isolate the country from international trade. It is necessary to maintain dollarization at a natural level, at which benefits losses prevail from it [9]. In Ukraine this level should be in the range of 20–30% as a medium-term benchmark of the regulator's economic policy [2].

4.3. Modeling and analysis of financial dollarization phenomena

Financial dollarization, or the use of foreign currency for deposits and loans, is a significant issue for many economies, as it can lead to increased volatility and risks to financial stability. To better understand and analyze the drivers and consequences of dollarization, econometric models are often used. These models offer a systematic approach to understanding the drivers and consequences of dollarization by quantifying the relationships between various economic variables. Econometric models can simulate different scenarios to evaluate the effectiveness of potential policy interventions aimed at reducing dollarization levels, such as changes in monetary policy or regulatory adjustments. So, by leveraging such econometric models, policymakers, researchers, and financial analysts can gain deeper insights into the phenomenon of dollarization, devise strategies to manage its effects, and make informed decisions to enhance economic stability and performance.

However, due to the interdependence of variables such as deposit and loan dollarization, using separate econometric equations can lead to biased and inconsistent estimates. Therefore, a system of simultaneous equations is more appropriate for analyzing the dynamics of dollarization, as it accounts for the feedback effects and interrelatedness of the variables. To fully understand and estimate the complex interrelationships between the different variables affecting financial dollarization, it is important to utilize the system of simultaneous equations, which is better suited to capture the interdependent nature of the economic system and provide a more accurate and comprehensive analysis of the issue.

A system of simultaneous equations is a powerful tool in econometrics that allows for the analysis of complex economic relationships between multiple variables. One of the key benefits of this approach is that it can provide a more accurate estimation of the relationships between variables, which can lead to more accurate forecasts. Additionally, a system of simultaneous equations can provide insights into the dynamic interactions between variables, which can help policymakers make more informed decisions. Furthermore, this approach can be used to test the robustness of economic theories and models, which can lead to a better understanding of economic behavior. Overall, a system of simultaneous equations can provide valuable insights into an economy functioning and can help policymakers make better decisions.

Such a system consists of linear regressions, where the dependent variable of one multifactorial regression becomes an independent variable in another regression. Such a systematic view allows to analyze how both direct and indirect effects influence the system and its outputs. The systematic approach is widely applicable for the analysis of macroeconomic indicators and specifically the effects on monetary transmission mechanism and provides a framework for policymakers to conduct scenario analysis.

The relationship between consumer price index, exchange rate, key policy rate, deposit dollarization, and loan dollarization has been the subject of much research and analysis in the field of macroeconomics. These variables were chosen because they are important indicators of the stability and health of a country's financial system. CPI is a measure of the average change in prices over time of goods and services consumed by households, and it reflects the level of inflation in an economy. The exchange rate, on the other hand, is the value of one currency in relation to another, and it can have a significant impact on a country's international trade and investment. The key policy rate is set by NBU to influence borrowing costs and money supply in an economy. Finally, DD and LD are important measures of the degree of dollarization in a country's financial system, which is a key indicator of financial stability. By analyzing the relationship between these variables using econometric tools, we can gain a better understanding of the factors that affect financial dollarization and how they interact with each other.

The objective of the empirical analysis was to estimate the effects of monetary policy and macroeconomic stability on the dollarization level in Ukraine [10].

Following the above mentioned, the system includes 5 linear regressions of main macroeconomic indicators and dollarization ratios. The dependent variables are the consumer price index (CPI), the exchange rate of UAH to USD on the FX market (ER_MARKET), policy rate of NBU (KEY_R), deposit dollarization as a part of FX deposits in total deposits of residents (DD), and loan dollarization as a part of FX loans in total loans (LD).

The basic underlying assumptions are the following:

A. Dollarization of deposits is impacted by the difference between deposit rates denominated in different currencies, and the volume of enterprise lending, and by macroeconomic indicators, for example the exchange rate on the FX market and CPI. This assumption is set based on the theory analysis about what investors take into account when choosing between instruments in different currencies.

B. Loan dollarization is influenced by the level of deposit dollarization as a redistributive function of banks - converting banks' liabilities (deposits) into assets (loans), and is also influenced by the macroeconomic environment presented in the model as the exchange rate and CPI.

C. The policy rate is developed according to Taylor Rule, hence its level is determined by the CPI gap and the output gap, as well as by the neutral interest rate.

D. Taking into account that Ukraine is a small open economy with high dependence on its trading partners, CPI is influenced by the levels of CPI of the main trading partners and the exchange rate of gryvnia to dollar. Being an inflation-targeting country, CPI is determined by the monetary policy instrument – the policy rate of NBU.

E. The exchange rate of gryvnia to dollar on the FX market was chosen instead of the official rate as far as because, in times of different exchange rate regimes, the market level would present a more realistic situation on the market. The exchange rate is influenced by the central bank rate rate, debt to GDP rate and amount of international reserves.

The framework of the developed system and its logical relationships are presented as a causal-structure diagram in Figure 4.5.

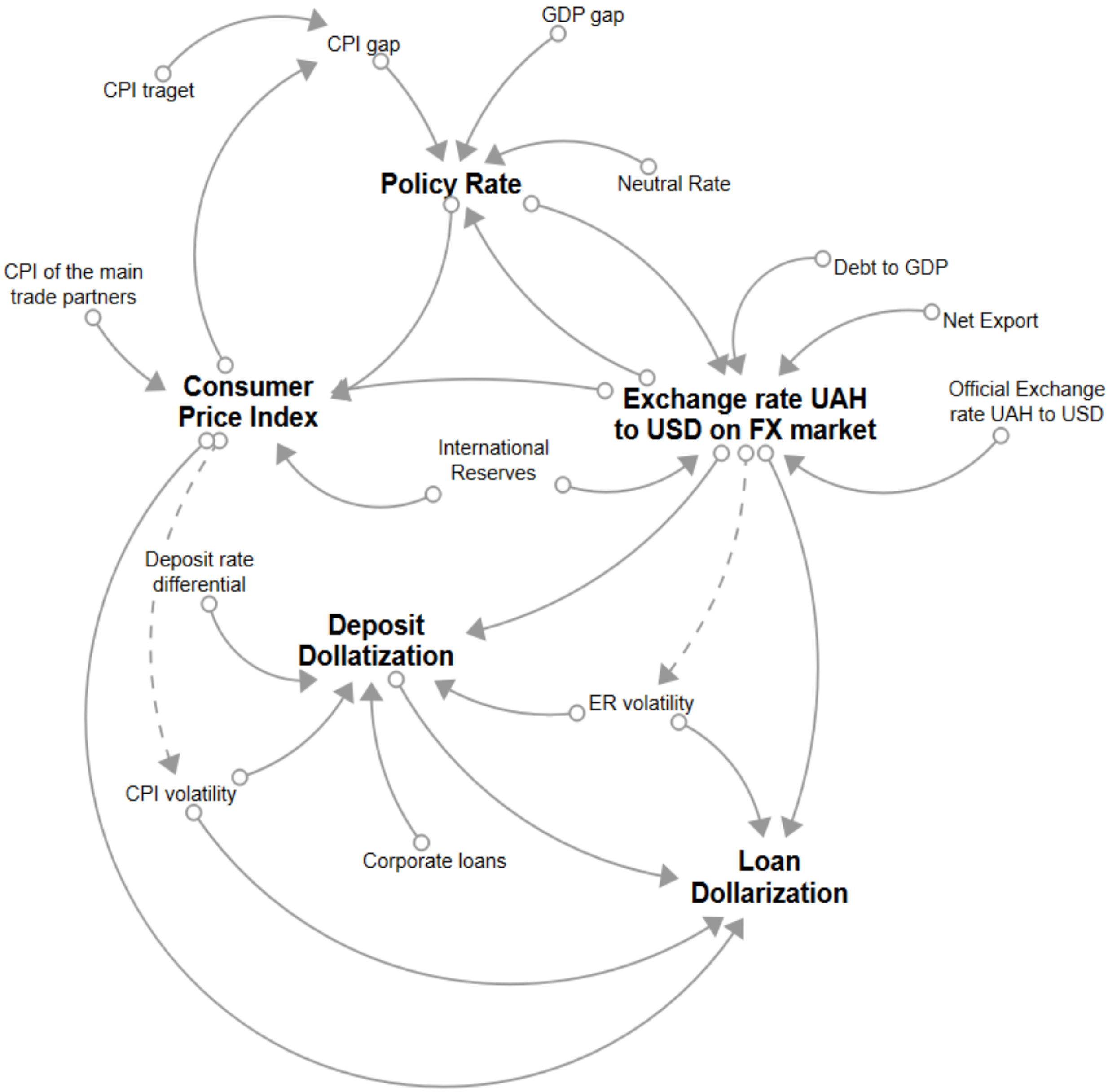

Figure 4.5. Causal diagram of the system of simultaneous equations, where a solid line depicts connections inside the system, while a dotted line presents the estimations outside the system

Source: developed by authors in Stella Architect Software

The general specification of the developed system can be presented as the following:

$CPI_t = f_1 (KEY\_R_{t-6}, ER\_MARKET_{t-3}, PCPI_{t-1}, CPI_{t-4}, INR\_RESERV_{t-7})$

$ER\_MARKET_t = f_2 (KEY\_R_{t-1}, ER\_MARKET_{t-1}, ER\_OFF_{t-1}, INR\_RESERV_{t-6}, DEBT\_TO\_GDP_t, NX_t)$

$KEY\_R_t = f_3 (KEY\_R_{t-1}, GDP\_GAP_{t-1}, CPI_t - CPI\_TARGET_t, ER\_MARKET_{t-1}, NR_{t-2})$

$DD_t = f_4 (DD_{t-1}, ER\_MARKET_t, ER\_MARKET\_VOL_{t-3}, CPI\_VOL_{t-4}, CREDIT\_TO\_BUSINESS_t, DEPOSIT\_RATE\_DIFFERENTIAL_{t-4})$

$LD_t = f_5 (LD_{t-1}, DD_t, ER\_MARKET_t, ER\_MARKET\_VOL_t, CPI\_VOL_{t-2}, CPI_{t-1})$ (4.1)

where t – time period, CPI – consumer price index to December previous year, %; ER_MARKET – exchange rate of UAH to USD on the FX market, UAH/ USD; KEY_R – policy rate of NBU, %; DD – a fraction of deposits of residents in foreign currency; LD – a fraction of loans to residents in foreign currency; PCPI – weighted on volumes of trade CPI of main trading partners; ER_OFF – official exchange rate of UAH to USD, UAH/USD; NX – net export, million USD; INR_RESERV – international reserves, million US dollars; DEBT_TO_GDP – the ratio of debt to real GDP; GDP_GAP – GDP gap, calculated using Kalman filter; CPI_TARGET – inflation target, %; NR – neutral real interest rate, %; CREDIT_TO_BUSINESS – loans to the corporate sector, million UAH; DEPOSIT_RATE_DIFFERENTIAL – spread between deposit rates in UAH and USD, %; ER_MARKET_VOL – volatility of exchange rate of UAH to USD; CPI_VOL – volatility of consumer price index.

Specification of CPI equation:

The main goal of NBU is to keep inflation controlled, stable, and on the targeted level. Since the beginning of the inflation-targeting policy, the key policy rate was the main instrument to stabilize inflation. The effect of the policy rate change is realized through several monetary transmission channels. The policy rate determines the value of money and affects the real sector, hence inflation. Though it takes time for the economy to respond to the changes, and NBU assumes that the average delay time fluctuates from 6 to 18 months. The lagged effect of the previous CPI of a year ago can be explained by the seasonal effect, typically, the Ukrainian economy is highly season-dependent, and producers' behavior patterns from year to year may be repetitive. The exchange rate with a lag of 3 quarters determines the effect of exchange rate fluctuations passthrough on the internal prices. Being one of the biggest agriculture producers in the world, Ukraine is very subject to fluctuations in prices on the external market, that's why it seems important to include weighted CPI of countries main trade partners: China, Poland, Turkey, Spain, Italy, Netherlands, Egypt, India, Germany, Romania, the USA, Slovakia, Hungary, Austria, and Czech Republic. Also, the volatility of raw materials and energy materials prices in the EU highly affects the situation on the global market and prices in Ukraine as well, as Ukraine imports a big fraction of fuel from Europe. International reserves are included to implement the effect of exchange rate volatility passthrough on the internal prices. According to the above-mentioned, the specification of the consumer price index is the following:

$$CPI_t = \alpha_0 + \alpha_1 * D(KEY\_R_{t-6}) + \alpha_2 * D(LOG(ER\_MARKET_{t-3}) + \\ + \alpha_3 * PCPI_{t-1} + \alpha_4 * CPI_{t-4} + \alpha_5 * LOG(INR\_RESERV_{t-7}) \quad (4.2)$$

where CPI_t – consumer price index to December of the previous year, %; ER_MARKET_t – exchange rate of UAH to USD on the FX market, UAH/USD; KEY_R_t – key policy rate of NBU, %; $PCPI_t$ – weighted on volumes of trade CPI of main trading partners; INR_RESERV_t – international reserves, million US dollars.

Specification of exchange rate equation:

The exchange rate is one of the most important variables to determine both inflation and the level of dollarization. In the quarterly projection model (QPM) which is a semi-structural model that NBU uses for its analysis, monetary policy operates through two main transmission channels: the interest rate channel and the exchange rate [11]. In the initial phase, an increase in interest rates causes the local currency to appreciate due to uncovered interest parity. The economy's openness causes the influence of the exchange rate on the consumer prices in Ukraine vis the mechanism of imported inflation, and they also affect economic activity by influencing demand for foreign goods, which in turn affects inflation [11]. Moreover, the effect of key policy rate change is asymmetrical, meaning that large changes have more effect than small changes. To catch this difference DUMMY1 is introduced in the model, DUMMY1 is a binary variable that represents the volume of change in the policy rate, where 1 is set when the absolute change of policy rate is bigger than the average absolute change in the time series, and 0 is set when it is smaller. International reserves play a crucial role in maintaining exchange rate stability during economic shocks that may arise from periods of crisis. When the exchange rate is fixed, the central bank of Ukraine makes interventions in the foreign exchange market to maintain the stability of the exchange rate. On the other hand, during a floating exchange rate regime, central bank rate changes have a bigger influence on the exchange rate. A rise in the central bank rate causes an appreciation of the currency, while a decrease causes a depreciation. With the history of switching between floating and fixed regimes, the official exchange rate is introduced to represent the limitations of the NBU on the FX market. Net export is included in the specification to reflect the effect of the trade balance on the exchange rate. Additionally, the debt to GDP ratio reflects the impact of changes in external liabilities, as well as the demand and supply of foreign currency, and therefore, affect the exchange rate. According to the above-mentioned, the specification of the exchange rate equation is the following:

$$LOG(ER\_MARKET_t) = \alpha_0 + \alpha_1 * D(KEY\_R_{t-1}) * DUMMY1_t + \\ + \alpha_2 * D(KEY\_R_{t-1}) * (1-DUMMY1_t) + \alpha_3 * LOG(ER\_OFF_{t-1}) + \\ + \alpha_4 * LOG(INR\_RESERV_{t-6}) + \alpha_5 * LOG(DEBT\_TO\_GDP_t) + \alpha_6 * \\ D(NX_t) \quad (4.3)$$

where ER_MARKET_t – exchange rate of UAH to USD on the FX market, UAH/USD; KEY_R_t – policy rate of NBU, %; INR_RESERV_t – international reserves, million US dollars; $DEBT\_TO\_GDP_t$ – the ratio of debt to real GDP; $DUMMY1_t$ – dummy-variable of the volume of change of policy rate; ER_OFF_t – official exchange rate of UAH to USD, UAH/USD; NX_t – net export, million USD.

Specification of policy rate equation:

The key policy rate is the main tool for the inflation-targeting policy of NBU. The most famous rule of monetary policy is the Taylor rule. It has been modified and applied to national models of many central banks, depending on its needs and purposes, and also taking into account specific features of individual economies. To capture the conservative behavior of a central bank, the policy rate in QPM and its monetary policy rule specification considers its lagged value, which represents persistence in the reaction function. Incorporating both the GDP gap and CPI gap in the model demonstrates the balance or trade-off between stabilizing output and managing inflation, highlighting the flexible nature of the inflation targeting framework [11].

Over the long run, after all, shocks have dissipated, the central bank rate reaches its neutral level which indicates an equilibrium value for the interest rate and short-term dynamics, signifying a state of neither being accommodative nor restrictive in monetary policy [11]. The exchange rate is considered through the indirect impact – it impacts inflation, which in turn can influence the central bank's monetary policy decisions. DUMMY2 is introduced in the model, DUMMY2 is a binary variable that represents the volume of change in the exchange rate, where 1 is set when the absolute change of exchange rate is bigger than the average absolute change in the time series, and 0 is set when it is smaller. According to the above-mentioned, the specification of the policy rate equation is the following:

$$KEY\_R_t = \alpha_0 + \alpha_1 * KEY\_R_{t-1} + \alpha_2 * D(GDP\_GAP_{t-1}) + \quad (4.4)$$
$$+ \alpha_3 * (CPI_t - CPI\_TARGET_t) + \alpha_4 * D(ER\_MARKET_{t-1}) * DUMMY2_t$$
$$+ + \alpha_5 * D(ER\_MARKET_{t-1}) * (1-DUMMY2_t) + \alpha_6 * D(NR_{t-2})$$

where KEY_R_t – policy rate of NBU, %; CPI_t – consumer price index to December previous year, %; ER_MARKET_t – exchange rate of UAH to USD on the FX market, UAH/USD; GDP_GAP_t – GDP gap, calculated using Kalman filter; CPI_TARGET_t – inflation target, %; NR_t – neutral real interest rate, %; $DUMMY2_t$ – dummy-variable of the volume of change of exchange rate.

Specification of deposit dollarization equation:

Based on the analyzed literature, deposit dollarization is mostly seen as a response to high uncertainty about the macroeconomic situation in the nearest future. The equation includes a lagged deposit dollarization ratio to account for persistence effects. The exchange rate is considered in the model as it falls under the MVP framework: depreciation of the national currency may increase the incentive for deposit dollarization as individuals and businesses seek to protect the value of their savings from currency fluctuations and invest in a more stable currency. The same incentive applies to inflation: if people experience a relatively low level of inflation, the credibility of the central bank rises as economic agents assume that the central bank keeps inflation under control, and hence their expectations about future inflation become anchored to the central bank's target and forecast. Having stable, moderate inflation, the demand for investing in national currency instruments increases. However, there is evidence from research that in the short term, it is rather inflation volatility that is perceived by households and business entities rather than inflation itself [12]. During crisis years it becomes more difficult for the central bank to manage inflation, hence economic agents expect bigger inflation deviations and higher depreciation rates. Consequently, inflation volatility and exchange rate volatility have been introduced in the model estimated using the GARCH methodology. The volume of corporate lending is used in the equation as the proxy for the demand for funding in banks. With the increase in demand for corporate lending, banks would try to engage more funding, e.g. they would rise interest rates. Taking into account that the business sector actively engages in trading with foreign companies and customers, they would need funds in foreign currency to conduct their business operations. Volatilities are presented as lagged values because it takes time for the economic agents to perceive the fluctuations in these indicators. The interest rate differential determines the spread between the yield on hryvnia and FX deposits. With the increase of the spread, hryvnia instruments would seem more attractive for investors than FX instruments. According to the above-mentioned, the specification of the deposit dollarization equation is the following:

where DD_t – a fraction of deposits of residents in foreign currency; ER_MARKET_t – exchange rate of UAH to USD on the FX market, UAH/USD; $CREDIT\_TO\_BUSINESS_t$ – loans to the corporate sector, million UAH; $DEPOSIT\_RATE\_DIFFERENTIAL_t$ – spread between deposit rates in UAH and USD, %; $ER\_MARKET\_VOL_t$ – volatility of exchange rate of UAH to USD; CPI_VOL_t – volatility of consumer price index.

Specification of loan dollarization equation:

There is an important empirical evidence that a positive correlation between deposit and loan dollarization remains. As deposits are an important lending source, it affects banks' decisions and capacities to provide loans in foreign currency. Moreover, with expected depreciation, banks may receive FX gains from the revaluation of loans denominated in foreign currency, basically shifting currency risk to their borrowers. However, depreciation also increases credit risk, hence, banks have to find an optimal balance for FX lending. Considering currency risk, LD would greatly depend both on the exchange rate and its volatility. When inflation increases, it leads to a decrease in the purchasing power of the domestic currency. This, in turn, increases the cost of borrowing in domestic currency for businesses. As a result, businesses may decide to borrow in foreign currency as it may provide lower borrowing costs due to lower interest rates in foreign currency. However, borrowing in foreign currency also carries the risk of exchange rate fluctuations, which can lead to an increase in the cost of borrowing in domestic currency if the domestic currency depreciates against the foreign currency. Therefore, the decision to borrow in foreign currency is influenced by a trade-off between the potential cost savings from lower interest rates and the risk of exchange rate fluctuations. According to the above-mentioned, the specification of the loan dollarization equation is the following:

$$LD_t = \alpha_0 + \alpha_1 * LD_{t-1} + \alpha_2 * DD_t + \alpha_3 * DLOG(ER\_MARKET_t) + \quad (4.6)$$
$$+ \alpha_4 * ER\_MARKET\_VOL_t + \alpha_5 * CPI_{t-1} + \alpha_6 * CPI\_VOL_{t-2}$$

where , LD_t – a fraction of loans to residents in foreign currency; DD_t – a fraction of deposits of residents in foreign currency; CPI_t – consumer price index to December previous year, %; ER_MARKET_t – exchange rate of UAH to USD on the

FX market, UAH/USD; *ER_MARKET_VOL*$_t$ – volatility of exchange rate of UAH to USD; *CPI_VOL*$_t$ – volatility of consumer price index.

To make a conclusion, the model involves 5 equations of main macroeconomic and financial variables: consumer price index, exchange rate, key policy rate, and deposit and loan dollarization, they are endogenous variables. Among the exogenous variables are CPI of the main trading partners, official exchange rate, international reserves, debt to GDP ratio, net export, GDP gap, inflation target, neutral interest rate, volatilities of CPI and exchange rate, lending to business, deposit rate differential. Determined (lagged) variables in the system are key policy rate, exchange rate, CPI, international reserves, and deposit and loan dollarization ratios. This model gives the possibility to include the transmission of macroeconomic variables and monetary instruments' effects on financial dollarization. Specifications of the equations of the system, determination and Durbin-Watson coefficients are presented in table 4.2.

Table 4.2. System's equations specification

№	Specification of the system's equations	Determination coefficient
1	Consumer price index equation, %	
	CPI = 36.74 - 0.82*D(KEY_R(-6)) + 95.66*D(LOG(ER_MARKET(-3))) + 2.17*PCPI(-1) + 0.16*CPI(-4) - 4.3*LOG(INR_RESERV(-7))	90,33% DW=2.15
2	Exchange rate equation, UAH/USD	
	LOG(ER_MARKET) = -0.09 - 0.015*D(KEY_R(-1))*DUMMY1 - 0.005*D(KEY_R(-1))*(1-DUMMY1) + 0.073*LOG(INR_RESERV(-6)) + 0.162*LOG(DEBT_TO_GDP) + 0.762*LOG(ER_OFF(-1)) - 9.212e-06*D(NX)	85,69% DW=2.14
3	Key policy rate equation, %	
	KEY_R = 2.26 + 0.76*KEY_R(-1) - 4.76*D(GDP_GAP(-1)) + 0.14*(CPI-CPI_TARGET) + 3.19*(D(ER_MARKET(-1)))*DUMMY2 + 1.06*(D(ER_MARKET(-1)))*(1-DUMMY2) - 1.09*D(NR(-2))	88,72% DW=1.45
4	Deposit dollarization equation	
	DD = -2.77 + 0.66*DD(-1) + 0.14*DLOG(ER_MARKET) + 0.000404*ER_MARKET_VOL(-3) + 9.489e-05*CPI_VOL(-4) + 0.21*LOG(CREDIT_TO_BUSINESS) + 0.0035*DEPOSIT_RATE_DIFFERENTIAL(-4)	91,59% DW=2.2
5	Loan dollarization equation	
	LD = -0.118 + 0.94*LD(-1) + 0.32*DD + 0.11*DLOG(ER_MARKET) – 0.00013*CPI_VOL(-2) - 0.00056*ER_MARKET_VOL + 0.00086*CPI(-1)	98,24% DW=1.82

Source: developed by authors in EViews 12

The dataset includes 34 quarterly observations from 2014 till the 1st half of 2022 with forecasting of next 4 quarters.

The conclusion on the equations' adequacy is presented in table 4.3-4.7.

Table 4.3. Results of testing for compliance with classical assumptions for the consumer price index equation

№	Assumption	Test	Critical value	Conclusion
1	Absence of heteroskedasticity	White Test, H0 – absence of heteroskedasticity	0.9480	Yes
2	Absence of autocorrelation	Breusch-Godfrey LM Test, H0- absence of serial correlation	0.9779	Yes
		Durbin-Watson test	2.15	Yes
3	Absence of multicollinearity	Test VIF, H0 – absence of multicollinearity	<10	Yes
4	Residuals normal distribution	Jarque-Bera test, H0 – normal distribution	0.56	Yes
5	Correctness of specification	RESET-test, H0 – correct specification	0.0193	No
		Adjusted R-squared	0.92	Yes
		Fisher F-criteria	p-value < 0.1	Yes

Source: developed by authors in EViews 12

The equation of the consumer price index is consistent with most of the tests, except the RESET-test for the correctness of specification. Hence, additional criteria were taken into account, such as the high explanatory power of the regression (R-squared 92%), and all the independent variables are significant with confidence limits of 10%.

Table 4.4. Results of testing for compliance with classical assumptions for the exchange rate equation

№	Assumption	Test	Critical value	Conclusion
1	Absence of heteroskedasticity	White Test, H0 – absence of heteroskedasticity	0.7278	Yes
2	Absence of autocorrelation	Breusch-Godfrey LM Test, H0- absence of serial correlation	0.8479	Yes
		Durbin-Watson test	2.14	Yes

Continuation of Table 4.4

№	Assumption	Test	Critical value	Conclusion
3	Absence of multicollinearity	Test VIF, H0 – absence of multicollinearity	<10	Yes
4	Residuals normal distribution	Jarque-Bera test, H0 – normal distribution	0.9	Yes
5	Correctness of specification	RESET-test, H0 – correct specification	0.7230	Yes
		Adjusted R-squared	0.86	Yes
		Fisher F-criteria	p-value < 0.1	Yes

Source: developed by authors in EViews 12

The equation of the exchange rate is consistent with all of the tests, has high explanatory power of the regression (R-squared 86%), and all the independent variables are significant with confidence limits of 10%.

Table 4.5. Results of testing for compliance with classical assumptions for key policy rate equation

№	Assumption	Test	Critical value	Conclusion
1	Absence of heteroskedasticity	White Test, H0 – absence of heteroskedasticity	0.1279	Yes
2	Absence of autocorrelation	Breusch-Godfrey LM Test, H0- absence of serial correlation	0.3301	Yes
		Durbin-Watson test	1.45	Yes
3	Absence of multicollinearity	Test VIF, H0 – absence of multicollinearity	<10	Yes
4	Residuals normal distribution	Jarque-Bera test, H0 – normal distribution	0.07	Unclear
5	Correctness of specification	RESET-test, H0 – correct specification	0.7160	Yes
		Adjusted R-squared	0.89	Yes
		Fisher F-criteria	p-value < 0.15	Yes

Source: developed by authors in EViews 12

The equation of the key policy rate is consistent with most of the tests, the test of the normal distribution of residuals is unclear, the problem for that can be a very limited number of observations, however taking into account other tests, and the prevalence of the problem of non-normal distribution for small datasets, the equation was developed as best possible to satisfy key tests, it also has high explanatory power of the regression (R-squared 89%), and all the independent variables are significant with confidence limits of 15%.

Table 4.6. Results of testing for compliance with classical assumptions for deposit dollarization equation

№	Assumption	Test	Critical value	Conclusion
1	Absence of heteroskedasticity	White Test, H0 – absence of heteroskedasticity	0.5093	Yes
2	Absence of autocorrelation	Breusch-Godfrey LM Test, H0- absence of serial correlation	0.3337	Yes
		Durbin-Watson test	2.2	Yes
3	Absence of multicollinearity	Test VIF, H0 – absence of multicollinearity	<10	Yes
4	Residuals normal distribution	Jarque-Bera test, H0 – normal distribution	0.87	Yes
5	Correctness of specification	RESET-test, H0 – correct specification	0.1304	Yes
		Adjusted R-squared	0.92	Yes
		Fisher F-criteria	p-value < 0.05	Yes

Source: developed by authors in EViews 12

The equation of the deposit dollarization is consistent with all of the tests, has high explanatory power of the regression (R-squared 92%), and all the independent variables are significant with confidence limits of 5%.

The equation of the loan dollarization is consistent with most of the tests, has high explanatory power of the regression (R-squared 98%), and all the independent variables are significant with confidence limits of 5%.

Table 4.7. Results of testing for compliance with classical assumptions for loan dollarization equation

№	Assumption	Test	Critical value	Conclusion
1	Absence of heteroskedasticity	White Test, H0 – absence of heteroskedasticity	0.5085	Yes
2	Absence of autocorrelation	Breusch-Godfrey LM Test, H0- absence of serial correlation	0.7360	Yes
		Durbin-Watson test	1.82	Yes
3	Absence of multicollinearity	Test VIF, H0 – absence of multicollinearity	<10	No
4	Residuals normal distribution	Jarque-Bera test, H0 – normal distribution	0.33	Yes
5	Correctness of specification	RESET-test, H0 – correct specification	0.2014	Yes
		Adjusted R-squared	0.98	Yes
		Fisher F-criteria	p-value < 0.05	Yes

Source: developed by authors in EViews 12

Previously specified regression equations are then combined and united into one system. To conduct this step, exogenous and determined (lagged endogenous) variables have been defined. This division is needed to test the system for the identity check according to the condition of the order. The condition of the order is defined based on the following formula:

$$(K\text{-}k)=(m\text{-}1) \tag{4.7}$$

where K – the sum of exogenous and determined variables in the system, k – the sum of exogenous and determined variables in the equation, and m – the number of endogenous variables in the equation.

If (K-k) is lower than (m-1) then the system is underidentified, if it is greater – the system is overidentified. The developed system has 28 exogenous and determined variables and 5 endogenous. Every equation was tested separately for the identity check (see Table 4.8).

Table 4.8. Results of the system test for the identity check according to the condition of the order

Endogenous variables	Exogenous variables	Determined (lagged endogenous) variables	Condition of the	Conclusion
Consumer price index equation				
CPI_t	$PCPI_{t-1}$	KEY_R_{t-6}, ER_MARKET_{t-3}, CPI_{t-4}, INR_RESERV_{t-7}	28-5>1-1	Overidentified
Exchange rate equation				
ER_MARKET_t	ER_OFF_{t-1}, INR_RESERV_{t-6}, $DEBT\_TO\_GDP_t$, NX_t, DUMMY1	KEY_R_{t-1}, ER_MARKET_{t-1}	28-7>1-1	Overidentified
Key policy rate equation				
KEY_R_t, CPI_t	GDP_GAP_{t-1}, CPI_TARGET_t, $NR_{t-2,}$ DUMMY2	KEY_R_{t-1}, ER_MARKET_{t-1}	28-6>2-1	Overidentified
Endogenous variables	Exogenous variables	Determined (lagged endogenous) variables	Condition of the order	Conclusion
Deposit dollarization equation				
DD_t, ER_MARKET_t	$ER\_MARKET\_VOL_{t-3}$, CPI_VOL_{t-4}, $CREDIT\_TO\_BUSINESS_t$, $DEPOSIT\_RATE\_DIFFERENTIAL_{t-4}$	DD_{t-1}	28-5>2-1	Overidentified
Loan dollarization equation				
LD_t, DD_t, ER_MARKET_t	$ER\_MARKET\_VOL_t$, CPI_VOL_{t-2}	LD_{t-1}, CPI_{t-1}	28-4>3-1	Overidentified

Source: developed by authors

The system can be estimated based on a two-stage or three-stage least squares estimation method. The estimated system output from both methods is shown in Annex B.

Based on the decrease of the determinant residual covariance value from 7,19E-11 to 5,95E-11 when switching from the two-stage to three-stage least squares method, the latter was chosen for final system estimation.

The system was therefore tested for the residual autocorrelations using the Portmanteau Autocorrelation test. Results of the test confirm that there are no residual autocorrelations in the system up to lag 12.

It is crucial to assess the forecast quality of any model as it enables the evaluation of the model's ability to predict outcomes and analyze various scenarios of potential economic events based on different initial conditions and assumptions. By assessing how well the model can forecast future outcomes, we can determine its usefulness for decision-making purposes. If the model consistently produces inaccurate forecasts, it may not be suitable for making reliable predictions, and relying on its results could lead to poor decisions. Estimating the forecast quality of a model also provides insights into the model's underlying assumptions and parameters and can help identify areas where improvements can be made. Ultimately, by evaluating the forecast quality of a model, we can gain a better understanding of its limitations and potential biases, and make more informed decisions based on its predictions.

The first step to assess forecast quality is to simulate the model and compare it with historical results. Simulated and historical results for endogenous variables are shown in Figure 4.6 and Figure 4.7.

When analyzing results for macroeconomic variables, we can see that the simulated results replicate the actual behavior pretty accurately. What is important in such results is that it manages not only to capture the trend but also to replicate the turning points. The model managed to capture the changes in the economy caused by the russian full-scale invasion, and the consequent actions of the NBU – the increase of the central bank rate, a sharp growth in the market exchange rate and the surge in inflation. A very accurate forecast for the last periods allows relying on the model for short-term forecasting.

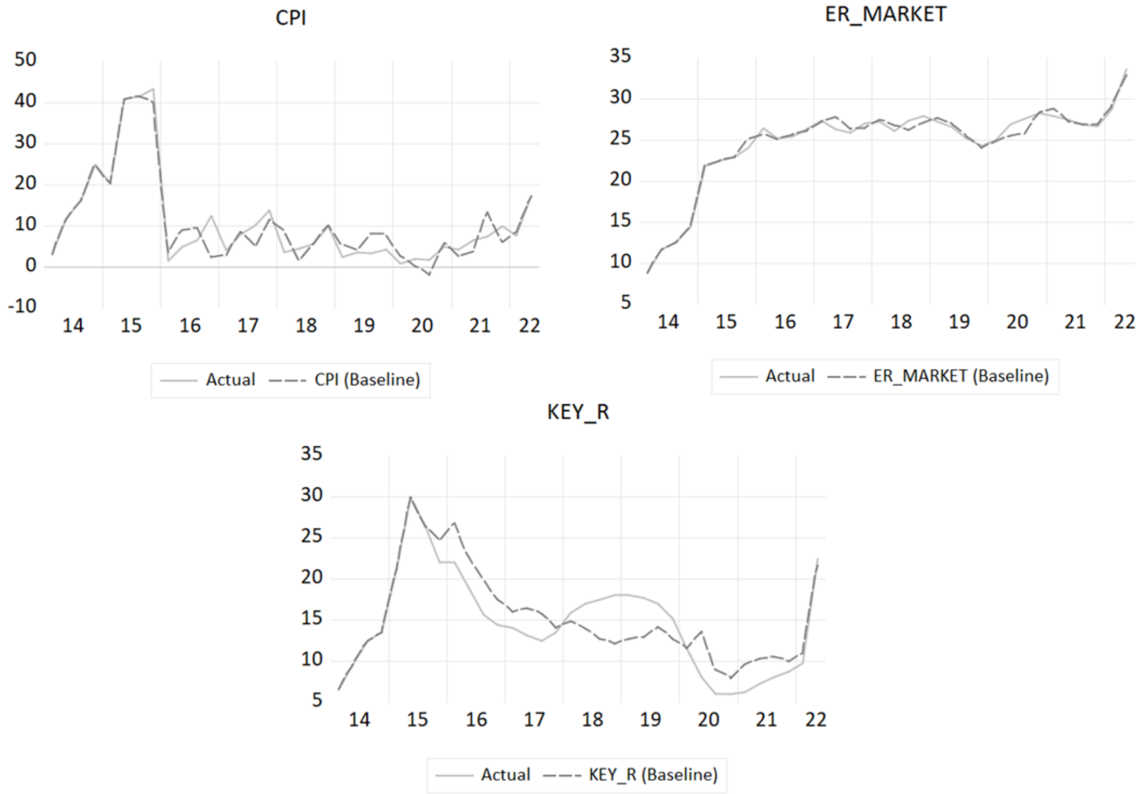

Figure 4.6. Historical and simulated results for consumer price index, exchange rate, and key policy rate

Source: developed by authors in EViews 12

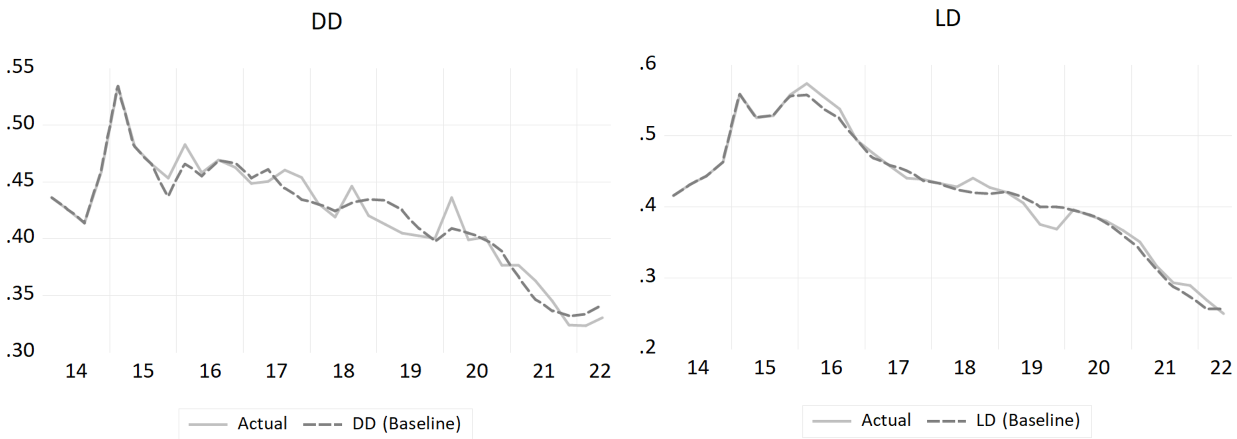

Figure 4.7. Historical and simulated results for deposit and loan dollarization

Source: developed by authors in EViews 12

Deposit and loan dollarization simulated results are also pretty accurate and manage to replicate the turning points, however for the DD, the peaks are rather smoothed by the model.

Deposit and loan dollarization is going to stay at a relatively high level due to still high inflation risks and exceeding their pre-war level. As the market is highly uncertain and limited, and the transmission mechanism is not as effective as before the war, NBU has to pay attention to macroprudential regulatory tools.

A system of simultaneous equations proved to be a very efficient method to analyze how the macroeconomic situation affects financial dollarization. Deposit dollarization is driven by its previous level, the exchange rate, and its volatility, as well as by consumer price index volatility. It also depends on the demand for corporate lending, reflecting the redistributive function of banks and the difference between national and foreign currency deposit rates. In the meantime, loan dollarization depends on deposit dollarization, exchange rate, inflation, and their volatilities. In the model, only macroeconomic indicators and monetary policy tools are endogenized, which brings to a conclusion that a stable, controlled macroeconomic environment, increases the confidence of both investors, borrowers, and banks, providing grounds for trust to NBU, the national currency instruments, and consequently for lower levels of financial dollarization.

In addition, as one of the financial stability goals is to ensure low financial dollarization, monetary policies should be followed by relevant macroprudential policies.

Scenario analysis is an essential part of developing a system of simultaneous equations for analyzing complex economic systems such as financial dollarization. This technique involves creating hypothetical scenarios based on different assumptions and modeling the impact of these scenarios on the system under study. Through scenario analysis, we can explore how the system may react to changes in key variables and evaluate the effectiveness of different policy options. This approach can help policymakers and researchers identify potential risks and challenges and develop effective strategies to manage them. By incorporating scenario analysis into the system of simultaneous equations, we can enhance our understanding of complex economic phenomena and improve the accuracy of our forecasting and policymaking.

Next step will be developing the System Dynamics model. The System Dynamics (SD) approach is another method that enables analyzing complex problems, such as the causes and consequences of financial dollarization. In essence, system dynamics provides a powerful framework for analyzing dollarization, allowing for a deep understanding of its dynamics and informing more effective policy decisions. This approach is particularly valuable in economics, where the interplay of various factors can be complex and non-intuitive. It allows modeling relationships and feedback in the system based on incorporated assumptions. When analyzing such systems it appears to be a flexible tool: it is applicable for changing parameters, developing scenarios, and testing hypotheses. While developing the system dynamics model the modeler receives incentives for leverage points in the system. These insights from the developed model can be very valuable for policymakers, and system dynamics software provides opportunities for versatile approach in analyzing the problem and finding possible solutions.

There is little literature on the analysis of financial systems using system dynamics, hence this research aims to provide grounds for the application of SD models in the risk-management practices of banks. Dollarization can be analyzed in terms of stocks (such as the total amount of foreign currency deposits) and flows (such as changes in the rate of foreign currency deposits over time). System dynamics models use differential equations to represent these stocks and flows, providing a dynamic view of how dollarization evolves.

The key part of the model structure is a simplified balance sheet and financial results statement of banks. Assets of the bank consist of hryvnia loans, FX loans, bonds, and reserves. Liabilities consist of hryvnia deposits, FX deposits, and financial capital. The balance sheet structure is important because it allows the calculation of important risk management indicators, such as liquidity ratios, and others, which then can be used by the regulators to analyze the financial health of the banking sector and for the development of macroprudential strategies.

The financial result includes banks' income and expenses, such as net interest income, net commission income, foreign currency gains or losses, and other income and expenses.

Macroeconomic indicators, such as inflation, policy rate, and exchange rate are taken exogenously, in contrast to the system of simultaneous equations developed in the previous part, for simplification purposes. These macroeconomic indicators are mostly used in terms of perception, relative changes, and expectations.

In contrast to the system of simultaneous equations, both hryvnia and FX deposit and loan rates are endogenized. This structure allows tracking of the response of banks to various changes both in the macroeconomic situation and monetary policy. Also exchange rate is taken exogenously, and this part of the model can be developed in further research. System dynamics models can simulate different economic scenarios and policy interventions to see their potential impacts on dollarization. For example, the model could simulate the effect of a new monetary policy or regulatory changes on the level of foreign currency deposits and loans.

The simplified causal-loop diagram is presented in Figure 4.8.

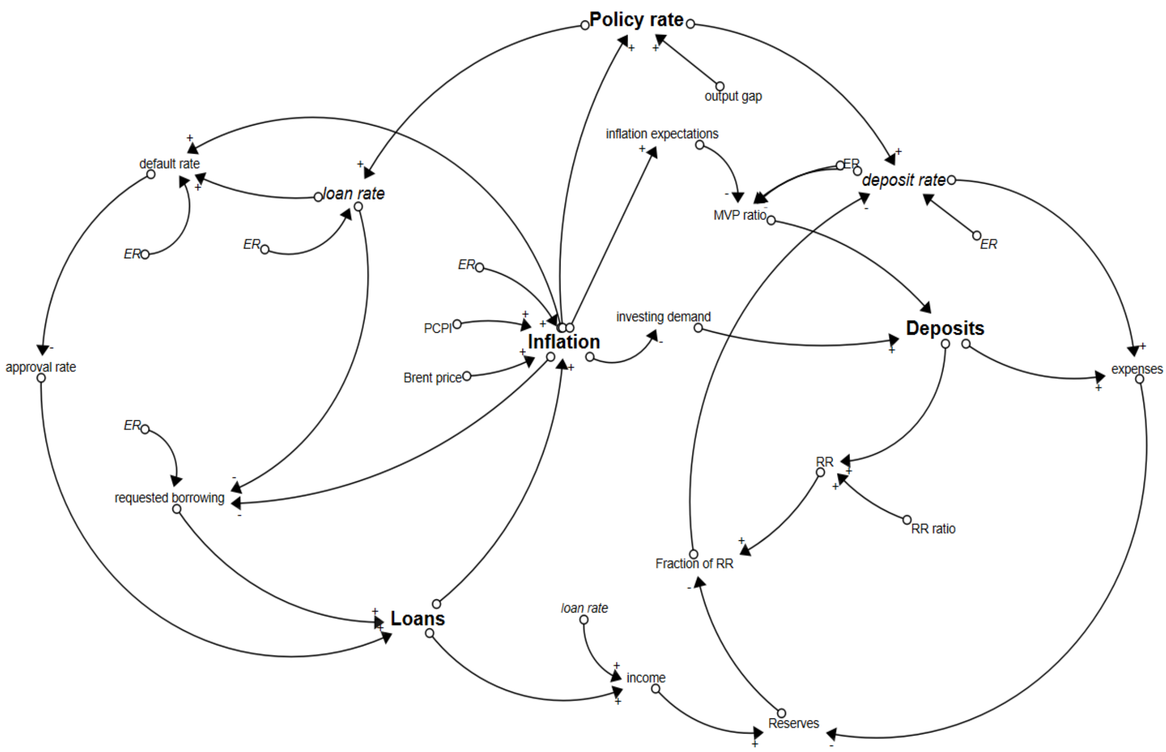

Figure 4.8. Simplified causal-loop diagram of banking sector and monetary policy

Source: developed by authors in Stella Architect

The assumptions developed to describe deposit dollarization are the following:

1. Demand for investing in deposits is driven by its persistent level and changes in inflation – with the increase in inflation, purchasing power of individuals and businesses decreases, hence people invest less, as they have to pay more to maintain their needs.
2. With hryvnia depreciation people tend to invest in foreign currency deposits to hedge from currency risk.
3. With the increase in inflation expectations, people tend to invest in foreign currency deposits due to higher uncertainty and a desire to hedge from inflationary risks.
4. Inflation expectations depend on the monetary credibility and forecast of the NBU. Monetary credibility is adjusted with a delay of 2 years based on the gap between actual inflation and its target. With the decrease of inflation closer to its target, the monetary credibility increases, and consequently inflation expectations will be closer to the forecast communicated by the NBU.
5. If the deposit rate differential that is a difference between hryvnia and FX deposit rates increases it means that hryvnia deposits have higher yields than FX deposits, hence investors would prefer to hold them in their portfolios.
6. Hryvnia deposit rate is positively affected by the change in the policy rate, this assumption is based on the estimated correlation of 0,65.
7. FX deposit rate is also positively affected by policy rate with the estimated correlation of 0,31. It is negatively affected by the change in the exchange rate, as banks don't have the incentive to carry currency risk, the estimated correlation is -0,77. The required reserves ratio set by NBU also affects the willingness of banks to increase the deposit rate on FX deposits: with the increase of the ratio banks will lower their interest rate, and the estimated correlation is -0,3.

The assumptions developed to describe loan dollarization are the following:

1. The demand for loans in hryvnia is driven by the respective interest rate. With the increase of the hryvnia loan rate, customers will be less willing to take loans due to the high costs of its maintenance. The same logic is applied to the effect of inflation on demand for hryvnia loans: higher inflation may reduce the purchasing

power of customers, making them more cautious about taking on new debt, also it can reduce demand for credit as businesses and consumers cut back on spending.

2. The demand for FX loans is driven by the respective loan rate: with the increase in the rate, customers will be willing to take fewer loans due to high service costs. It can also be driven by the difference in loan rates in hryvnia and FX: usually, FX rates are lower than the ones nominated in hryvnia. The exchange rate negatively affects FX borrowing demand, as with hryvnia depreciation costs of debt maintenance increase as well.
3. Hryvnia loan rate is positively affected by the policy rate, the estimated correlation is 0,87, and by the hryvnia deposit rate: if banks increase deposit rates, they will want to increase the spread as well to prevent losing interest income. The estimated correlation between hryvnia deposit and loan rates is 0,85.
4. FX loan rate is positively affected by the policy rate, the estimated correlation is 0,32, and is negatively affected by the exchange rate: with hryvnia depreciation banks will try to manage the risks associated with foreign currency lending, such as exchange rate fluctuations and default risk. The estimated correlation between FX loan rates and the exchange rate is -0,6.

SD model overview is shown in Annex C in regard to separate model structures: Monetary Policy, Deposits, Loans, Interest Rates, Customers demand for savings, Customers demand for borrowings, Balance Sheet, and P&L.

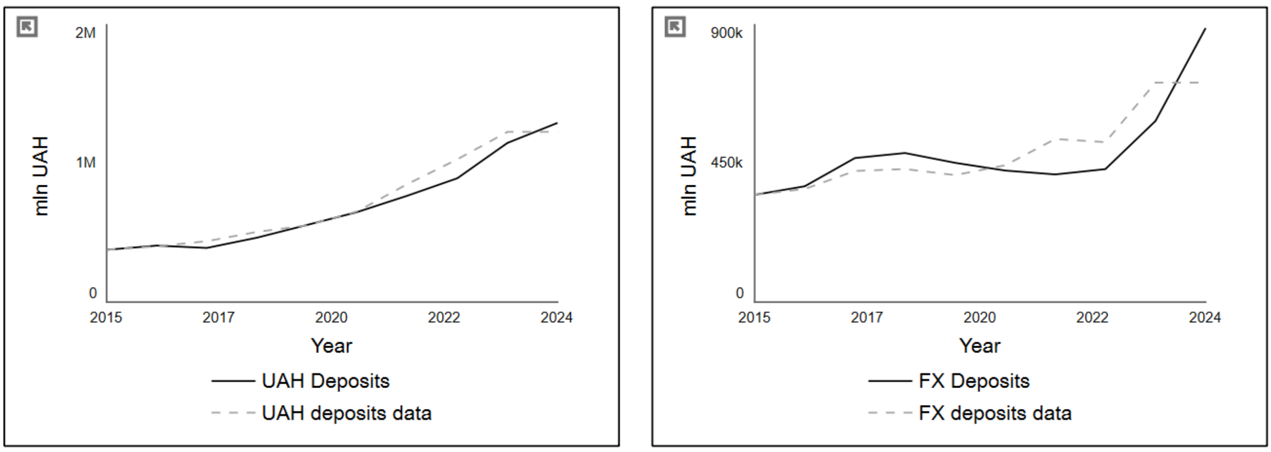

Figure 4.9. Deposits simulation from 2015 till 2024

Source: developed by authors in Stella Architect

Simulation for deposit dynamics is shown in Figure 4.9. From the graphs, we can see that the simulated results reflect historical data very accurately. Total deposit demand also accounts for the effect of currency restrictions, based on sensitivity analysis estimated multiplier for the increase in demand for deposits in 2022 is 0,4.

Simulated deposit dollarization is also consistent with the historical data (see Figure 4.10). In 2022 even though FX deposits have increased a lot, the overall growth rate of deposits was higher, hence it didn't exceed the pre-war levels. A combination of currency restrictions and an increase in reserve requirements restricted excessive dollarization in 2022. However, the dollarization will continue increasing and as of the end of 2023, it will reach 41%. This result is similar to the one derived from a system of simultaneous equations.

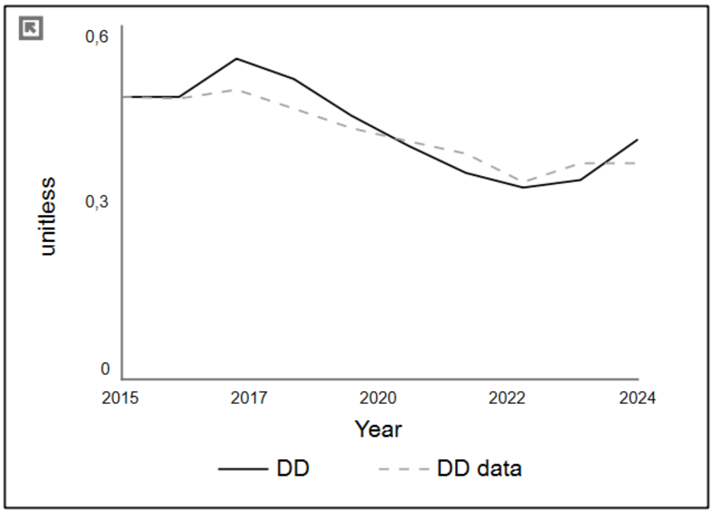

Figure 4.10. Deposits dollarization simulation from 2015 till 2024

Source: developed by authors in Stella Architect

In contrast, loans simulation is more accurate after 2016 and has a gap at the beginning of the simulation, however, this gap between actual and simulated data occurs due to delays in the system, hence the model couldn't account for lagged effects that occurred before 2015 (see Figure 4.11). This problem can be easily solved with the expansion of the analyzed period. The model shows the overall trend in the decrease of loans in the financial system. This result is consistent with the Financial Stability Report of NBU where it is mentioned that having high liquidity banks don't have incentives to provide loans with higher currency and default risk [7].

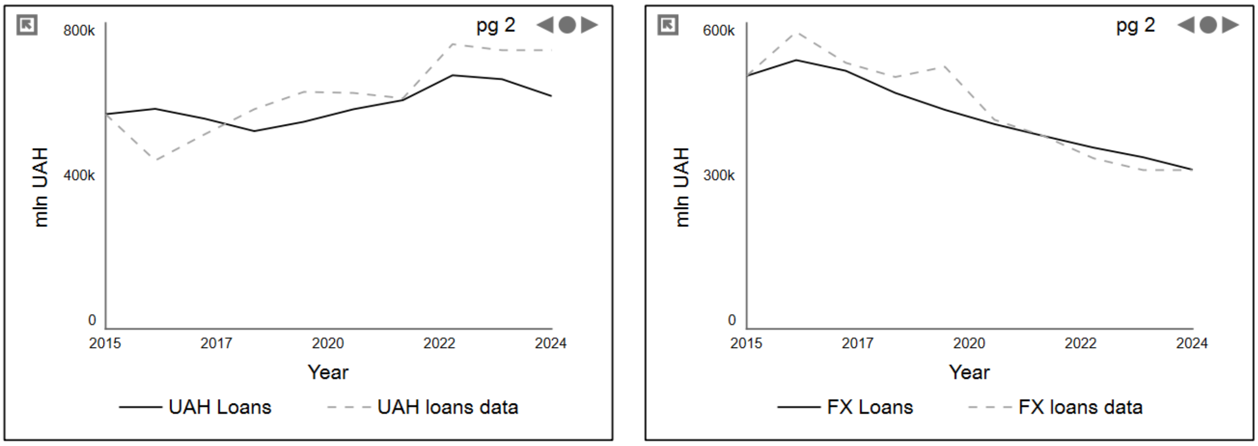

Figure 4.11. Loans simulation from 2015 till 2024

Source: developed by authors in Stella Architect

Loans dollarization, according to Figure 4.12, will stay on the same level. Even though FX loans are decreasing, overall lending is decreasing a bit faster. This outcome can be a result of the decrease in total lending demand from businesses and individuals, due to a decrease in their purchasing power and high uncertainty about their capabilities to fulfill debt obligations. Also, due to the decrease in foreign trade, and the decline in economic activity in general, the demand for foreign currency decreased as well. The low level of loan dollarization would be explained through the overall decrease in demand for borrowings in both hryvnia and foreign currency.

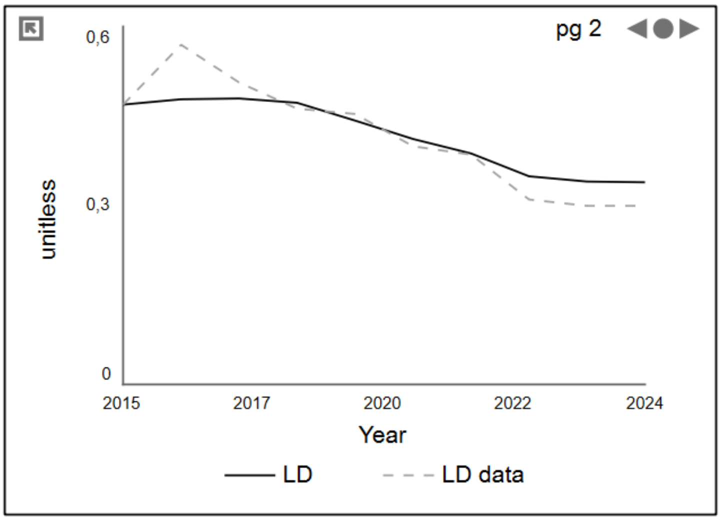

Figure 4.12. Loans dollarization simulation from 2015 till 2024

Source: developed by authors in Stella Architect

To sum up, the system dynamics approach appeared to be a useful tool for analyzing a complex system such as the banking sector. The iterative nature of the modeling process deepened the understanding of the interactions between different variables and feedback loops. The high accuracy of the simulation within the complexity of the system, as well as the possibility to observe both short-term and long-term effects of different policy choices, are the main advantages of the system dynamics approach. According to the results of the SD model, deposit dollarization will continue increasing, however, its growth will be moderate. At the same time loan dollarization will stay on the same level due to both decreases in overall demand for borrowings and banks' unwillingness to take on additional risks during the crisis period.

4.4. De-dollarization policies and prospects for the de-dollarization of the Ukrainian economy

De-dollarization policies are becoming increasingly important for many countries as they seek to reduce their dependence on foreign currencies and promote economic stability. While the specific strategies for de-dollarization may vary, it is generally recognized that reducing dollarization can help countries avoid financial crises and currency shocks. However, the success of de-dollarization policies can depend on a range of factors, such as the strength of a country's financial institutions, the degree of public trust in the national currency, and the effectiveness of government policies in promoting alternative investment options. Therefore, it is important for policymakers to carefully consider the various approaches to de-dollarization and choose those that are most likely to be successful in their specific economic and political context.

The paper of Alvarez-Plata and Garcia-Herrero proposes a classification of de-dollarization strategies based on the policy approach adopted by the central bank [13]. They classify these strategies into two broad categories: market-based and administrative-based. Market-based strategies aim to reduce dollarization through the promotion of alternative financial instruments in local currency, such as government