance 1989-2023. www.macrotrends.net. Retrieved 2023-05-14.

Minfin. (2022). Як змінився імпорт та експорт України під час війни. <https://minfin.com.ua/ua/2022/12/21/97647452/>

NBU. (2022). NBU Fixes Official UAH/USD Exchange Rate at a New Level and Takes Additional Measures to Balance the FX Market and Support Resilience of Economy during the War. <https://bank.gov.ua/en/news/all/nbu-zafiksuvav-ofitsiyniy-kurs-grivni-do-dolara-ssha-na-novomu-rivni-ta-vjiv-nizku-dodatkovih-zahodiv-dlya-zbalansuvannya-valyutnogo-rinku-ta-pidtrimannya-stiykosti-ekonomiki-v-umovah-viyni>

NBU. (2023a). External Sector Statistics <https://bank.gov.ua/en/statistic/sector-external#1>

NBU. (2023b). Inflation Report <https://bank.gov.ua/en/monetary/report>

NBU. (2023c). NBU Comment on Change in Real GDP in 2022. <https://bank.gov.ua/en/news/all/komentar-natsionalnogo-banku-schodo-zmini-realnogo-vvp-u-2022-rotsi>

NBU. (2023d). Official hryvnia exchange rates. <https://bank.gov.ua/en/markets/exchangerate-chart>

Oleinikov, & Serova. (2019). Devaluation of hryvnia in the system of regulation of foreign trade in Ukraine. [https://doi.org/https://doi.org/10.31617/zt.knute.2019\(104\)09](https://doi.org/https://doi.org/10.31617/zt.knute.2019(104)09)

Petersen, T. (2021). International Competitiveness and Terms of Trade. <https://globaleurope.eu/globalization/international-competitiveness-and-terms-of-trade/>

Rumyantsev, A. P., & Kovalenko, Y. O. (2006). World market of services.

Santos, S. P., Belton, V., & Howick, S. (2002). Adding value to performance measurement by using system dynamics and multicriteria analysis. *International Journal of Operations & Production Management*, 22(11), 1246-1272. <https://doi.org/10.1108/01443570210450284>

Schmitz, M., Clercq, M., Fidora, M., Lauro, B., & Pinheiro, C. (2011). Revisiting the Effective Exchange Rates of the Euro. *Journal of Economic and Social Measurement*, 38. <https://doi.org/10.3233/JEM-130374>

Smith, N. (2017). The Concepts of Devaluation, Valorization and Depreciation in Marx: Toward A Clarification. *Human Geography*, 10(1), 4-19. <https://doi.org/10.1177/194277861701000102>

SSSU. (2023a). National Accounts of Ukraine 2021 https://www.ukrstat.gov.ua/druk/publicat/kat_u/2023/02/NR_2021.pdf

SSSU. (2023b). Товарна структура зовнішньої торгівлі України. https://ukrstat.gov.ua/operativ/operativ2022/zd/tsztt/arh_tsztt2022_u.html

Stein-Parbury, J. (2006). The Student's Guide to Research Ethics. *Journal of Advanced Nursing - J ADV NURS*, 53, 256-256. https://doi.org/10.1111/j.1365-2648.2006.03746_3.x

Stepanenko, & Pylynskyi. (2015). Ukraine after the Euromaidan <https://doi.org/10.3726/978-3-0351-0798-2>

Sterman, J. (2000). Business Dynamics, System Thinking and Modeling for a Complex World. [http://lst-iiep.iiep-unesco.org/cgi-bin/wwwi32.exe/\[in=epidoc1.in\]/?t2000=013598/\(100\)](http://lst-iiep.iiep-unesco.org/cgi-bin/wwwi32.exe/[in=epidoc1.in]/?t2000=013598/(100)), 19.

Sterman, J. (2002). System dynamics modeling: Tools for learning in a complex world. *Engineering Management Review, IEEE*, 43, 42-42. <https://doi.org/10.1109/EMR.2002.1022404>

Vijayasri, G. V. (2013). The Importance of International Trade in the World. *International Journal of Marketing, Financial Services & Management Research*. 111-119.

Vogler, S., Schneider, P., & Zimmermann, N. (2019). Preparing Price Studies – Key Methodological Decisions. In (pp. 269-318). <https://doi.org/10.1016/B978-0-12-813166-4.00015-2>

Yol, M., A., & Baharumshah, A., Z. (2005). The effect of exchange rate changes on trade balances in North Africa: Evidences International Trade and Finance Association 15th International Conference,

Model Documentation

Total	Count	Including Array Elements
Variables	77	143
Sectors	8	
Stocks	5	9
Flows	6	12
Converters	66	122
Constants	12	12
Equations	60	122
Graphicals	21	43
Macro Variables	48	

	Equation	Properties	Units	Documentation	Annotation
Top-Level Model:					
Foreign_Currency_Demand(t)	$Foreign_Currency_Demand(t - dt) + (Change_of_FC_Demand) * dt$	INIT Foreign_Currency_Demand = Total_Real_Imports_in_USD_DATA	mln US D/year	Demand for foreign currency is a complex concept. The model assumes that demand mainly depends on the volume of imports. In addition, the influence of such factors as changes in terms of trade and the influence of international investments was added.	
Inventory[AGR](t)	$Inventory[AGR](t - dt) + (Nominal_GDP[AGR] - Real_AD[AGR]) * dt$	INIT Inventory[AGR] = 78000	mln UA H	The volume of stocks on the market by	

				industry.	
Inventory[Mining](t)	$Inventory[MINING](t - dt) + (Nominal_GDP[MINING] - Real_AD[MINING]) * dt$	INIT Inventory[Mining] = 60000			
Inventory[Manufacturing](t)	$Inventory[MANUFACTURING](t - dt) + (Nominal_GDP[MANUFACTURING] - Real_AD[MANUFACTURING]) * dt$	INIT Inventory[Manufacturing] = 240000			
Official_ER(t)	$Official_ER(t - dt) + (change_of_Official_ER) * dt$	INIT Official_ER = Official_ER_DATA	UAH/USD	The exchange rate expresses the price of one currency unit relative to another currency.	
Price_Index(t)	$Price_Index(t - dt) + (chng_of_Price_Index) * dt$	INIT Price_Index = 1	per year	The price index reflects the change in prices over a certain period of time.	
Real_Imports_in_UAH[AGR](t)	$Real_Imports_in_UAH[AGR](t - dt) + (chng_of_Real_Imports[AGR]) * dt$	INIT Real_Imports_in_UAH[AGR] = Real_Imports_DATA[AGR]	mln UAH	Volumes of real imports, which are presented for three main industries of the economy - agricultural, mining and manufacturing.	
Real_Imports_in_UAH[Mining](t)	$Real_Imports_in_UAH[MINING](t - dt) + (chng_of_Real_Imports[MINING]) * dt$	INIT Real_Imports_in_UAH[MINING] = Real_Imports_DATA[MINING]			
Real_Imports_in_UAH[Manufacturing](t)	$Real_Imports_in_UAH[MANUFACTURING](t - dt) + (chng_of_Real_Imports[MANUFACTURING]) * dt$	INIT Real_Imports_in_UAH[MANUFACTURING] = Real_Imports			

		_DATA[MANUFACTURING]			
Change_of_FC_Demand	$\text{Foreign_Currency_Demand} * \text{Effect_of_Real_Imports_growth_rate} * \text{TOT} * \text{Effect_of_international_investment} * (1 - \text{policy_status_1}) + \text{Foreign_Currency_Demand} * \text{Effect_of_Real_Imports_growth_rate} * \text{TOT} * \text{policy_effect_of_international_investment} * \text{policy_status_1}$		mln US D/year	The change in demand for foreign currency is formed mainly due to changes in imports, or more precisely, its growth. The change in terms of trade and the impact of international investments have a smaller impact.	
change_of_Official_ER	$((\text{Official_ER} * \text{Effect_of_FC_Demand_and_Expectations} - \text{Official_ER})) / \text{ER_adj_time}$		UA H/USD/Year	The change in the exchange rate reflects the impact of the effect of changes in foreign currency demand and expectations, which are adjusted for time. Exchange rate fluctuations depend on the time dimension.	
chnge_of_Price_Index	$(\text{indicated_price} - \text{Price_Index}) / \text{Index_Price_adj_time}$		1/Years ²	The change in the price index is based on the gap between the indicated prices and the current prices, which are adjusted for time.	
chnge_of_Real	$((\text{Real_GDP} * \text{fraction_of_import})$		mln	The volume of	

_Imports[Industries]	ts_with_policy*(Relative_Price_Index*Effect_of_GDP_and_Import_Price))-Real_Imports_in_UAH)/Official_ER_growth_rate		UAH/year	imports is calculated based on the share of imports multiplied by GDP. The change in import volumes is influenced by the impact of relative prices, the effect of GDP and changes in import prices. Also, since imports create demand for foreign currency, the dynamics of imports is determined by the change in the exchange rate. The growth of the exchange rate has a negative effect on the price of imports, and, accordingly, leads to a decrease in its volumes.	
Nominal_GDP[Industries]	GDP_capacity*Capacity_utilization		mln UAH/Years	The total volume of produced goods by three industries (manufacturing, mining, agriculture).	UNIFLOW
Real_AD[Industries]	IF Inventory >0 THEN Nominal_AD/Price_Index ELSE 0		mln UAH/Years	To determine the real aggregate demand, it is necessary to	UNIFLOW

				adjust the nominal demand for the level of inflation.	
Average_CP_Inflation	"Effect_of_Cost-push_inflation"[AGR]*0.25+ "Effect_of_Cost-push_inflation"[MINING]*0.25 + "Effect_of_Cost-push_inflation"[MANUFACTURING]*0.5		dmn 1	Weighted average cost inflation for all industries, with the following coefficients. Manufacturing -0.5, Agriculture - 0.25, Mining - 0.25.	
Average_DP_inflation	"Effect_of_demand-pull_inflation"[AGR]*0.25+ "Effect_of_demand-pull_inflation"[MINING]*0.25 + "Effect_of_demand-pull_inflation"[MANUFACTURING]*0.5		dmn 1	Weighted average demand-pull inflation for all industries, with the following coefficients. Manufacturing -0.5, Agriculture - 0.25, Mining - 0.25.	
Capacity_utilization[Industries]	IF TIME < 2022 THEN desired_GDP/GDP_capacity ELSE 0.85		dmn 1	The production capacities of the industries that are utilized to manufacture the goods and services.	
CPI_UKR	GRAPH(TIME) Points: (2010.00, 1.091), (2011.00, 1.046), (2012.00, 0.998), (2013.00, 1.005), (2014.00, 1.249), (2015.00, 1.433), (2016.00, 1.124), (2017.00, 1.137), (2018.00, 1.098), (2019.00, 1.041), (2020.00, 1.050), (2021.00, 1.100), (2022.00, 1.266)		dmn 1	The inflation index shows the change in the prices in Ukraine of goods and services over a certain period of time. Sources: https://index.mfnfin.com.ua/ua/	

				economy/index /inflation/	
CPI_WORLD	<p>GRAPH(TIME) Points: (2010.00, 1.0330), (2011.00, 1.0480), (2012.00, 1.0370), (2013.00, 1.0260), (2014.00, 1.0230), (2015.00, 1.0140), (2016.00, 1.0160), (2017.00, 1.0220), (2018.00, 1.0240), (2019.00, 1.0220), (2020.00, 1.0190), (2021.00, 1.0350), (2022.00, 1.0870)</p>		dmn 1	<p>Index of changes in world prices for all countries.</p> <p>Sources: Inflation, consumer prices (annual %) https://data.worldbank.org/indicator/FP.CPI.TOTL.ZG</p>	
Deflator_GDP [AGR]	<p>GRAPH(TIME) Points: (2010.00, 1.090), (2011.00, 1.110), (2012.00, 1.073), (2013.00, 1.038), (2014.00, 1.223), (2015.00, 1.556), (2016.00, 1.097), (2017.00, 1.113), (2018.00, 1.100), (2019.00, 0.978), (2020.00, 1.234), (2021.00, 1.311), (2022.00, 0.986), (2023.00, 0.933), (2024.00, 0.974), (2025.00, 0.916), (2026.00, 0.986), (2027.00, 1.014), (2028.00, 1.014), (2029.00, 0.980), (2030.00, 0.991)</p>		dmn 1	<p>The GDP deflator is expressed as the ratio of nominal GDP to real GDP and shows the level of inflation in the country.</p> <p>Sources: https://www.ukrstat.gov.ua/</p>	
Deflator_GDP [MINING]	<p>GRAPH(TIME) Points: (2010.00, 1.186), (2011.00, 1.224), (2012.00, 0.960), (2013.00, 1.027), (2014.00, 1.151), (2015.00, 1.396), (2016.00, 1.390), (2017.00, 1.434), (2018.00, 1.180), (2019.00, 1.057), (2020.00, 0.896), (2021.00, 1.795), (2022.00, 1.096), (2023.00, 0.980), (2024.00, 0.945), (2025.00, 1.101), (2026.00, 1.246), (2027.00, 1.217), (2028.00, 1.113), (2029.00, 1.020), (2030.00, 0.997)</p>				
Deflator_GDP	GRAPH(TIME) Points:				

[MANUFACTURING]	(2010.00, 1.032), (2011.00, 1.049), (2012.00, 1.151), (2013.00, 1.054), (2014.00, 1.287), (2015.00, 1.439), (2016.00, 1.188), (2017.00, 1.178), (2018.00, 1.131), (2019.00, 1.036), (2020.00, 1.055), (2021.00, 1.289), (2022.00, 1.177), (2023.00, 1.078), (2024.00, 1.043), (2025.00, 1.107), (2026.00, 1.142), (2027.00, 1.061), (2028.00, 1.003), (2029.00, 1.003), (2030.00, 1.043)				
desired_GDP[Industries]	$\text{MAX}(0, \text{SMTH1}(\text{Real_AD}, 1) + \text{desired_inventory_rate})$		mln UA H/year	The required volume of GDP, according to the needs of aggregate demand and the desired size of inventory.	
desired_inventory[Industries]	$\text{SMTH1}(\text{Real_AD} * \text{desired_inventory_coverage_ratio}, 1)$		mln UA H	The desired level of inventory is calculated to determine the necessary quantity of goods to meet the demand in the market.	
desired_inventory_coverage_ratio	0.8		year	The inventory level reflects the amount of time that can be covered solely by the use of inventory.	
desired_inventory_gap_adj_time	1.05		year	The time required to cover the inventory gap.	
desired_inventory_rate[Industries]	$(\text{desired_inventory} - \text{Inventory}) / \text{desired_inventory_gap_adj_time}$		mln UA H/year	Desired inventory level adjusted for current	

				inventory and time required to close the gap.	
Domestic_demand[AGR]	<p>GRAPH(TIME) Points: (2010.00, 65686), (2011.00, 83956), (2012.00, 64448), (2013.00, 88024), (2014.00, 87113), (2015.00, 97973), (2016.00, 117406), (2017.00, 108805), (2018.00, 149395), (2019.00, 85077), (2020.00, 147487), (2021.00, 244334), (2022.00, 184000), (2023.00, 181000), (2024.00, 242000), (2025.00, 262000), (2026.00, 261000), (2027.00, 296000), (2028.00, 317000), (2029.00, 326000), (2030.00, 328000)</p>		mln UA H	<p>Volumes of aggregate demand for goods.</p> <p>Sources: https://www.ukrstat.gov.ua/</p>	
Domestic_demand[MINING]	<p>GRAPH(TIME) Points: (2010.00, 176915), (2011.00, 241195), (2012.00, 210025), (2013.00, 175111), (2014.00, 142742), (2015.00, 220426), (2016.00, 211885), (2017.00, 306624), (2018.00, 348630), (2019.00, 305945), (2020.00, 192752), (2021.00, 376647), (2022.00, 248732.4), (2023.00, 270000), (2024.00, 320000), (2025.00, 320000), (2026.00, 380000), (2027.00, 400000), (2028.00, 400000), (2029.00, 420000), (2030.00, 480000)</p>				
Domestic_demand[MANUFACTURING]	<p>GRAPH(TIME) Points: (2010.00, 217237), (2011.00, 300449), (2012.00, 409937), (2013.00, 417078), (2014.00, 438706), (2015.00, 574263), (2016.00, 857679), (2017.00, 1067756), (2018.00, 1269924), (2019.00, 1430021), (2020.00, 1342908), (2021.00, 1690696), (2022.00, 1300000), (2023.00, 1400000), (2024.00, 1250000), (2025.00, 1420000), (2026.00, 1680000), (2027.00, 1700000), (2028.00, 1880000), (2029.00, 2010000), (2030.00, 2100000)</p>				

"Effect_of_Cost-push_inflation"[Industries]	$(1 - \text{fraction_of_imports_with_policy}) * \text{Producer_Price_Index} + \text{fraction_of_imports_with_policy} * \text{Import_Price_Index} / 100$		dmn l	Cost inflation shows the change in prices for resources (materials, raw materials, wages) necessary for the production of goods.
"Effect_of_demand-pull_inflation"[Industries]	$\text{Real_AD} / \text{Nominal_GDP}$		dmn l	Demand-pull inflation shows how much the demand for goods and services exceeds the market supply.
Effect_of_FC_Demand_and_Expectations	$(\text{FC_Demand_growth_rate} * \text{Expected_value_of_ER} * (1 - \text{policy_status_2}) + \text{FC_Demand_growth_rate} * \text{Policy_Expected_value_of_ER} * \text{policy_status_2})$		dmn l	The variable reflects the multiplicative effect of two factors - changes in foreign currency demand and expectations.
Effect_of_GDP_and_Import_Price[Industries]	$\text{effect_of_GDP_on_Import} * 0.7 + \text{effect_of_Import_Price_on_Import} * 0.3$		dmn l	The effects of changes in price and GDP are multiplied by coefficients that reflect the degree of importance of the effects. For the GDP effect - 0.7, and for the price effect - 0.3
effect_of_GDP_on_Import[Industries]	$\text{GDP_growth_rate}^{\text{GDP_elasticity_of_Imports}}$		dmn l	This variable considers how much the volume of imports will change with a

				change in GDP.	
effect_of_Import_Price_on_Import	$\text{Import_Price_growth_rate}^{\text{price_elasticity_of_Imports}}$		dmnl	This variable considers how much the volume of imports will change with a change in Import Prices.	
Effect_of_international_investment	<p>GRAPH(TIME) Points: (2010.00, 0.090438356), (2011.00, 0.0775), (2012.00, 0.075560109), (2013.00, 0.070260274), (2014.00, 0.102273973), (2015.00, 0.252958904), (2016.00, 0.177868852), (2017.00, 0.132082192), (2018.00, 0.171273973), (2019.00, 0.169794521), (2020.00, 0.079153005), (2021.00, 0.075328767), (2022.00, 0.186575342), (2023.00, 0.250)</p>		dmnl	The dynamics of international investments are based on the change in the interest rate. A higher rate promotes greater leverage through higher returns on securities. The higher the indicators of international financial assistance, the more stable the national currency is due to the increase in demand for it.	
Effect_of_Real_Imports_growth_rate	$\text{Real_Imports_growth_rate[AGR]}*0.25+$ $\text{Real_Imports_growth_rate[Mining]}*0.25+$ $\text{Real_Imports_growth_rate[Manufacturing]}*0.5$		per year	This variable reflects the weighted average growth rate of import volumes. The largest industry of the economy is Manufacturing. Therefore, the weight coefficient is 0.5, for the remaining Agricultural	

				and Mining industries, the weight is 0.25.
ER_adj_time	0.4		year	A time indicator that displays the rate of change of the exchange rate and the achievement of the desired level.
Expected_value_of_ER	<p>GRAPH(TIME) Points: (2010.00, 0.978), (2011.00, 0.978), (2012.00, 1.000), (2013.00, 1.166), (2014.00, 1.227), (2015.00, 1.238), (2016.00, 1.210), (2017.00, 1.144), (2018.00, 1.028), (2019.00, 0.934), (2020.00, 1.133), (2021.00, 0.950), (2022.00, 1.088), (2023.00, 1.110), (2024.00, 1.077), (2025.00, 1.177), (2026.00, 1.199), (2027.00, 1.199), (2028.00, 1.149), (2029.00, 1.133), (2030.00, 1.133)</p>		dmn l	<p>The expectations of the population have a high influence on the level of the exchange rate. When negative expectations appear on the market, panic begins and people actively start buying a more stable currency relative to the national currency unit. Therefore, the exchange rate begins to rapidly devalue. In the conditions of improved expectations, there is a strengthening of the exchange rate.</p> <p>The data is calculated based on the historical dynamics of changes in the</p>

				interbank exchange rate.	
Export[AGR]	GRAPH(TIME) Points: (2010.00, 33590), (2011.00, 47180), (2012.00, 77343), (2013.00, 75524), (2014.00, 110795), (2015.00, 185799), (2016.00, 216795), (2017.00, 253619), (2018.00, 277789), (2019.00, 341439), (2020.00, 326801), (2021.00, 449742), (2022.00, 314819.4)		mln UA H per year	Sources: https://www.ukrstat.gov.ua/	GF EXT RAP OLA TED
Export[MINING]	GRAPH(TIME) Points: (2010.00, 29679), (2011.00, 44585), (2012.00, 39608), (2013.00, 45354), (2014.00, 57142), (2015.00, 61155), (2016.00, 63133), (2017.00, 92705), (2018.00, 100230), (2019.00, 108259), (2020.00, 133761), (2021.00, 214132), (2022.00, 149892.4)				
Export[MANUFACTURING]	GRAPH(TIME) Points: (2010.00, 375131), (2011.00, 487724), (2012.00, 432171), (2013.00, 384255), (2014.00, 451705), (2015.00, 567085), (2016.00, 627559), (2017.00, 770370), (2018.00, 870875), (2019.00, 806402), (2020.00, 811773), (2021.00, 1119275), (2022.00, 783492.5)				
Export_Price_Index	GRAPH(TIME) Points: (2010.00, 126.0), (2011.00, 125.6), (2012.00, 98.1), (2013.00, 101.0), (2014.00, 94.8), (2015.00, 82.3), (2016.00, 96.2), (2017.00, 115.9), (2018.00, 111.8), (2019.00, 100.1), (2020.00, 104.6), (2021.00, 148.2), (2022.00, 90.8), (2023.00, 95.0), (2024.00, 105.0), (2025.00, 115.0), (2026.00, 120.0), (2027.00, 110.0), (2028.00, 125.0), (2029.00, 127.0), (2030.00, 125.0)		dmn l	The export price index is based on the Paasche Price Index, which shows the change in the price of export goods and services according to the base year. Sources: https://www.ukrstat.gov.ua/	

Exports[AGR]	GRAPH(TIME) Points: (2010.00, 33590), (2011.00, 47180), (2012.00, 77343), (2013.00, 75524), (2014.00, 110795), (2015.00, 185799), (2016.00, 216795), (2017.00, 253619), (2018.00, 277789), (2019.00, 341439), (2020.00, 326801), (2021.00, 449742), (2022.00, 310000), (2023.00, 300000), (2024.00, 350000), (2025.00, 320000), (2026.00, 430000), (2027.00, 420000), (2028.00, 450000), (2029.00, 500000), (2030.00, 550000)		mln UA H	Export volumes by industry. Sources: https://www.ukrstat.gov.ua/	
Exports[MINING]	GRAPH(TIME) Points: (2010.00, 29679), (2011.00, 44585), (2012.00, 39608), (2013.00, 45354), (2014.00, 57142), (2015.00, 61155), (2016.00, 63133), (2017.00, 92705), (2018.00, 100230), (2019.00, 108259), (2020.00, 133761), (2021.00, 214132), (2022.00, 149892.4), (2023.00, 160000), (2024.00, 150000), (2025.00, 150000), (2026.00, 210000), (2027.00, 200000), (2028.00, 210000), (2029.00, 230000), (2030.00, 240000)				
Exports[MANUFACTURING]	GRAPH(TIME) Points: (2010.00, 375131), (2011.00, 487724), (2012.00, 432171), (2013.00, 384255), (2014.00, 451705), (2015.00, 567085), (2016.00, 627559), (2017.00, 770370), (2018.00, 870875), (2019.00, 806402), (2020.00, 811773), (2021.00, 1119275), (2022.00, 770000), (2023.00, 740000), (2024.00, 1030000), (2025.00, 910000), (2026.00, 910000), (2027.00, 1090000), (2028.00, 1160000), (2029.00, 1160000), (2030.00, 1220000)				
FC_Demand_growth_rate	Foreign_Currency_Demand/INT(Foreign_Currency_Demand)		dmn l	Reflecting the dynamics of changes in demand for	

				foreign currency. The greater the growth in demand for foreign currency. The higher the rate of growth.	
fraction_of_imports[AGR]	<p>GRAPH(TIME) Points: (2010.00, 0.163286111), (2011.00, 0.141365084), (2012.00, 0.208428858), (2013.00, 0.199313622), (2014.00, 0.19269107), (2015.00, 0.139591666), (2016.00, 0.158095905), (2017.00, 0.151912735), (2018.00, 0.14295805), (2019.00, 0.158667677), (2020.00, 0.154058408), (2021.00, 0.110514493), (2022.00, 0.1275), (2023.00, 0.1014), (2024.00, 0.1029), (2025.00, 0.1174), (2026.00, 0.1087), (2027.00, 0.1159), (2028.00, 0.1203), (2029.00, 0.1145), (2030.00, 0.1290)</p>		dmn	<p>Share of imports according to self-calculated data from an official source.</p> <p>Sources: https://www.ukrstat.gov.ua/</p>	
fraction_of_imports[MINEING]	<p>GRAPH(TIME) Points: (2010.00, 1.88599567), (2011.00, 1.9480699), (2012.00, 1.765710171), (2013.00, 1.488262116), (2014.00, 1.323854256), (2015.00, 1.531747887), (2016.00, 0.907926047), (2017.00, 1.098649878), (2018.00, 0.98010455), (2019.00, 0.782342841), (2020.00, 0.595072814), (2021.00, 0.596734524), (2022.00, 0.681983858), (2023.00, 0.551), (2024.00, 0.562), (2025.00, 0.632), (2026.00, 0.638), (2027.00, 0.667), (2028.00, 0.643), (2029.00, 0.701), (2030.00, 0.725)</p>				
fraction_of_i	GRAPH(TIME) Points:				

imports[MANUFACTURING]	(2010.00, 1.389139395), (2011.00, 1.67336784), (2012.00, 1.647605513), (2013.00, 1.76298858), (2014.00, 1.717559232), (2015.00, 1.601647588), (2016.00, 1.71559066), (2017.00, 1.656785105), (2018.00, 1.710808925), (2019.00, 1.71837779), (2020.00, 1.464080848), (2021.00, 1.509855079), (2022.00, 1.725548917), (2023.00, 1.638), (2024.00, 1.493), (2025.00, 1.435), (2026.00, 1.623), (2027.00, 1.536), (2028.00, 1.507), (2029.00, 1.594), (2030.00, 1.623)				
fraction_of_imports_with_policy[Industries]	$\text{fraction_of_imports} * (1 - \text{policy_status_3}) + \text{fraction_of_imports} * 0.7 * \text{policy_status_3}$		dmn l	Share of imports with adjustment of future values according to the policy.	
GDP_capacity [Industries]	$\text{labor} * \text{labor_productivity}$		mln UA H/year	Maximum production capacities of industries.	
GDP_elasticity_of_Imports	0.95		dmn l	GDP elasticity reflects the impact of GDP on imports. In other words, to what extent a change in GDP contributes to a change in imports. The coefficient is close to 1, which means that the growth of GDP will lead to the growth of Imports as much as the GDP has	

				changed.	
GDP_growth_rate[Industries]	Nominal_GDP/DELAY(Nominal_GDP, 0.5)		dmn l	The indicator reflects the rate of GDP growth.	
GDP_in_UA_H_DATA[AGR]	GRAPH(TIME) Points: (2010.00, 85341.0), (2011.00, 114894.0), (2012.00, 117335.0), (2013.00, 136368.0), (2014.00, 165934.0), (2015.00, 249012.0), (2016.00, 288578.0), (2017.00, 314628.0), (2018.00, 373753.0), (2019.00, 368109.0), (2020.00, 410974.0), (2021.00, 625004.0), (2022.00, 437502.8)		mln UA H per year	Sources: https://www.ukrstat.gov.ua/	
GDP_in_UA_H_DATA[Mining]	GRAPH(TIME) Points: (2010.00, 71585.0), (2011.00, 96938.0), (2012.00, 90260.0), (2013.00, 88602.0), (2014.00, 86014.0), (2015.00, 111220.0), (2016.00, 144145.0), (2017.00, 190279.0), (2018.00, 226685.0), (2019.00, 232393.0), (2020.00, 204701.0), (2021.00, 369992.0), (2022.00, 258994.4)				
GDP_in_UA_H_DATA[MANUFACTURING]	GRAPH(TIME) Points: (2010.00, 247942.0), (2011.00, 294824.0), (2012.00, 318064.0), (2013.00, 290024.0), (2014.00, 327651.0), (2015.00, 438702.0), (2016.00, 546930.0), (2017.00, 691861.0), (2018.00, 789727.0), (2019.00, 822705.0), (2020.00, 874436.0), (2021.00, 1119575.0), (2022.00, 783702.5)				
Import_in_UA_H_DATA[AGR]	GRAPH(TIME) Points: (2010.00, 13935.0), (2011.00, 16242.0), (2012.00, 24456.0), (2013.00, 27180.0), (2014.00, 31974.0), (2015.00, 34760.0),		mln UA H per year	Sources: https://www.ukrstat.gov.ua/	

	(2016.00, 45623.0), (2017.00, 47796.0), (2018.00, 53431.0), (2019.00, 58407.0), (2020.00, 63314.0), (2021.00, 69072.0), (2022.00, 55258.0)				
Import_in_UAH_DATA[MINING]	GRAPH(TIME) Points: (2010.00, 135009.0), (2011.00, 188842.0), (2012.00, 159373.0), (2013.00, 131863.0), (2014.00, 113870.0), (2015.00, 170361.0), (2016.00, 130873.0), (2017.00, 209050.0), (2018.00, 222175.0), (2019.00, 181811.0), (2020.00, 121812.0), (2021.00, 220787.0), (2022.00, 176630.0)				
Import_in_UAH_DATA[MANUFACTURING]	GRAPH(TIME) Points: (2010.00, 344426.0), (2011.00, 493349.0), (2012.00, 524044.0), (2013.00, 511309.0), (2014.00, 562760.0), (2015.00, 702646.0), (2016.00, 938308.0), (2017.00, 1146265.0), (2018.00, 1351072.0), (2019.00, 1413718.0), (2020.00, 1280245.0), (2021.00, 1690396.0), (2022.00, 1352317.0)				
Import_Price_growth_rate	Import_Price_Index/DELAY(Import_Price_Index, 1)		dmnl	This indicator reflects the dynamics of changes in import prices.	
Import_Price_Index	GRAPH(TIME) Points: (2010.00, 118.1), (2011.00, 120.6), (2012.00, 110.2), (2013.00, 101.3), (2014.00, 98.3), (2015.00, 89.8), (2016.00, 96.4), (2017.00, 114.0), (2018.00, 112.3), (2019.00, 100.2), (2020.00, 99.6), (2021.00, 124.6), (2022.00, 125.1), (2023.00, 123.0), (2024.00, 122.0),		dmnl	The export price index is based on the Paasche Price Index, which shows the change in the price of import goods and services according to	

	(2025.00, 115.0), (2026.00, 110.0), (2027.00, 105.0), (2028.00, 106.0), (2029.00, 110.0), (2030.00, 105.0)			the base year. Sources: https://www.ukrstat.gov.ua/	
Index_Price_adj_time	0.9		year	The time required to reach the indicated price.	
indicated_price	Price_Index*Average_CP_Inflation*Average_DP_inflation		per year	The indicated price is based on the impact of two types of inflation and is calculated as the cumulative impact of these indicators.	
labor[AGR]	GRAPH(TIME) Points: (2010.00, 3115.6), (2011.00, 3410.3), (2012.00, 3308.5), (2013.00, 3389), (2014.00, 3091.4), (2015.00, 2870.6), (2016.00, 2866.5), (2017.00, 2860.7), (2018.00, 2937.6), (2019.00, 3010.4), (2020.00, 2721.2), (2021.00, 2692.7), (2022.00, 2300), (2023.00, 1100), (2024.00, 1000), (2025.00, 1000), (2026.00, 1300), (2027.00, 1500), (2028.00, 1500), (2029.00, 1600), (2030.00, 1900)		person	The number of the working population in three main industries.	
labor[MINING]	GRAPH(TIME) Points: (2010.00, 784.7), (2011.00, 800.2), (2012.00, 414.3), (2013.00, 423), (2014.00, 382.2), (2015.00, 344.7), (2016.00, 345.8), (2017.00, 344.6), (2018.00, 355.2), (2019.00, 372.1), (2020.00, 363.4), (2021.00, 364.5), (2022.00, 310), (2023.00, 270), (2024.00, 240), (2025.00, 220), (2026.00, 250), (2027.00, 250), (2028.00, 260), (2029.00, 260), (2030.00, 290)				
labor[MANU]	GRAPH(TIME) Points:				

FACTURING]	(2010.00, 3461.5), (2011.00, 3352.7), (2012.00, 3236.7), (2013.00, 3170), (2014.00, 2898.2), (2015.00, 2573.9), (2016.00, 2494.8), (2017.00, 2440.6), (2018.00, 2426), (2019.00, 2461.5), (2020.00, 2358.6), (2021.00, 2313.2), (2022.00, 2000), (2023.00, 1400), (2024.00, 600), (2025.00, 900), (2026.00, 900), (2027.00, 700), (2028.00, 700), (2029.00, 1100), (2030.00, 1500)				
labor_productivity[Industries]	$(\text{ordinary_labor_productivity} + \text{ordinary_labor_productivity} * \text{reinvestment_in_technology}) * (1 - \text{policy_status_3}) + (\text{ordinary_labor_productivity} + \text{ordinary_labor_productivity} * \text{policy_reinvestment_in_technology}) * \text{policy_status_3}$		mln UA H/ye ar/pe rson	Labor productivity is adjusted for fraction of reinvestment.	
Net_Export[Industries]	(Exports- Real_Imports_in_UAH)		mln UA H	Net exports are the difference between exports and imports to reflect foreign demand for domestically produced goods.	
Nominal_AD[Industries]	Domestic_demand+Net_Export		mln UA H	Aggregate demand for goods, which according to economic theory consists of Consumption, Government purchase, Investment and Net Export.	
Official_ER_DATA	GRAPH(TIME) Points: (2010.00, 7.9768), (2011.00, 8.0522), (2012.00, 8.0653), (2013.00, 8.2913), (2014.00,		UA H/U SD	Sources: https://www.ukrstat.gov.ua/	

	16.38), (2015.00, 24.15), (2016.00, 27.2), (2017.00, 28.11), (2018.00, 27.76), (2019.00, 23.79), (2020.00, 28.33), (2021.00, 27.33), (2022.00, 36.9343), (2023.00, NaN), (2024.00, NaN), (2025.00, NaN), (2026.00, NaN), (2027.00, NaN), (2028.00, NaN), (2029.00, NaN), (2030.00, NaN)				
Official_ER_growth_rate	Official_ER/DELAY(Official_ER, 1)		dmn l	The rate of growth of the exchange rate shows the dynamics of the change in the official exchange rate.	
ordinary_labor_productivity [AGR]	GRAPH(TIME) Points: (2010.00, 29.3550199), (2011.00, 30.6370322), (2012.00, 27.94750913), (2013.00, 28.0586941), (2014.00, 36.99659659), (2015.00, 66.22778781), (2016.00, 96.33165543), (2017.00, 117.4286061), (2018.00, 137.2529862), (2019.00, 110), (2020.00, 160), (2021.00, 230), (2022.00, 100), (2023.00, 100), (2024.00, 140), (2025.00, 140), (2026.00, 160), (2027.00, 140), (2028.00, 160), (2029.00, 140), (2030.00, 150)		mln UA H/year/ person	The labor productivity of one worker per year.	
ordinary_labor_productivity [MINING]	GRAPH(TIME) Points: (2010.00, 103.5289495), (2011.00, 112.4537524), (2012.00, 171.8687747), (2013.00, 137.0661133), (2014.00, 136.2616071), (2015.00, 221.5061105), (2016.00, 376.742437), (2017.00, 581.8124916), (2018.00, 706.7690006), (2019.00, 738.3701532), (2020.00, 737.9556384), (2021.00, 1258.84231), (2022.00, 670), (2023.00, 460),				

	(2024.00, 430), (2025.00, 570), (2026.00, 700), (2027.00, 640), (2028.00, 700), (2029.00, 710), (2030.00, 720)				
ordinary_labor_productivity [MANUFACTURING]	GRAPH(TIME) Points: (2010.00, 65.60614944), (2011.00, 91.33591962), (2012.00, 81.15815483), (2013.00, 76.82664854), (2014.00, 92.94693021), (2015.00, 162.9420552), (2016.00, 283.2858842), (2017.00, 429.9656908), (2018.00, 524.6307102), (2019.00, 560.5464086), (2020.00, 571.3930341), (2021.00, 706.2310683), (2022.00, 400), (2023.00, 280), (2024.00, 370), (2025.00, 370), (2026.00, 520), (2027.00, 670), (2028.00, 760), (2029.00, 800), (2030.00, 860)				
policy_effect_of_international_investment	GRAPH(TIME) Points: (2023.000, 0.300), (2023.700, 0.300), (2024.400, 0.350), (2025.100, 0.350), (2025.800, 0.298), (2026.500, 0.246), (2027.200, 0.250), (2027.900, 0.250), (2028.600, 0.200), (2029.300, 0.200), (2030.000, 0.150)		dmn l	According to the basic scenario, in the first months of the post-war period, it is necessary to raise the rate, and then gradually adjust it with a downward trend.	
Policy_Expected_value_of_ER	GRAPH(TIME) Points: (2010.00, 0.978), (2011.00, 0.978), (2012.00, 1.000), (2013.00, 1.166), (2014.00, 1.227), (2015.00, 1.238), (2016.00, 1.210), (2017.00, 1.144), (2018.00, 1.028), (2019.00, 0.934), (2020.00, 1.133), (2021.00, 0.950), (2022.00, 1.088), (2023.00, 1.110), (2024.00, 1.077), (2025.00, 1.177), (2026.00, 1.166), (2027.00, 1.144), (2028.00, 1.116), (2029.00,		dmn l	Future expectations of the population depend on many factors. According to the base scenario, expectations are expected to improve due to the end of the war, the attraction of	

	1.110), (2030.00, 1.122)			infections, and the return of the workforce.	
policy_reinvestment_in_technology	0.2		dmn 1	The future policy envisages an increase in the investments involved to increase the production capacity of enterprises of the industries.	
policy_start_time	2022		year	Year of introduction of the policy. By default, the start of the policy is 2022. However, other years of policy implementation are also possible.	
policy_status_1	IF(policy_switch_1=1)AND(policy_start_time<TIME)THEN(1)ELSE(0)		dmn 1	To activate the status of the policy, it is necessary that two conditions be fulfilled - the inclusion of the policy switch and the determination of the time period of the policy's application.	
policy_status_2	IF(policy_switch_2=1)AND(policy_start_time<TIME)THEN(1)ELSE(0)		dmn 1	To activate the status of the policy, it is necessary that two conditions be fulfilled - the inclusion of the policy switch and the	

				determination of the time period of the policy's application.	
policy_status_3	IF(policy_switch_3=1)AND(policy_start_time<TIME)THEN(1)ELSE(0)		dmn 1	To activate the status of the policy, it is necessary that two conditions be fulfilled - the inclusion of the policy switch and the determination of the time period of the policy's application.	
policy_switch_1	0		dmn 1	The value of the policy switch can only be 0 or 1, where 0 - the policy is not implemented, and 1 - the policy is applied.	
policy_switch_2	0		dmn 1	The value of the policy switch can only be 0 or 1, where 0 - the policy is not implemented, and 1 - the policy is applied.	
policy_switch_3	0		dmn 1	The value of the policy switch can only be 0 or 1, where 0 - the policy is not implemented, and 1 - the policy is	

				applied.	
price_elasticity_of_Imports	-0.1		dmn l	The price elasticity of imports reflects the impact of price changes on imports. The relationship is inverse, meaning that an increase in price reduces imports by 10%.	
Producer_Price_Index	GRAPH(TIME) Points: (2010.00, 1.187), (2011.00, 1.142), (2012.00, 1.003), (2013.00, 1.017), (2014.00, 1.318), (2015.00, 1.254), (2016.00, 1.357), (2017.00, 1.165), (2018.00, 1.142), (2019.00, 0.926), (2020.00, 1.145), (2021.00, 1.622), (2022.00, 1.800), (2023.00, 1.700), (2024.00, 1.650), (2025.00, 1.500), (2026.00, 1.600), (2027.00, 1.400), (2028.00, 1.300), (2029.00, 1.200), (2030.00, 1.210)		dmn l	The producer price index reflects the level of changes in the prices of raw materials, materials and intermediate consumption goods, which affect the cost of goods produced by national manufacturers. Sources: https://www.ukrstat.gov.ua/	
Real_GDP[Industries]	Nominal_GDP/Deflator_GDP		mln UA H/ye ar	Real GDP is calculated by dividing nominal GDP by the deflator.	
Real_GDP_DATA[AGR]	GRAPH(TIME) Points: (2010.00, 78294.49541), (2011.00, 103508.1081), (2012.00, 109352.2833), (2013.00, 131375.7225), (2014.00, 135677.8414), (2015.00, 160033.419), (2016.00, 263061.0757), (2017.00, 282684.6361),		mln UA H per year	Sources: https://www.ukrstat.gov.ua/	

	(2018.00, 339775.4545), (2019.00, 376389.5706), (2020.00, 333042.1394), (2021.00, 476738.3677), (2022.00, 435759.761), (2023.00, 435759.761), (2024.00, 435759.761), (2025.00, 435759.761), (2026.00, 435759.761), (2027.00, 435759.761), (2028.00, 435759.761), (2029.00, 435759.761), (2030.00, 435759.761)				
Real_GDP_D ATA[MININ G]	GRAPH(TIME) Points: (2010.00, 60358.34739), (2011.00, 79197.71242), (2012.00, 94020.83333), (2013.00, 86272.63875), (2014.00, 74729.80017), (2015.00, 79670.48711), (2016.00, 103701.4388), (2017.00, 132691.0739), (2018.00, 192105.9322), (2019.00, 219860.9272), (2020.00, 228460.9375), (2021.00, 206123.6769), (2022.00, 208530.1127), (2023.00, 208530.1127), (2024.00, 208530.1127), (2025.00, 208530.1127), (2026.00, 208530.1127), (2027.00, 208530.1127), (2028.00, 208530.1127), (2029.00, 208530.1127), (2030.00, 208530.1127)				
Real_GDP_D ATA[MANU FACTURING]	GRAPH(TIME) Points: (2010.00, 240253.876), (2011.00, 281052.4309), (2012.00, 276337.0982), (2013.00, 275165.0854), (2014.00, 254585.0816), (2015.00, 304865.8791), (2016.00, 460378.7879), (2017.00, 587318.3362), (2018.00, 698255.5261), (2019.00, 794116.7954), (2020.00, 828849.2891), (2021.00, 868560.8999), (2022.00, 636122.1591), (2023.00, 636122.1591),				

	(2024.00, 636122.1591), (2025.00, 636122.1591), (2026.00, 636122.1591), (2027.00, 636122.1591), (2028.00, 636122.1591), (2029.00, 636122.1591), (2030.00, 636122.1591)				
Real_Import_DATA[AGR]	GRAPH(TIME) Points: (2010.00, 12784.40367), (2011.00, 14632.43243), (2012.00, 22792.17148), (2013.00, 26184.9711), (2014.00, 26143.90842), (2015.00, 22339.33162), (2016.00, 41588.87876), (2017.00, 42943.39623), (2018.00, 48573.63636), (2019.00, 59720.8589), (2020.00, 51307.94165), (2021.00, 52686.49886), (2022.00, 55037.84861), (2023.00, 55037.84861), (2024.00, 55037.84861), (2025.00, 55037.84861), (2026.00, 55037.84861), (2027.00, 55037.84861), (2028.00, 55037.84861), (2029.00, 55037.84861), (2030.00, 55037.84861)		mln UA H	Sources: https://www.ukrstat.gov.ua/	
Real_Import_DATA[MINING]	GRAPH(TIME) Points: (2010.00, 113835.5818), (2011.00, 154282.6797), (2012.00, 166013.5417), (2013.00, 128396.2999), (2014.00, 98931.36403), (2015.00, 122035.1003), (2016.00, 94153.23741), (2017.00, 145781.0321), (2018.00, 188283.8983), (2019.00, 172006.6225), (2020.00, 135950.8929), (2021.00, 123001.1142), (2022.00, 142214.1707), (2023.00, 142214.1707), (2024.00, 142214.1707), (2025.00, 142214.1707), (2026.00, 142214.1707), (2027.00, 142214.1707), (2028.00, 142214.1707), (2029.00, 142214.1707),				

	(2030.00, 142214.1707)			
Real_Import_DATA[MANUFACTURING]	GRAPH(TIME) Points: (2010.00, 333746.124), (2011.00, 470304.0991), (2012.00, 455294.5265), (2013.00, 485112.9032), (2014.00, 437264.9573), (2015.00, 488287.6998), (2016.00, 789821.5488), (2017.00, 973060.2716), (2018.00, 1194581.786), (2019.00, 1364592.664), (2020.00, 1213502.37), (2021.00, 1311401.086), (2022.00, 1097659.903), (2023.00, 1097659.903), (2024.00, 1097659.903), (2025.00, 1097659.903), (2026.00, 1097659.903), (2027.00, 1097659.903), (2028.00, 1097659.903), (2029.00, 1097659.903), (2030.00, 1097659.903)			
Real_Imports_growth_rate[Industries]	TREND(Real_Imports_in_USD, 1)		per year	
Real_Imports_in_USD[Industries]	Real_Imports_in_UAH/Official_ER		mln USD/year	Volumes of real imports expressed in foreign currency.
reinvestment_in_technology	0.05		dmnl	The share of reinvested profit in the development and technology of domestic production.
Relative_Price_Index	$((CPI_UKR/INIT(CPI_UKR))/(CPI_WORLD/INIT(CPI_WORLD)))/(Official_ER_growth_rate)$		dmnl	Relative price shows how much price growth in one country is higher or lower than in another. Or how price growth in Ukraine differs

				from price changes in the world.	
TOT	Export_Price_Index/Import_Price_Index		dmnl	The terms of trade reflect the ratio of export prices to import prices, measuring the change between inflows and outflows of foreign currency.	
Total_Real_Imports_in_UAH	Real_Imports_in_UAH[AGR]+Real_Imports_in_UAH[MINING]+Real_Imports_in_UAH[MANUFACTURING]		mln UAH	The total indicator of the real volume of imports in the national currency for all sectors, which is necessary to determine the initial value of the demand for the foreign currency.	
Total_Real_Imports_in_USD_DATA	Real_Imports_in_USD[AGR]+Real_Imports_in_USD[MINING]+Real_Imports_in_USD[MANUFACTURING]		mln USD/year	Cumulative volume of imports in foreign currency by all industries.	

Run Specs	
Start Time	2010
Stop Time	2030
DT	1/4
Fractional DT	True
Save Interval	0.25
Sim Duration	1.5
Time Units	Year

Pause Interval	0
Integration Method	Euler
Keep all variable results	True
Run By	Run
Calculate loop dominance information	True
Exhaustive Search Threshold	1000

Array Dimension	Indexed by	Elements
Industries	Label (3)	AGR MINING MANUFACTURING

Custom Unit	Aliases	Equation
US Dollars	USD \$	
kilowatt hours per day		kWh/day
kilowatts	kilowatt	kW
Per Year		1/year

APPENDIXES

APPENDIX A

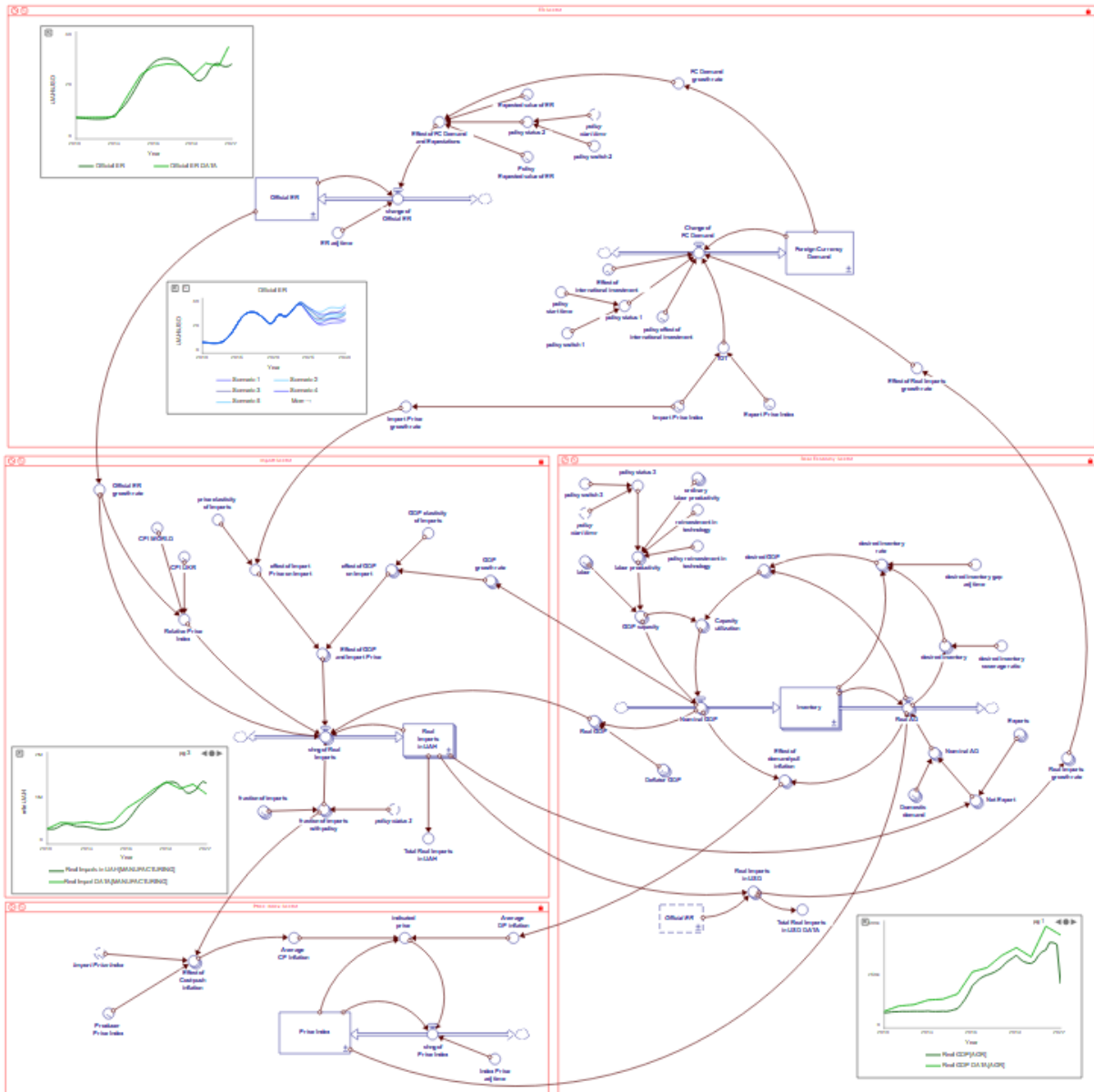


Figure A.1. All model sectors

APPENDIX B

Table B.1. Data for Export and Import by industry

		Mining	Manufacturing	AGR		Mining	Manufact.	AGR
2010	Export	29679	375131	33590	Import	135009	344426	13935
2011	Export	44585	487724	47180	Import	188842	493349	16242
2012	Export	39608	432171	77343	Import	159373	524044	24456
2013	Export	45354	384255	75524	Import	131863	511309	27180
2014	Export	57142	451705	110795	Import	113870	562760	31974
2015	Export	61155	567085	185799	Import	170361	702646	34760
2016	Export	63133	627559	216795	Import	130873	938308	45623
2017	Export	92705	770370	253619	Import	209050	1146265	47796
2018	Export	100230	870875	277789	Import	222175	1351072	53431
2019	Export	108259	806402	341439	Import	181811	1413718	58407
2020	Export	133761	811773	326801	Import	121812	1280245	63314
2021	Export	214132	1119275	449742	Import	220787	1690396	69072
2022	Export	149892.4	783492.5	314819.4	Import	176629.6	1352317	55257.6

Table B.2. Data for Net Export and GDP by industry

		Mining	Manufact.	AGR		Mining	Manufact.	AGR
2010	Net Export	-105330	30705	19655	GDP	71585	247942	85341
2011	Net Export	-144257	-5625	30938	GDP	96938	294824	114894
2012	Net Export	-119765	-91873	52887	GDP	90260	318064	117335
2013	Net Export	-86509	-127054	48344	GDP	88602	290024	136368
2014	Net Export	-56728	-111055	78821	GDP	86014	327651	165934
2015	Net Export	-109206	-135561	151039	GDP	111220	438702	249012
2016	Net Export	-67740	-310749	171172	GDP	144145	546930	288578
2017	Net Export	-116345	-375895	205823	GDP	190279	691861	314628
2018	Net Export	-121945	-480197	224358	GDP	226685	789727	373753
2019	Net Export	-73552	-607316	283032	GDP	232393	822705	368109
2020	Net Export	11949	-468472	263487	GDP	204701	874436	410974
2021	Net Export	-6655	-571121	380670	GDP	369992	1119575	625004
2022	Net Export	-26737.2	-568824	259561.8	GDP	258994.4	783702.5	437502.8