

A System Dynamics Model of Ukraine's Monetary Sector

Oleksandr Faryna

PhD student, National University of “Kyiv-Mohyla Academy”
Kyiv, Ukraine
farynaoleksandr@gmail.com

Abstract

This paper presents a system dynamics model of the monetary sector of the Ukrainian economy. It is one of the products of a project for developing system dynamics modeling capacity among economists at the National University of “Kyiv-Mohyla Academy”, organized by the University of Bergen and funded by the Norwegian Center for International Cooperation in Education. Prepared by a PhD student from Kiev, the monetary sector is a sub-model of a comprehensive macroeconomic model being developed by a team of Ukrainian students taking a special topics course in macroeconomic dynamics in Bergen.

Keywords: macroeconomics, MacroLab, monetary policy, Ukraine

Introduction

The project between University of Bergen and University of “Kyiv-Mohyla Academy” is aimed to develop a system dynamics macroeconomic model of Ukraine. Using the model developed by D. Wheat for the US economy called MacroLab as a base (Wheat, 2007), students work on separate sectors of Ukrainian economy and connect them into a big model. MacroLab presents general relationships within the economy of the country including a set of separate models: production, income distribution, consumption, government, monetary, price, exchange rate, international trade.

This paper presents current results of Ukrainian monetary sector modeling. The purpose of the model is to investigate and explain the process of creating money in Ukraine and to illustrate the relationship of monetary policy and general macroeconomic equilibrium. Comparing to MacroLab, which in most cases reflects economic relationships inherent to the US economy, the monetary policy on regulating the money supply in the system is much different in Ukraine. MacroLab illustrates the policy of interest rate targeting conducted by the Federal Reserve System. In order to keep inflation and employment on the desired level, the FED determines the Target Fed Fund Rate. Using open market operations by buying or selling bonds, the FED influences reserves supply which, in turn, has an effect on interest rates. Lower interest rates stimulate demand for loans increasing the supply

of money in economy, and vice versa. For a long time, this was a useful policy to ensure stability and economic growth.

Ukrainian monetary policy is based on the exchange rate targeting in order to ensure the stability of domestic currency and prices. The National Bank of Ukraine, being the general monetary policy maker and regulator, determines the target exchange rate and conducts foreign currency interventions balancing the supply and demand for foreign currency on the foreign-exchange market. National Bank (NBU) provides a limited information on its activities. Providing access to statistical information, central bank is not providing the information on the decision it makes. Thus, a big challenge is to express the activity of the National Bank in the model. Nevertheless, having information on the general goals of monetary policy and central bank's basic tools of monetary base adjustment, we attempt to develop a structure that explains the behavior of money supply in Ukraine and represents decisions of central bank on achieving its goals.

Monetary Transmission Mechanism Model

The basic model of the monetary sector represents the monetary transmission mechanism that reflects the process of money supply creation in the country. The structure of the system is constructed by using the aggregate balance sheet approach presenting assets and liabilities of the banking system excluding central bank. Assets include stocks of reserves, bonds, and total loans. Deposits, equity, and other liabilities of banks are added together in liabilities part of the balance sheet. The balance sheet approach was used in order to keep track of the balance between assets and liabilities and to represent the way banks manage their portfolios.

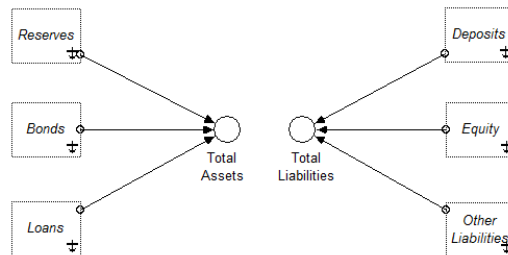


Figure 1. The balance sheet of banking sector

The asset portfolio in the simplified model include three stocks that differ by its liquidity level. Reserves, which include currency on the correspondent accounts in National Bank of Ukraine, are the most liquid assets. Bonds can be purchased or sold in the short period. Total loans are the least liquid assets as it takes time for loans to be repaid. Managing their assets banks firstly determine the level of reserves that are required by central bank's regulations. The next step is to determine the amount of the mid-term liquidity due to the desired liquidity ratio. The last step is to manage the stock of total loans. If banks have additional resources

after satisfying the reserves demand and liquidity ratio, they can increase lending constrained by the demand for loans. There are three main sources of financial resources for banks. The first is the equity of banks. Other resources are attracted in the form of deposits and loans from other banks. Deposits include current accounts and saving accounts of households, firms, government, and financial institutions. Banks should also manage their liabilities in order to meet the required or desired capital adequacy ratio, which is done by changing the stock of Equity.

Different combinations of the main stocks in the model form the monetary base and money supply. Reserves and Cash together are monetary base – the actual amount of domestic currency issued by the central bank and put to the financial system. Deposits and Cash together form money supply (M2) – the amount of money available in the country.

When banks manage their balance sheets and invest their assets to different instruments, deposits are created, which increases the money stock. Figure 2 shows the causal-loop diagram that explains the multiplication process and money supply formation. To start with, assume the bank receives deposit from households in the form of cash. Received money from deposit enter the banking system and become assets for the bank that can be used for bank activity.

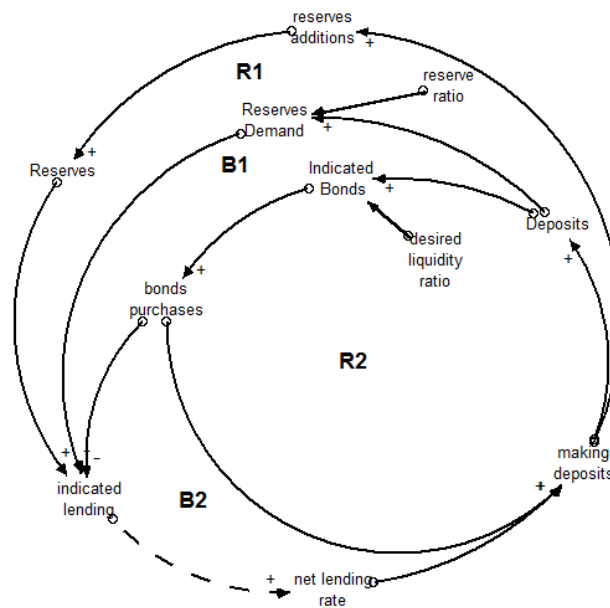


Figure 2. Monetary transmission mechanism (CLD – 1)

Managing their assets, banks are obliged to reserve the part of the deposit due to the reserve limit requirements. The rest money are used in the particular model to purchase bonds and give loans to households and firms. Assuming that money stay in the domestic financial system and borrowers do not take money in the form of cash, money from loans are deposited to other banks. Receiving new resources, the other bank should repeat the procedure of deposit reservation and then it uses the rest of money for purchasing new bonds or giving new loans if there is no constraint on demand for loans. In MacroLab for the US economy, the demand for loans is influenced by interest rates. Interest rate serves as the input to other sectors, such as capital formation sector and consumption sector, within the big macroeconomic model. In these sectors, interest rates influence consumption and investments the part of which form the demand for loans. Theoretically, low interest rates should increase the demand for loans, and, thus, increase lending and money supply in the system. Practically, the increase of the demand for loans in Ukraine is mostly caused due to the inflation. Interest rates on loans are extremely high in Ukraine

and their effect is not deeply investigated yet. The causes of the demand on loans should be discovered in further research. In the particular model, we assume that all available financial resources of banks for lending are transformed to actual loans with no constraint on the demand side. The change in demand for lending in the model would be reflected by the change of desired liquidity ratio. Decreasing the desired amount of bonds in the portfolio, banks free additional resources for lending. Moreover, fluctuations of the desired liquidity ratio can be explained by different perceptions of the financial risks in the system. The higher is the risk, the higher is the ratio as banks try to avoid additional risk and invest their assets to less risky instruments, such as state bonds. If financial risks in the system stay insignificant and demand for loans rises, banks would decrease the desired liquidity ratio and increase lending to meet the demand. At this stage of the research, before we investigate the cause and effect relationships between interest rates and lending, the desired liquidity ratio is taken as exogenous input.

A simple monetary transmission mechanism with the reserve limit ratio of 5% will create money supply that is 20 times higher than monetary base. Two reinforcing loops (R1 and R2) determine the money multiplication process and two balancing loops (B1 and B2) take care of the required reserve limit and desired liquidity ratios. However, the part of money in the financial system is being withdrawn from banks by households in the form of cash, thus reducing the multiplier.

Figure 3 shows additional causal relationships within the monetary transmission mechanism. Balancing loop B3, taking into account the cash to deposit ratio, is responsible for keeping Cash stock on its desired level. The monetary transmission mechanism that takes into account cash withdrawals with 5% required reserve ratio and 50% cash to deposit ratio will create money supply that is 2.7 times higher than

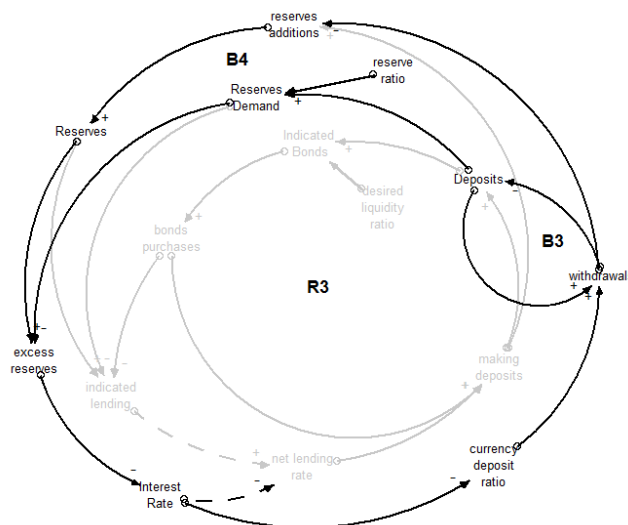


Figure 3. Monetary transmission mechanism (CLD – 2)

monetary base. On the other side, cash to deposit ratio is influenced by interest rates of banking sector. Theoretically, higher interest rates on deposits attract more deposits from households and cash to deposit ratio decreases. However, comparing historical data of cash to deposit ratio and interest rate changes in Ukraine, the relationship is inverse. Practically, the higher is the interest rate the higher are withdrawals from the banking sector. The hypothesis is that inflation at the same time causes the increase of cash withdrawals and interest rate growth. If inflation

remains low, higher interest rates are more attractive for households to deposit money. On the other hand, high inflation would encourage cash withdrawals despite the high interest rates. Moreover, the cash to deposit ratio can be caused by uncertainties and lack of confidence to the banking system from households. The representation of endogenous structure for interest rates requires increased attention in further research and the effect of interest rates in particular model of Ukrainian banking sector is not presented, while cash to deposit ratio is taken as exogenous input.

Figure 4 shows the stock and flow diagram of the monetary transmission mechanism. Assets are presented at the left side of the diagram, while liabilities at the right side. Trying to keep reserves on the demanded level due to NBU's requirements, banks determine the amount of resources for lending. Before giving new loans, banks manage the stock of bonds due to the desired liquidity ratio. Available resources that are left after adjusting desired liquid assets are being used for new lending. Bond purchases are subtracted from indicated lending in order to avoid the steady state error and keep the reserves stock strictly on its demanded level. Loans, that are being paid back after one year on average increase the stock of reserves and can be used for giving new loans. Net lending and bond purchases stay in financial system and form new deposits that, in turn, are feeding back to the stock of reserves.

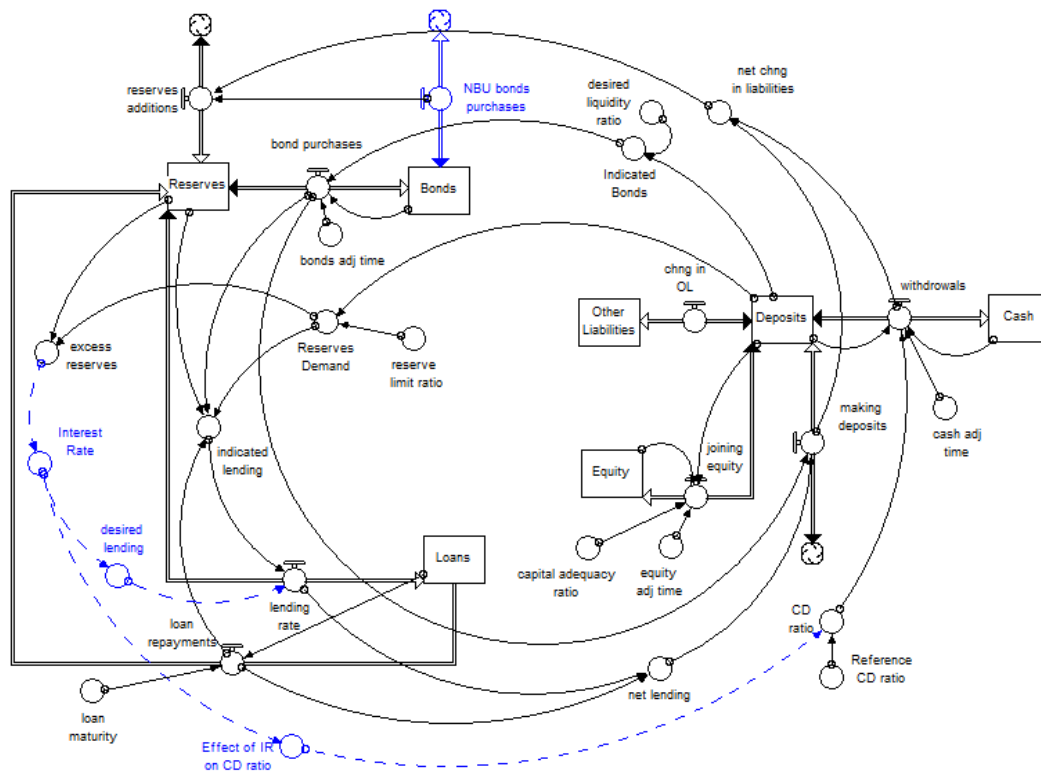


Figure 4. Monetary transmission mechanism. SFD

Managing their liabilities, banks determine the desired capital adequacy ratio. Assuming that banking system contains all money in the system except of cash and that all transactions are made using bank accounts, the decision to change

equity will affect the stock of deposits. In instance, if banks are willing to increase equity to the desired level, they usually reinvest their profits or attract new shareholders. Assuming that profits are received on deposit accounts due to bonds and loans repayments, and that potential shareholders are keeping their resources in the form of deposits, the growth of equity will decrease the total amount of deposits in the banking system. The same process characterizes the change of the other liabilities stock. On the current stage of research, causes of other liabilities change are not investigated yet, thus, the change in other liabilities is taken exogenously.

The stock of cash is being adjusted due to the cash to deposit ratio. Withdrawing money from banks, households decrease reserves of banks that can cause liquidity problems in banking system. Ukrainian money sector characterizes by a high share of cash in money supply as most of payments by households are conducted in cash. Moreover, the amount of cash in the system is sensitive to inflation in the country. Permanently high inflation provides that households quickly withdraw money from bank accounts in order to maintain their purchase ability. Thus, the time to adjust the stock of Cash is shorter than in the MacroLab (half a year on average in Ukraine).

In order to conduct analysis tests, the model was initialized in equilibrium. Assume that NBU makes the injection of 50 billion UAH of new money to the financial system at the three-year point. If the average reserve ratio is 11.5 %, which is the initial historical ratio in the model, a simple money multiplier theory provides that money supply will increase by 435 billion UAH. On the other side, due to the multiplier theory that takes cash in to account, the injection of new money will create two times higher money supply (estimated historical cash to deposit ratio is 0.73 initially). Figure 5 shows the result of simulation for monetary base and money supply.

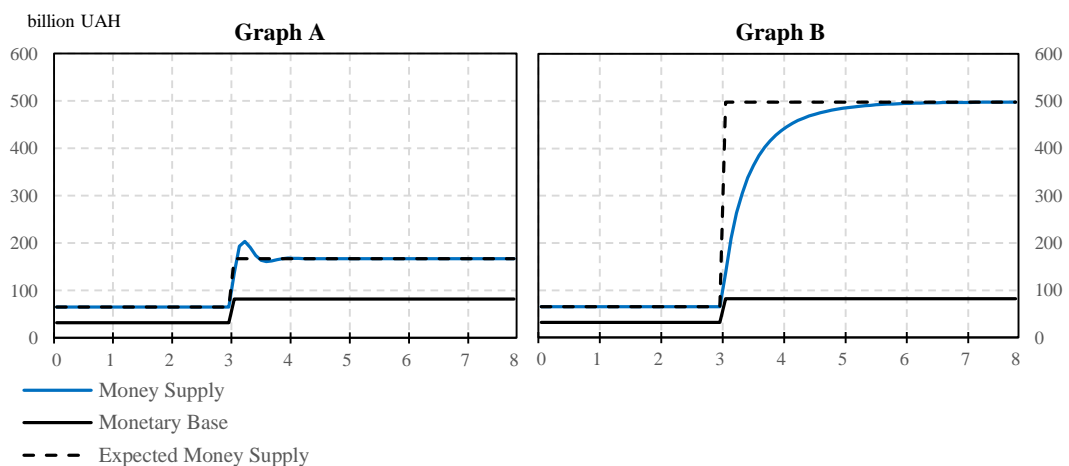


Figure 5. Monetary transmission mechanism test simulation
A – cash drain is ON. B – cash drain is OFF.

Within the transmission mechanism that takes into account cash drain, money supply increases and overshoots before stabilizing at the new equilibrium level (see graph A). The reason of that is the counteracting loop that takes care of balancing

the stock of cash. The increased deposits caused the increase of withdrawals and money leave the banking sector. The average time to adjust the stock of cash is 0.5 years and households withdraw money that have been already multiplied by banking sector. The result is the decrease of money supply. If the cash adjustment loop is not working (see graph B), money supply increases smoothly to the expected level due to the simple multiplier theory.

The next step is to explain the monetary base adjustment policy of the central bank, aimed at regulating money supply, and construct the endogenous structure that reflects the real monetary policy decisions of the major regulator.

Monetary Policy Model

The National Bank of Ukraine, the major monetary policy maker, defines its main goals. Monetary policy of Ukrainian central bank aims to ensure stable prices and stable value of domestic currency. These two goals are closely correlated as the stability of domestic currency, meaning invariable exchange rate, influences the price level in the country. In order to explain the causal factors that influence the price level and exchange rate, we developed two simple experimental model structures. The first model illustrates the structure of price formation. The second model explains the formation of exchange rate and represents the policy of exchange rate targeting. These two models will serve as a basis to illustrate the policy decisions on money supply and monetary base adjustment.

Price level. In order to construct a price model, we define two driving causes of the price change (Gordon, 1988). The first is the demand-pull effect. Prices change if the real aggregate demand is higher than amount of produced goods and services. Due to the General equilibrium theory, higher demand causes the increase in price. On the other side, another causal factor of price change is the cost-push effect when prices are changed due to the drop of potential output.

Figure 6 illustrates the causal-loop diagram of the price formation. The price level is presented in the form of index as a stock with initial value of 1. It means that the first year serves as a base year to measure the price level. The general macroeconomic equilibrium provides that the real aggregate

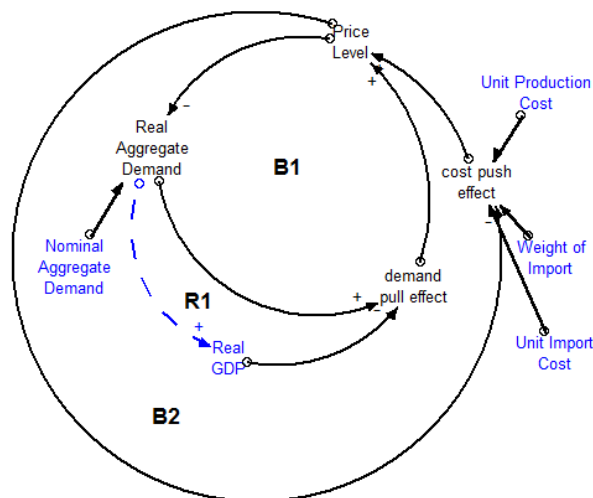


Figure 6. Causal-loop diagram of price formation

demand equals to production. Real aggregate demand can be determined as the nominal aggregate demand divided by the price level. In other words, prices should be on the level that allows purchasing of all produced goods and services in the country. If the nominal aggregate demand increases due to government spending or consumption, the purchase ability with current prices (potential real aggregate demand) is higher. This creates the demand-pull effect on prices. Increased prices lower the purchase ability until the real demand balances with real production. Thus, the balancing loop B1 exists in order to equilibrate real demand and supply. On the other side, increased real aggregate demand serves as the impulse for production. In the big macroeconomic model, real aggregate demand is an input to Labor and Capital sectors. The higher is the long-run expected demand, the higher is hiring of workers and investments that form the main production factors – Labor and Capital. Thus, before prices are adjusted by the balancing loop and the real demand is higher than real production, GDP increases smoothly.

Another cause of inflation is the cost-push effect. This effect influences the aggregate supply and occurs due to increased cost of production. Internal causes appear due to growth of wages and interest rates for loans. External causes appear due to increased prices on imported goods and services that are used in production. The change of exchange rate and imported inflation are the first reasons of import price change. In instance, if the exchange rate increases, meaning the devaluation of domestic currency, imported goods and services become more expensive for domestic buyers. The cost-push effect will cause the increase in price level until it balances with the cost changes. This creates the balancing loop B2.

To illustrate stated relationships we run the experimental model with two scenarios. The first scenario is the increase of nominal demand by 5% at the three-year point (the cost-push effect is turned off). The second scenario is the increase of exchange rate by 20% (the demand-pull effect is turned off). Figure 7 shows the results of simulations.

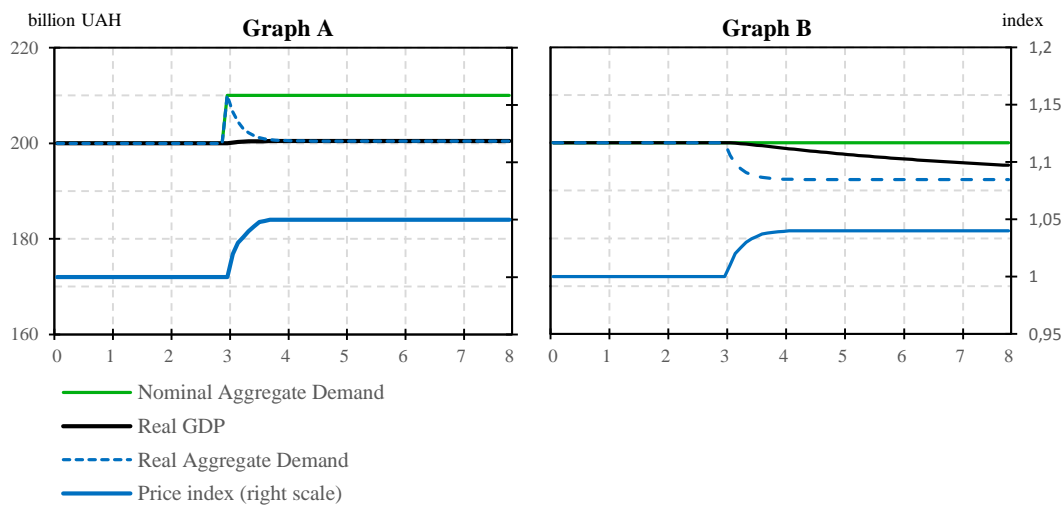


Figure 7. Price Model Test
A – 5% shock of nominal demand. B – 20% decrease of exchange rate

The increase in nominal demand cause the increase in potential real demand and creates the pressure on the price level. The price will grow until the real demand becomes equal to real production. For the period of price adjustment, higher real demand causes a small increase in production. Second graph shows the simulation with cost-push effect. Assuming that the weight of imports is 20% of production, prices should increase by 4%. Producers are now paying higher prices for imported goods and services. Usually, they shift the production cost growth to consumers by increasing prices of finished goods. If the central bank does not provide any adjustments to increase the money supply and, thus, increase the nominal demand, the purchase ability drops due to increased prices which, in turn, causes a smooth decrease of production.

The main feature of the price formation in Ukraine is a strong dependence on foreign trade and capital flows in production process, thus, the cost-push effect has the biggest pressure on the price level in Ukraine. On the other side, the demand-pull effect has inconsiderable influence on the price level. This conclusion can be made by comparing the values of real aggregate demand and real GDP for the chosen time horizon. For the most time, demand was lower than production. The only exception was the period before financial crises in 2008 mostly caused by the decrease of exchange rate. Thus, the exchange rate of domestic currency attracts the most attention by monetary policy makers in Ukraine.

Exchange rate targeting. Due to the strong dependence of Ukraine to foreign trade and capital flows, a stable exchange rate is the main goal of the central bank's policy. In early 2000s' the National Bank of Ukraine issued a note that declared a managed float exchange rate regime. A managed float policy provides that exchange rate is determined by market forces on the interbank foreign-exchange open market. Central bank, joining this market, conducts foreign currency interventions in order to influence demand and supply on the market and avoid exchange rate volatility. To illustrate the formation of exchange rate we developed a simple experimental model.

Figure 8 presents the causal-loop diagram of exchange rate formation by market forces. The supply and demand of currency can be represented as continuous inflows and outflows of foreign currency on the internal market as the result of foreign trade and international flows of capital. Moreover, additional supply or demand can be created by internal causes in the form of increased savings in foreign currency. In the experimental simple model we

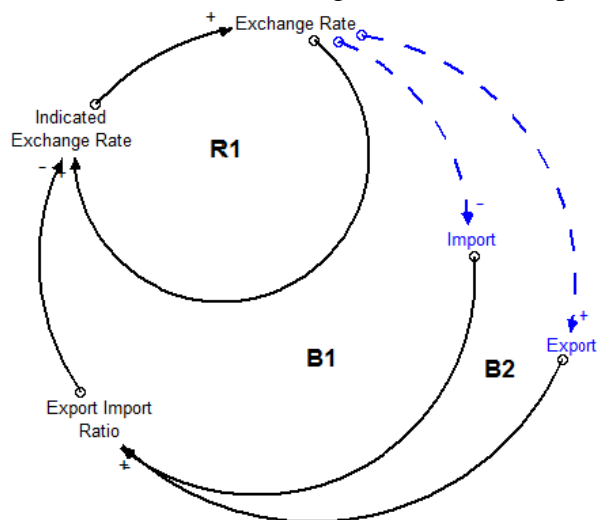


Figure 8. Causal-loop diagram of exchange rate formation

present two main foreign currency flows in Ukraine: currency received from other countries due to export and currency paid for import to other countries. The export to import ratio represents the pressure on the exchange rate. The reinforcing loop R1 is working when currency inflow is different from outflow. At the same time, exports and imports are influenced by exchange rate. Simply, the higher is the exchange rate, the more costly are foreign goods to import, and the cheaper are goods and services to export. This relationship should be presented in the international trade sector within the big macroeconomic model and feedback to the exchange rate model. In order to represent the effect of exchange rate on international flows of currency, in this simple model exchange rate has a smoothed effect on imports and export (dashed blue lines on CLD). Two counteracting loops B1 and B2 are responsible for balancing export and import due to changes of exchange rate.

The key goal of National Bank of Ukraine is to ensure a stable and permanent behavior of exchange rate. For this purpose, NBU joins the interbank foreign-exchange market and uses its powerful tool of interventions selling or buying foreign currency due to imbalances of the supply and demand on the market creating an additional flow of foreign currency. In the model, the “Target Ex Rate” represents the value of exchange rate in the long-run perspective. If export to import ratio is different from 1 in long-run, which is explained by

chronic deficit of balance of payment, central bank changes its target smoothly until the balance of payment reacts on the new exchange rate. Figure 9 shows the causal-loop diagram with exchange rate targeting policy. Balancing loop B3 in this model determines the value of currency interventions in order to reach the target level. The higher is the exchange rate from its target level, the greater is the amount of foreign currency sold by central bank on the open market. Reinforcing loop (R2) determines the variable target of the exchange rate due to the real flows of currency. Reinforcing loops R3 and R4 are responsible for activating NBU’s interventions due to changes in exports and imports. Counteracting loops B4 and B5 work on balancing imports and exports by influencing the target exchange rate.

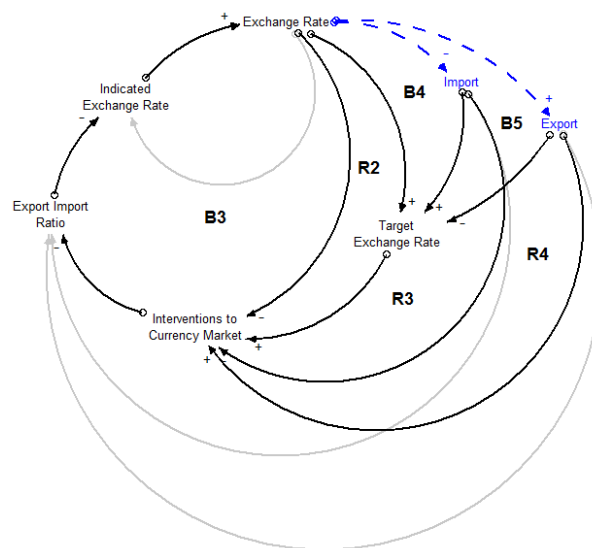


Figure 9. Causal-loop diagram of exchange rate targeting policy

In order to test the model, assume a sudden decrease of exports by 10% at the second-year point. Figure 10 presents the results of simulation. We run the model with and without targeting policy. If central bank does not join the foreign exchange market providing a free float policy (see graph A), exchange rate immediately reacts

on the decrease of foreign currency supply on the market. At the same time, the growth of exchange rate affects imports and exports. This effect creates additional delay in the system causing damped oscillations before stabilizing exchange rate on the new equilibrium level. The second run with targeting policy (see graph B) shows that foreign currency interventions are able to avoid volatility of exchange rate and ensure its smoothed change.

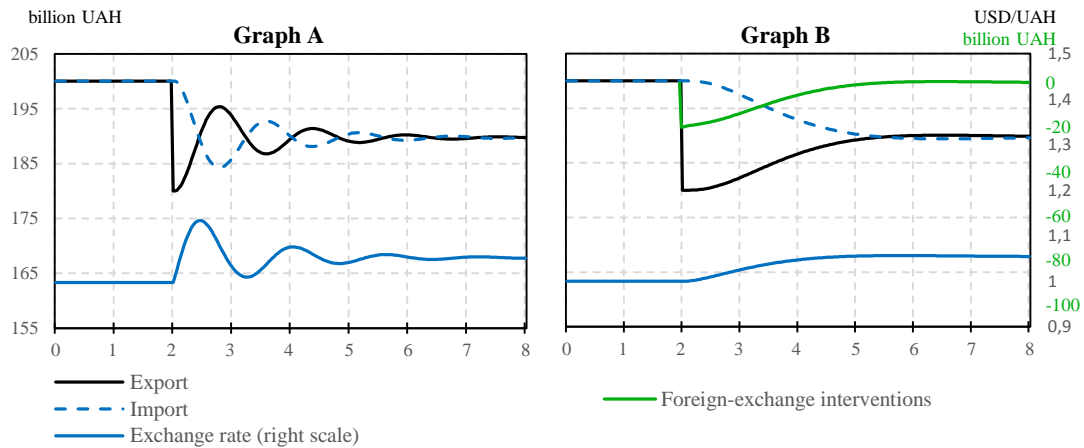


Figure 10. Exchange Rate Model Test
A – free float. B – exchange rate targeting

The managed float regime model is usually useful for emerging economies as it helps to avoid fluctuations in exchange rates on volatile markets. On the other hand, central bank should use its reserves of foreign currency in order to conduct interventions. This can be very dangerous for the financial system and economy as the country becomes dependent to foreign loans. Moreover, the R2 loop is usually broken in such foreign-exchange regime models and central bank defines a fixed target for exchange rate due to factors that are not based on foreign currency flows. For the period 2002-2010 Ukrainian central bank frequently conducted currency interventions in order to fix the exchange rate on the level of 5 UAH per USD. The financial crisis in 2008 was the cause of rapid decrease in exports and investments to the country, and, thus, a fast outflow of central bank's foreign assets. National Bank of Ukraine devaluated currency by 40% in order to balance foreign currency flows. The R2 loop of variable target is not working in Ukraine as the central bank strictly fixes exchange rate or rapidly devaluates domestic currency. Only in some cases, the National Bank determined the target for exchange rate due to the foreign currency flows and their potential pressure on the exchange rate.

Monetary base adjustment. As was discussed above, the policy of the National Bank of Ukraine is based on exchange rate targeting. According to the “impossible trinity” theory (Obstfeld, 2004), exchange rate targeting policy together with free flow of capital prevents the central bank of using independent monetary policy. In other words, the monetary policy of money supply adjustment of NBU depends on external causes. Due to the assumption that the price level in Ukraine is mostly caused by cost-push factors, NBU regulates the money supply in order to keep the purchase ability in the country by using its main monetary tools:

open market operations and refinancing of banks in the form of purchase agreements.

Figure 11 illustrates the causal-loop diagram of monetary policy of Ukrainian central bank. The cost-push effect causes the decrease of real aggregate demand. According to the quantitative theory of money, the amount of money available in the financial system equals to the price level multiplied by the real demand and divided by money velocity. Thus, in order to ensure the ability to purchase goods and services produced in the country with current prices, NBU determines the required amount

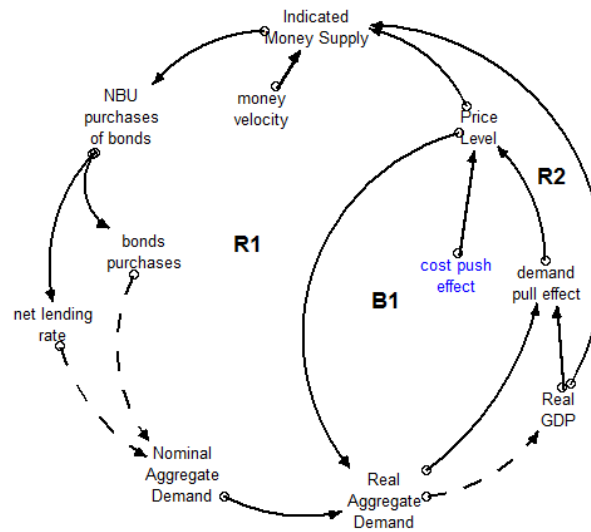


Figure 11. Causal-loop diagram of money supply adjustment

of money, meaning money supply, and required amount of monetary base using estimations of money multiplier. Injections of new money create money supply within the monetary transmission mechanism increasing the nominal demand and, thus, purchase ability. Two reinforcing loops (R1 and R2) are working in order to overcome the effect of the balancing loop B1 that is activated by cost-push effect.

Simulation results. In order to test the structure of monetary transmission and monetary policy models and explore whether it reproduces the actual historical behavior of money supply, we run the model with estimated parameters of cash to deposit, desired liquidity, and required reserve ratios of Ukrainian banking system for the period 2002-2010.

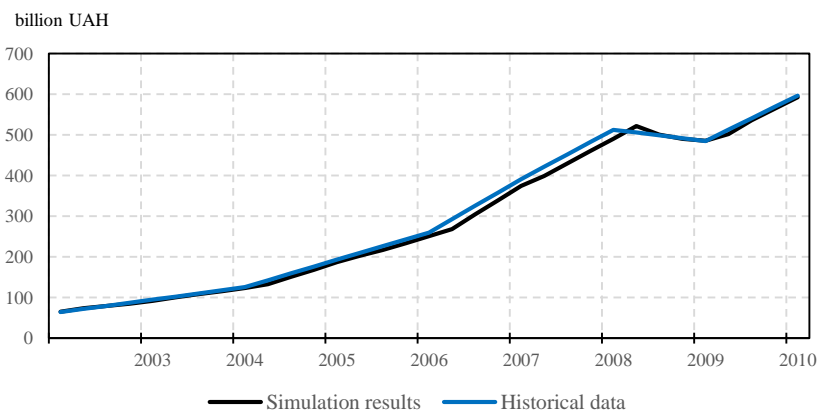


Figure 12. Money supply in Ukraine for the period 2002-2010.

Figure 12 portrays the results of simulation where blue curve shows historical behavior of money supply, while black curve presents simulation results. From

2002 money supply increases by more than nine times. This behavior was mostly caused by injections of new money by central bank. Moreover, the decrease of required reserve ratio and cash to deposit ratio due to the development of electronic payments and banking system in general had a positive effect on the money supply growth. The structure reproduces behavior that fits the data fairly well. However, a big limitation of the model is the use of exogenous inputs. In the monetary transmission mechanism, in addition to exogenously estimated ratios, the stock of other liabilities is changing exogenously. The monetary policy model uses as inputs exogenous data of domestic production and price level in order to determine the monetary base adjustment. These are the main fields of interest in further research. Endogenous structure of monetary transmission mechanism together with connection to the big macroeconomic model will be used in order to test the effects of different monetary policies, such as inflation targeting policy.

Conclusions

This paper presents the system dynamics model of Ukrainian monetary sector as a separate part of the big macroeconomic model of Ukraine within the project between National University of “Kyiv-Muhyla Academy” in Ukraine and University of Bergen in Norway. The model includes the monetary transmission mechanism model and the monetary policy model. Money creation process is presented using the balance sheet structure where banks manage their assets and liabilities trying to keep desired levels of reserves, giving loans to households and firms and buying state bonds providing the process of money supply creation in economy. National bank of Ukraine is the main institution that conducts monetary policy and is able to regulate money creation. Due to a strong dependence on foreign trade and international capital flows, Ukrainian monetary policy is aimed to keep stable exchange rate of domestic currency in order to ensure price stability. Thus, the policy of central bank appears in targeting the exchange rate using currency interventions on the open foreign-exchange market. Exchange rate targeting prevents the central bank of using independent monetary policy, thus, the money supply adjustment is conducted in order to keep the purchase ability and prevent the decline of domestic production due to the changes of production costs. The simulation showed that model structure generates behavior that fits the data fairly well. However, on the current step of the research the model includes exogenous inputs from other sectors, thus, the integration of the model structure to the main macroeconomic model of Ukraine is required in order to investigate the overall effects. The price level and exchange rate models, as well as interest rate model, require detailed structure in order to represent endogenous relationships within the big macroeconomic model. Moreover, the interactions of the monetary sector with consumption, capital, and international trade sectors require additional attention to these models.

The efficiency and feasibility of NBU's monetary policy of exchange rate targeting is under big discussion between economist and politicians in Ukraine. Stabilizing the exchange rate, National Bank is using its foreign reserves in order to cover the demand on foreign currency damping the pressure on exchange rate. In order to fill up foreign reserves, National Bank is taking new loans from foreign governments and international institutions. It appears that such policy is costly and is not controlling inflation in the country. The topical issue, within the cooperation with International Monetary Fund and orientation to European integration, is shifting from exchange rate targeting to inflation targeting, meaning the use of independent monetary policy of money supply regulation in order to manage inflation. The system dynamics model of money creation in Ukraine is an important tool to test the effect of different monetary policies on the banking system and represent the process of monetary policy implementation.

Moreover, the monetary transmission and monetary policy models within the big macroeconomic model of Ukraine can be used as a teaching tool in learning economics to represent economic cause and effect relationships in dynamics. Implementation of such techniques in the teaching process in National University of "Kyiv-Mohyla Academy" will be a valuable contribution to education and science development in Ukraine.

Literature

Levy-Yeyati, E., Sturzenegger, F. (2000). *Classifying exchange rate regimes: Deeds vs. Words*, Buenos Aires, Argentina

Mankiw, N. G. (2004). *Macroeconomics* (7th ed.). New York: Worth Publishers

Obstfeld, M., Shambaugh J.C., Taylor, A. M. (2004). *The Trilemma in History: Tradeoffs among Exchange Rates, Monetary Policies, and Capital Mobility*, The Review of Economics and Statistics, MIT Press, vol. 87(3), 423-438

Robert J. Gordon (1988). *Macroeconomics: Theory and Policy* (2nd ed.) Chap. 22.4, Modern theories of inflation, McGraw-Hill Companies

Sterman, J. D. (2000). *Business Dynamics: Systems Thinking and Modeling for Complex World*, MA: McGraw-Hill Companies

Wheat, I. D. (2007). *The Feedback Method: A System Dynamics Approach to Teaching Macroeconomics*, PhD dissertation, University of Bergen, Norway

Data source: <http://www.bank.gov.ua/>

APPENDIX

Monetary transmission mechanism and monetary policy equations

	Equations	Units
Reserves	$\text{Reserves}(t - dt) + (\text{reserves additions} - \text{net lending rate} - \text{bonds purchases}) * dt$ INIT Reserves = init(Reserves data)	UAH
Reserves additions	net chng in liabilities + NBU bonds purchases	UAH/y
net chng in liabilities	making deposits - net withdrawals	UAH/y
Deposits	$\text{Deposits}(t - dt) + (\text{making deposits} - \text{joining equity} - \text{net withdrawals} - \text{chng in OL}) * dt$ INIT Deposits = init(Total Deposits data)	UAH
Making deposits	net lending + bonds purchases	UAH/y
Bonds	$\text{Bonds}(t - dt) + (\text{bonds purchases} - \text{NBU bonds purchases}) * dt$ INIT Bonds = init(Bonds data)	UAH
Bonds purchases	(Indicated Bonds-Bonds)/bonds adj time	UAH/y
Indicated Bonds	desired liquidity ratio*Deposits	UAH
desired liquidity ratio	desired liquidity ratio data	1/1
Bonds adj time	0.04	years
Loans	$\text{Loans}(t - dt) + (\text{lending rate} - \text{loan repayments}) * dt$ INIT Loans init(Total Loans Data)	UAH
Net lending	lending rate – loan repayments	UAH/y
Loan repayments	Loans/5	
Indicated lending	(Reserves-Reserves Demand)/0.04-bonds purchases + loan repayments	UAH/y
Reserves Demand	Deposits*reserve limit ratio	UAH
Reserve limit ratio	reserve limit ratio data	1/1
Cash	$\text{Cash}(t - dt) + (\text{net withdrawals}) * dt$ INIT Cash = init(Cash data)	UAH
net withdrawals	(Deposits*CD ratio-Cash)/Cash adj time	UAH/y
Cash adj time	0.5	years
CD ratio	CD ratio data	1/1
Equity	$\text{Equity}(t - dt) + (\text{joining equity}) * dt$ INIT Equity = init(Equity data)	UAH
Joining equity	(capital adequacy ratio*Deposits-Equity)/equity adj time	UAH/y
Capital adequacy ratio	0.3	1/1
Equity adj time	0.5	years
Other Liabilities	$\text{Other Liabilities}(t - dt) + (\text{chng in OL}) * dt$ INIT Other Liabilities = init(Other Liabilities data)	UAH
Chng in OL	Chng in OL data	UAH/y
Total Assets	Reserves + Bonds + Loans	UAH
Total Liabilities	Deposits + Equity + Other Liabilities	UAH
Indicated MB adjustment	(Desired monetary base-Monetary Base)/time to chng MB	UAH/y
Desired monetary base	Desired Money Supply/Money Multiplier	UAH
Monetary Base	Reserves + Cash	UAH
Time to chng MB	0.25	years
Money Multiplier	(1+CD ratio)/(reserve limit ratio + CD ratio)	1/1
Desired Money Supply	potential real demand * price Index / money velocity * desired inflation	UAH
Potential real demand	Real Aggregate Demand Data	UAH
Price Index	Price data	1/1
Money Velocity	Money velocity data	1/year

Experimental price model equations

	Equations	Units
Price	$\text{Price}(t - dt) + (\text{chnge in price}) * dt$ INIT Price = 1	1/1
Chng in price	$(\text{Indicated Price} - \text{Price})/0.25$	1/year
Indicated Price	Price*demand-pull effect*cost-push effect	1/1
Demand-pull effect	Real Aggregate Demand / Real GDP	1/1
Real Aggregate Demand	Nominal Aggregate Demand / Price	UAH
Nominal Aggregate Demand	225	UAH
Real GDP	SMTH1(Real Aggregate Demand,5)	UAH
Cost-push effect	unit production cost / Price	1/1
Unit production cost	$(1 - \text{weight of import in production}) * \text{unit cost of domestic production} + \text{weight of import in production} * \text{unit import cost}$	1/1
Weight of import in production	0.2	1/1
Unit cost of domestic production	1	1/1
Unit import cost	imported inflation * Exchange Rate	1/1
Imported inflation	1	1/1
Exchange Rate	1	1/1

Experimental exchange rate model equations

	Equations	Units
Ex Rate	$\text{Ex Rate}(t - dt) + (\text{chnge in ex rate}) * dt$ INIT Ex Rate = 1	1/1
Chng in ex rate	$(\text{Indicated Ex Rate} - \text{Ex rate})/\text{ex rate adj time}$	1/year
Indicated Ex Rate	Ex rate/ Export/Import ratio	1/1
Ex rate adj time	0.04	years
Export/Import ratio	$(\text{Inwards}) / (\text{Outwards} + \text{Interventions to currency market})$	1/1
Imports	smth1(200/Ex rate,0.25)	USD/y
Exports	smth1(200*Ex rate,0.25)	USD/y
Target Ex rate	SMTH1((Ex rate/(Export/Import)),time to perceive ex rate)	1/1
Time to perceive ex rate	3	years
Interventions to currency market	$(\text{Export} * (\text{Target Ex rate}/\text{Ex rate}) - \text{Import})$	USD/y