National Bank of Ukraine

SMART: Systemic Macrofinancial Analysis Regulatory Toolkit for Ukraine

Kyiv, April 14, 2025

Motivation

- After the National Bank of Ukraine (NBU) received the mandate to conduct macroprudential policy, there was a need to develop tools for macro-level modeling of interrelations between the real and financial sectors. First of all, this is due to the fact that fluctuations in the financial sector can amplify shocks and vulnerabilities of the real sector, becoming the cause of the crisis or intensifying its consequences.
- At that time, the NBU already had a macro model – the Quarterly Projection Model (QPM) – to provide regular macroeconomic forecasts and recommendations for monetary policy. However, this model did not include the financial sector.
- Given that including the financial sector in the QPM could lead to its excessive complexity, it was decided to develop a separate **macrofinancial model for the purposes of macroprudential policy SMART** (*Systemic Macrofinancial Analysis Regulatory Toolkit*).
- The model was developed with technical assistance from the EBRD under the guidance of experts from OGResearch (Prague, Czech Republic).
- The development of the basic version of the model is completed in 2022, in 2023–2024 the adaptation of the model to war and postwar conditions is carried out.
- The model is implemented in Matlab using IRIS Toolbox.

Main areas of model use

The *main purpose* of SMART is to support financial stability decisions and help in choosing the path of macroprudential policy, taking into account current and future macroeconomic conditions.

The model is not intended for forecasting purposes, unlike QPM.

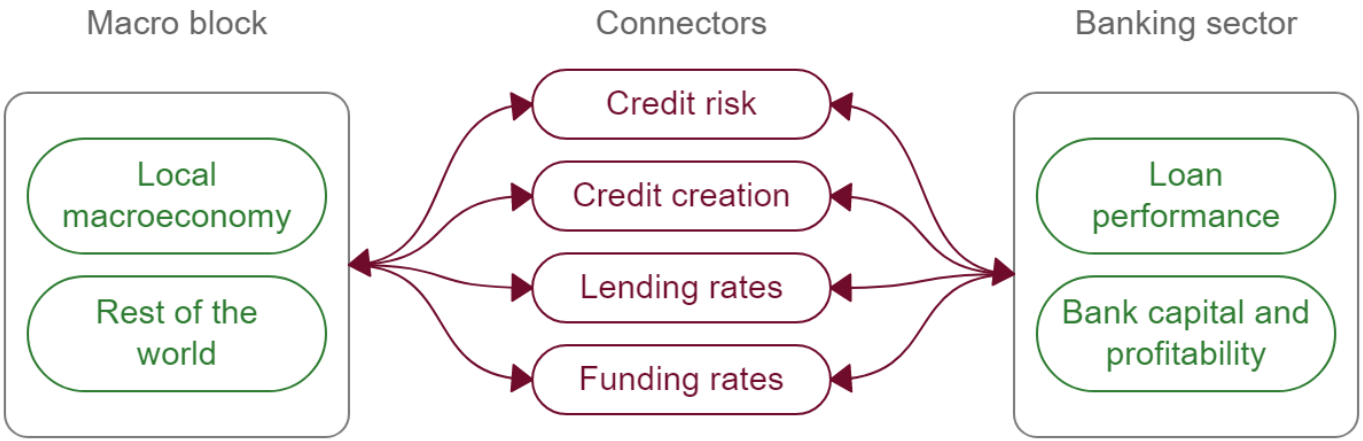
- **Simulation of scenarios to analyze the underlying dynamics of model variables and the effects of various shocks on the financial sector and the real economy**
  - The baseline scenario is built on the model equations and additionally adjusted against the current state of the economy and financial sector, as well as the macroeconomic forecast. This scenario does not include any exogenous shocks.
  - Simulation of scenarios with various macroeconomic and/or financial shocks, including for the purposes of stress-testing of the banking sector at the macro level.
  - Developing parameters of an adverse macroeconomic scenario for bank stress-testing: appropriate macroeconomic shocks are imposed on top of the baseline scenario.
- **Macroprudential policy effects analysis**
  - Effects of introduction/release of capital requirements, as well as liquidity requirements.

Main features of the model

1 The model is semi-structural	▪ includes structural and non-structural equations ▪ contains unobservable variables, including trends and gaps ▪ in the long run, model variables move to their steady states ▪ two-way interactions between the economy and the banking system ▪ does not describe the behaviour of economic agents (microfoundations) ▪ considers current and future (based on QPM) macroeconomic conditions
2 The banking sector is on an aggregate basis	▪ individual bank balance sheets are not included in the model ▪ does not cover the non-bank institutions
3 Nonlinearity and asymmetry of relationships between variables	▪ credit risk function: in crisis, changes in macroeconomic conditions affect borrowers' default rates to a greater extent than in “normal” times ▪ capital function: the lower the actual capital of banks is from the “comfortable” level, the more banks will raise loan rates ▪ asymmetry of the reaction of deposit rates to changes in the key policy rate
4 The presence of endogenous feedback effects	▪ definition: the results of a model are partially or fully used as input to the same model (feedback loop) ▪ example: deterioration in macroeconomic conditions leads to tighter lending conditions by banks, which further negatively affects the real sector

Model modules

The model includes the following **modules**: macroeconomic block (domestic and foreign economies) and banking sector (loans, bank capital and profitability) which are connected by 4 block-connectors (credit risk, credit creation, lending and funding rates).



Banking sector’s balance sheet

- The balance sheet of the banking sector is presented in the model at the aggregate level.
- Loans are separated by corporates and households, and deposits by currencies – national and foreign.
- Outstanding loans are classified as performing and non-performing.
- Capital includes retained earnings.

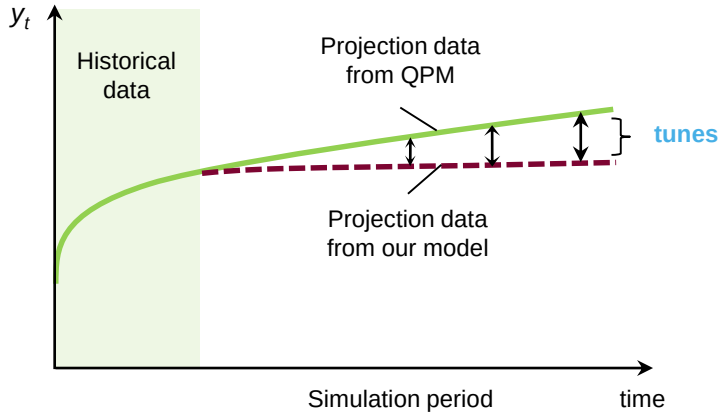
Assets	Liabilities and capital
Net loans	Liabilities
+ Outstanding loans	Deposits
– Provisions	Other liabilities
Government bonds	Capital
NBU certificates of deposit	Equity capital
Other net assets	Retained earnings

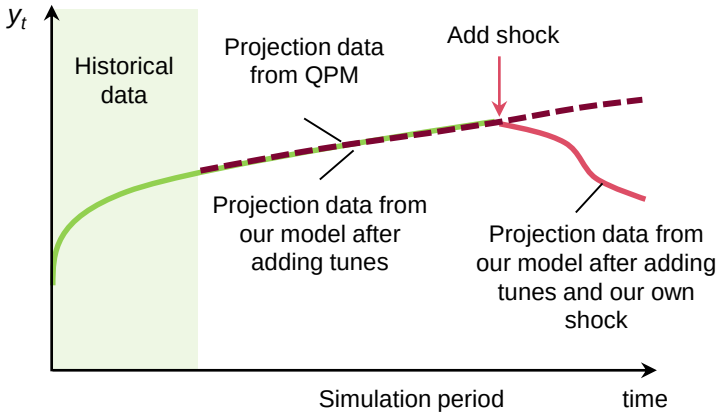
Macroeconomic module

- The module describes the dynamics of real and nominal GDP identities, GDP gap and trend, deflator, asset prices, CPI, inflation expectations, monetary policy reaction function (short-term money market rate), real and nominal exchange rates.
- We proceed from the assumption that macro block variables should generally show the same dynamics as the variables in the QPM.
- To make the dynamics of macro variables similar with variables from the QPM, we employed the following:
  - We applied the macroeconomic forecast from the QPM as a starting point for our own scenarios, namely – to allow the exact path of the QPM macro variables to be reproduced without losing the ability to change in response to shocks in other model variables (*the delta method*).
  - The variables derived from the QPM are domestic and foreign real GDP gap and its trend, the short-term money market rate and trend of its real form, inflation, and the nominal exchange rate to US dollar.

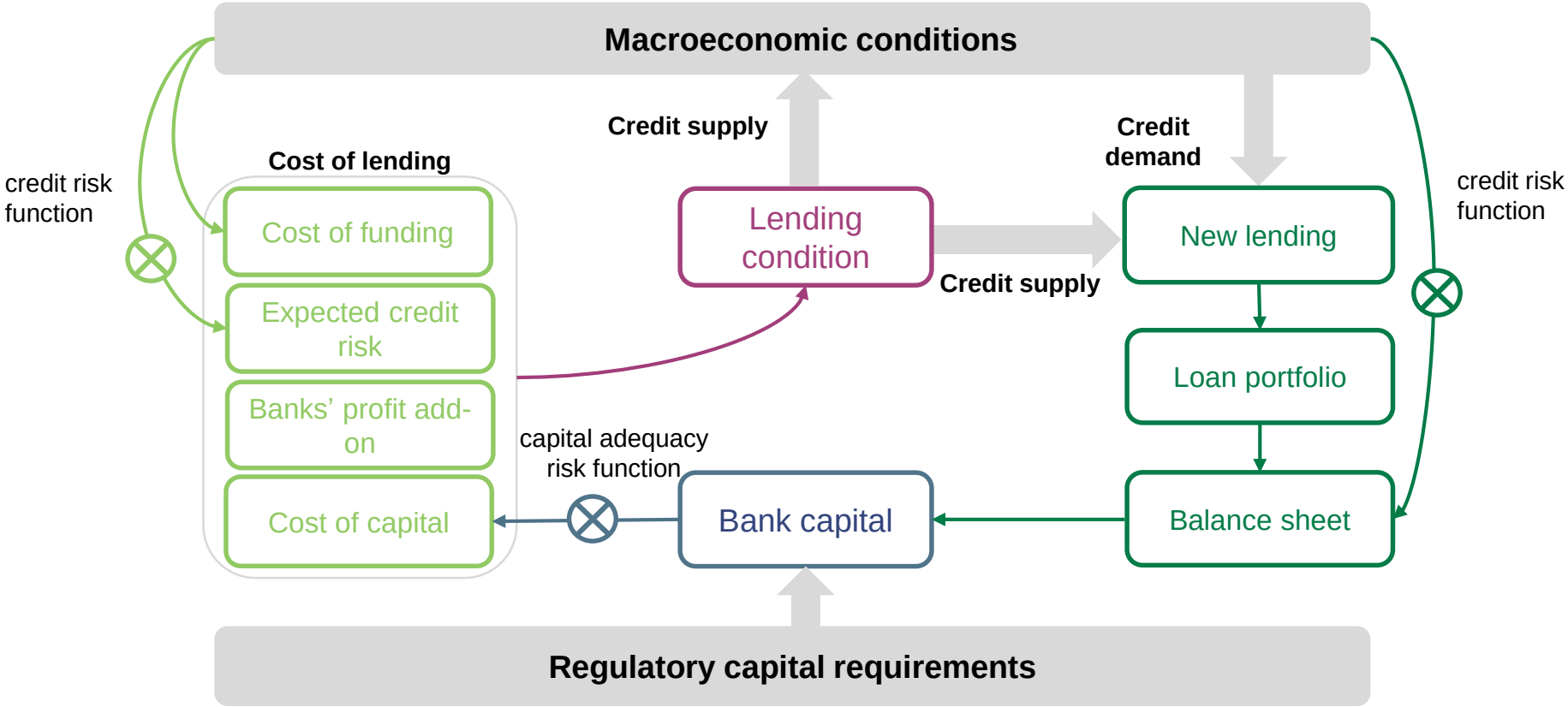
Macroeconomic module – The delta method procedure

i. Upload the historical data and macroeconomic forecast from the QPM.
ii. From QPM's set of variables, select macro variables used in our model.
iii. Simulate baseline scenario.
iv. Calculate the difference between the path of the variable from QPM (taken from i) and the path of the variable from our simulation (taken from iii) within the each variable from the selected set (see ii). This differences (add-factors) we call ***tunes***. Save obtained tunes and add them to our model macro equations (for each period of time *t*).
v. Then, for further scenarios building, we add shocks on top of the baseline scenario with tunes.



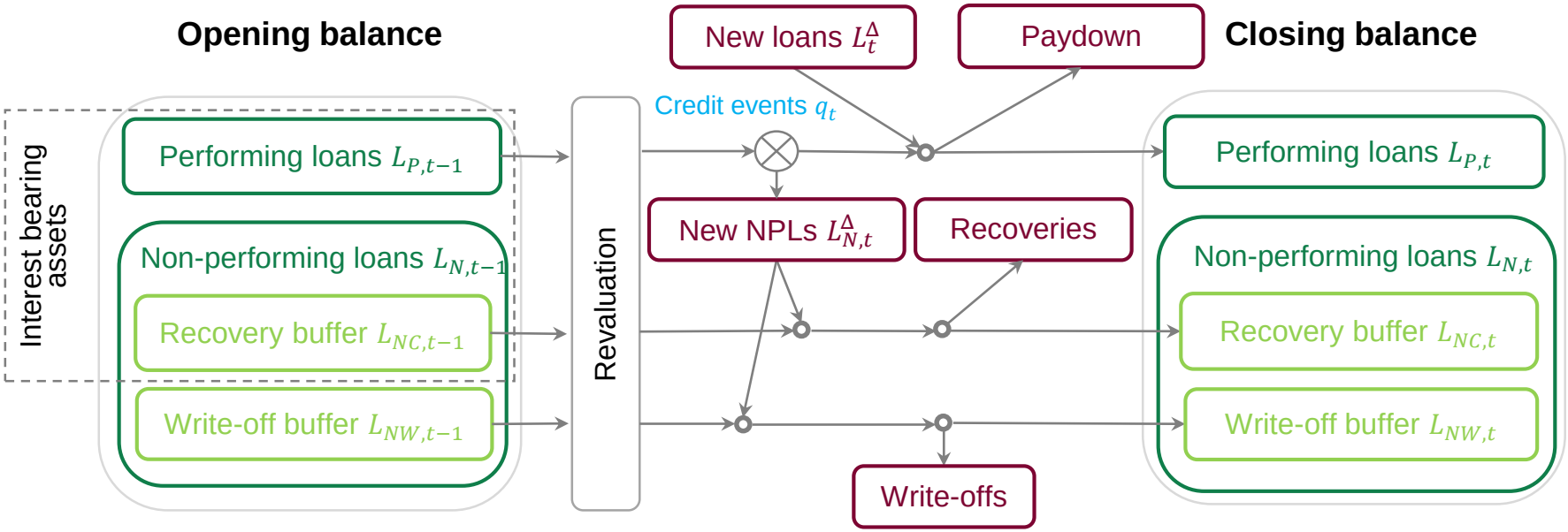


General scheme of model dynamics: lending in focus



⊗ – nonlinear relationship

Loan performance – Stock-flow dynamics

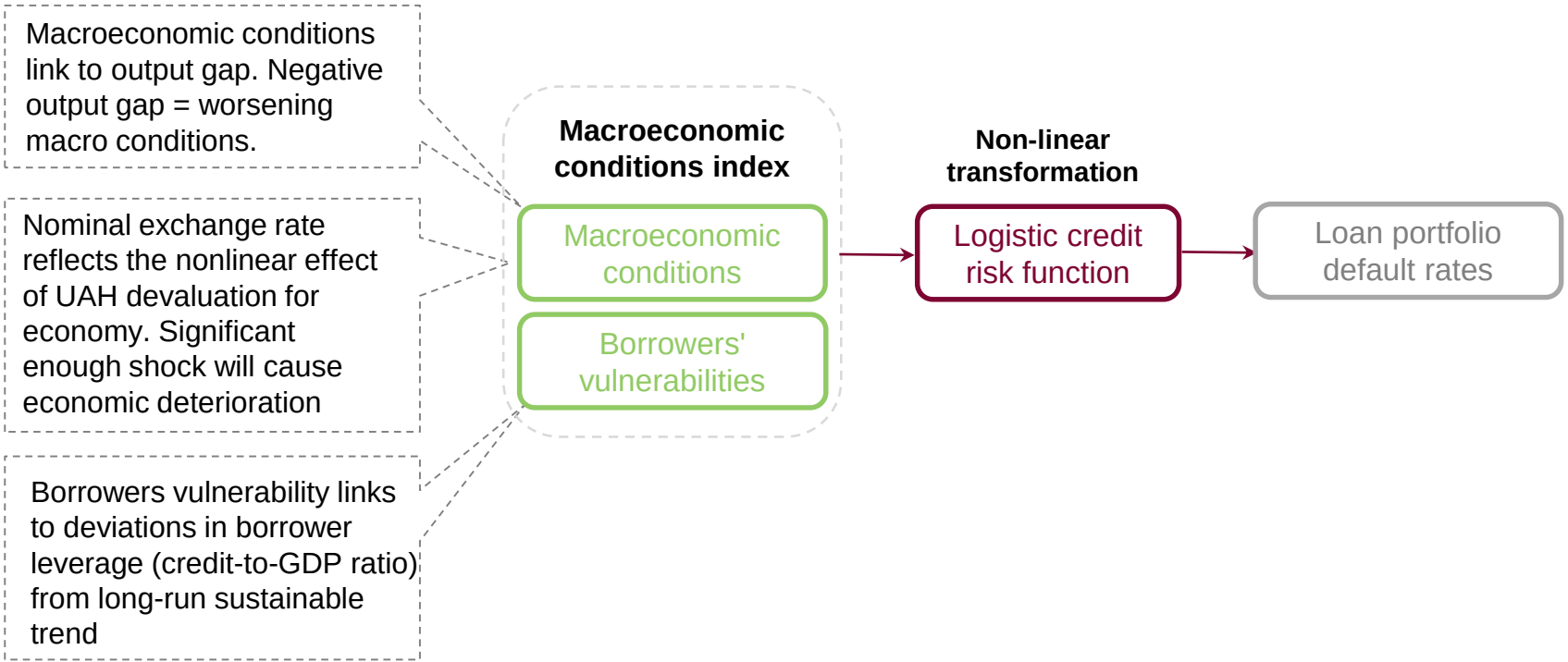


- Bank loan portfolio consists of two segments: **households** and **corporate sector**.
- Nonperforming loans break down into a **recovery buffer** (to be gradually recovered) $L_{NC,t}$ and a **write-off buffer** (to be gradually completely written-off) $L_{NW,t}$.

⊗ – nonlinear relationship

Credit risk

Credit risk function translates macroeconomic conditions and borrowers' vulnerabilities (macroeconomic condition index, MCI) into loan portfolio default rates.



Credit risk function

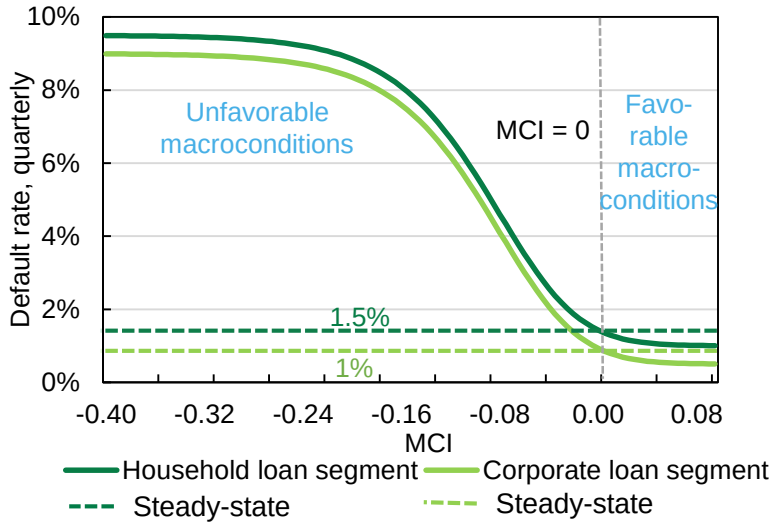
$$q_t = \underline{q} + \left(\overline{q} - \underline{q}\right) \cdot \left[1 + \exp\left(-\frac{MCI_t - \mu}{\sigma}\right)\right]^{-\exp\vartheta}$$

- The credit risk function is

  nonlinear: changes in the macroeconomic conditions index of the same magnitude can lead to different changes in the share of defaulted loans in crisis and “normal” times;

  asymmetric: in crisis times, changes in macroeconomic conditions affect the level of borrowers' defaults to a greater extent than in “normal” times.

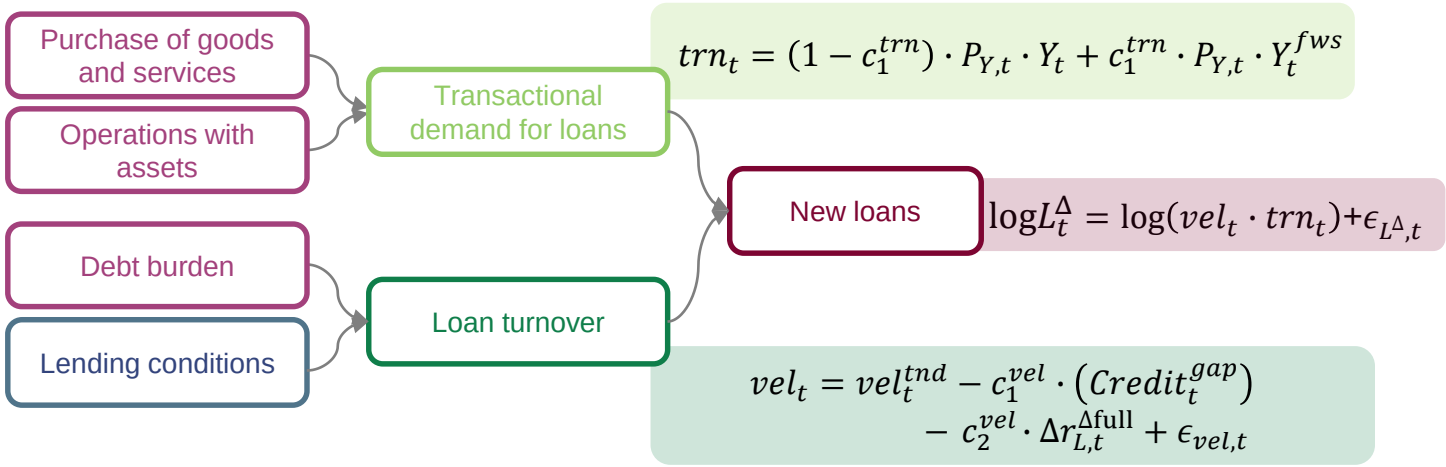
Schematic illustration of the credit risk function



- Macroeconomic conditions index indicates:

  MCI = 0 ⇒ “neutral” times
  MCI < 0 ⇒ unfavorable macroeconomic conditions: a decrease in the index leads to an increase in the portfolio default rate
  MCI > 0 ⇒ favorable macroeconomic conditions: an increase in the index leads to a decrease in the portfolio default rate

Credit creation



- The demand for new loans L_t^{Δ} is driven by the need to finance transactions in the economy:
  - transactions for the **purchase of goods and services**,
  - transactions related to **operations with assets.**
- Current period's transactions trn_t comprise new value added Y_t and trade in existing assets Y_t^{fws} adjusted on GDP deflator $P_{Y,t}$.
- The volume of transactions in monetary terms is weighted by the speed of loan turnover vel_t, which is influenced by the **loans-to-GDP gap** $Credit_t^{gap}$ and credit supply factors, such as **lending conditions** $\Delta r_{L,t}^{\Delta full}$.

Funding rates setting

Funding rates are considered separately for **local** and **foreign currency**. We do not divide liabilities between households and corporate sector.

New funding rates

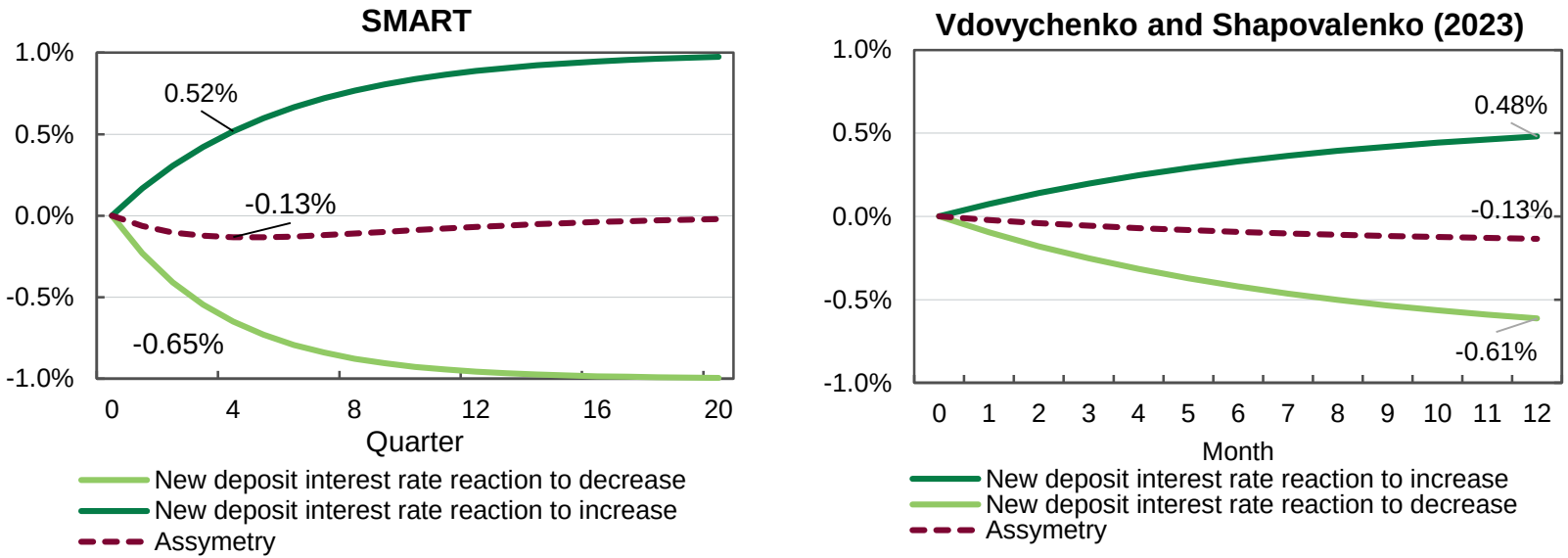
The new funding rates are set as a markup $r_{D,t}^{pm}$ over short-term funding liability rate $r_{P,t}$ (averaged across the currencies of denomination) as well as dynamics of interest rates (easing or tightening).

Short-term funding liability rate in local currency equals short-term money rate r_t.

Short-term funding liability rate in foreign currency equals foreign short-term money rate r_t^w.

Funding interest rates pass-through

New deposit interest rate reaction to key policy rate change by 1 p.p.



- Calibration of deposit interest rate pass-through according to Vdovychenko and Shapovalenko (2023).
- Full transmission: increase key policy rate – 17 quarters, decrease key policy rate – 12 quarters.
- Limitation of calibration: Vdovychenko and Shapovalenko (2023) – household term deposits in UAH; SMART – all deposits in UAH.

New lending rates and further transmission

Each period, banks set a **new lending rates** $r_{L,t}^{\Delta}$ for two segments (households and corporate sector) determined by the bank costs and risks:

In the real world, the observed lending rates typically only partially reflect the anticipated losses. The rest is expressed in new non-price lending conditions (collateral or insurance requirements, commissions etc).

So, **in the model**, we distinguish two types of new lending rates:

1 **New lending rates with full risk adjustment**

affect aggregate demand and asset prices

$$\left(1 + r_{L,t}^{\Delta\text{full}}\right) = \left(1 + r_{CR,t}\right) \cdot \left(1 + r_{BK,t}\right) \cdot \left(1 + r_{L,t}^{pm}\right)$$

- $r_{CR,t}$: Cost of funding adjusted for expected credit losses
- $r_{BK,t}$: Bank capital adequacy add-on
- $r_{L,t}^{pm}$: Profit margin add-on

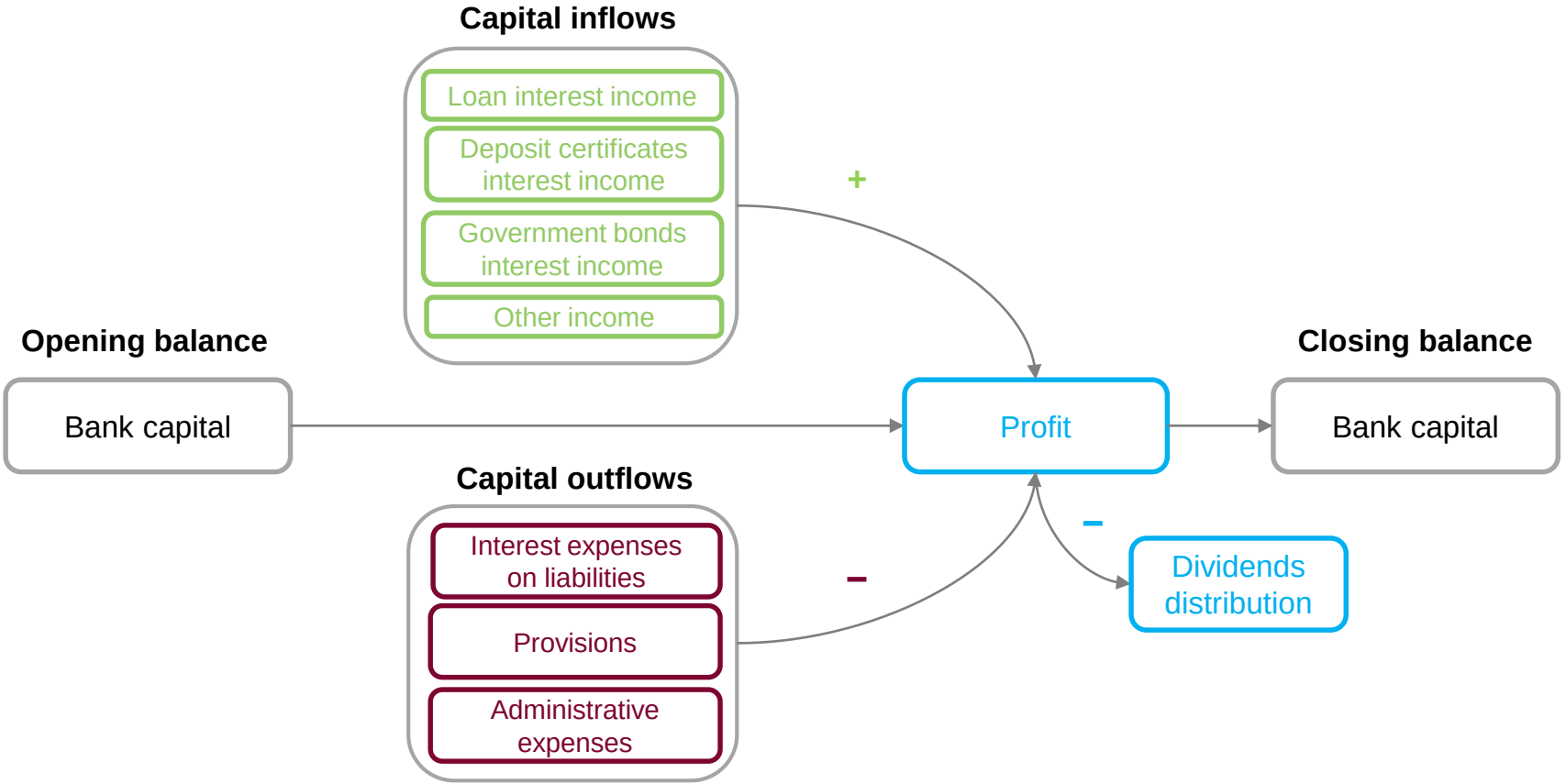
2 **New lending rates with partial risk adjustment**

impact stock lending rates and interest income

$$r_{L,t}^{\Delta\text{part}} = r_{L,t}^{*} + c_1 \cdot \left(r_{L,t}^{\Delta\text{full}} - r_{L,t}^{*}\right) + (1 - c_1) \cdot \left(\bar{r}_{L,t}^{\Delta\text{full}} - \bar{r}_{L,t}^{*}\right) + \epsilon_{r_{L,t}^{\Delta\text{part}}}$$

- $r_{L,t}^{*}$: Cost of funding
- $\left(r_{L,t}^{\Delta\text{full}} - r_{L,t}^{*}\right) + (1 - c_1) \cdot \left(\bar{r}_{L,t}^{\Delta\text{full}} - \bar{r}_{L,t}^{*}\right)$: Credit risk and capital adequacy adjustment

Bank capital – Accumulation and distribution



Bank capital – feedback to the real sector

- In the long run, banks try to achieve a **comfortable** (target) **level of capital adequacy** CAR^{tar}.
- The comfort level represents the minimum regulatory capital requirements and a certain "safety cushion" that banks hold to absorb losses in the event of an unexpected adverse shock.
- If the shock materializes, actual capital CAR_t falls below the comfortable level CAR^{tar}.
- As CAR_t approaches the **regulatory minimum level** CAR^{min}, banks include a higher capital premium rx_t in lending rates.

$CAR_t < CAR^{tar}$ ⇒ higher loan interest rates
⇒ tightening of lending conditions

$CAR_t > CAR^{tar}$ ⇒ lower loan interest rates
⇒ easing of lending conditions

Capital adequacy risk function

$$rx_t = \underline{rx} + \left(\overline{rx} - \underline{rx}\right) \cdot \left[1 + \exp\left(-\frac{CAR_t - CAR^{min}}{\sigma}\right)\right]^{-\exp\vartheta}$$