GIMM Model Basics

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What is it for?

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- Big-picture modeling of real-financial interactions with endogenous feedbacks
- Macroprudential policy analysis
- Scenario analysis with explicit assumptions
- Synthesize a variety of insights and inputs, including expert judgment

What is it not for?

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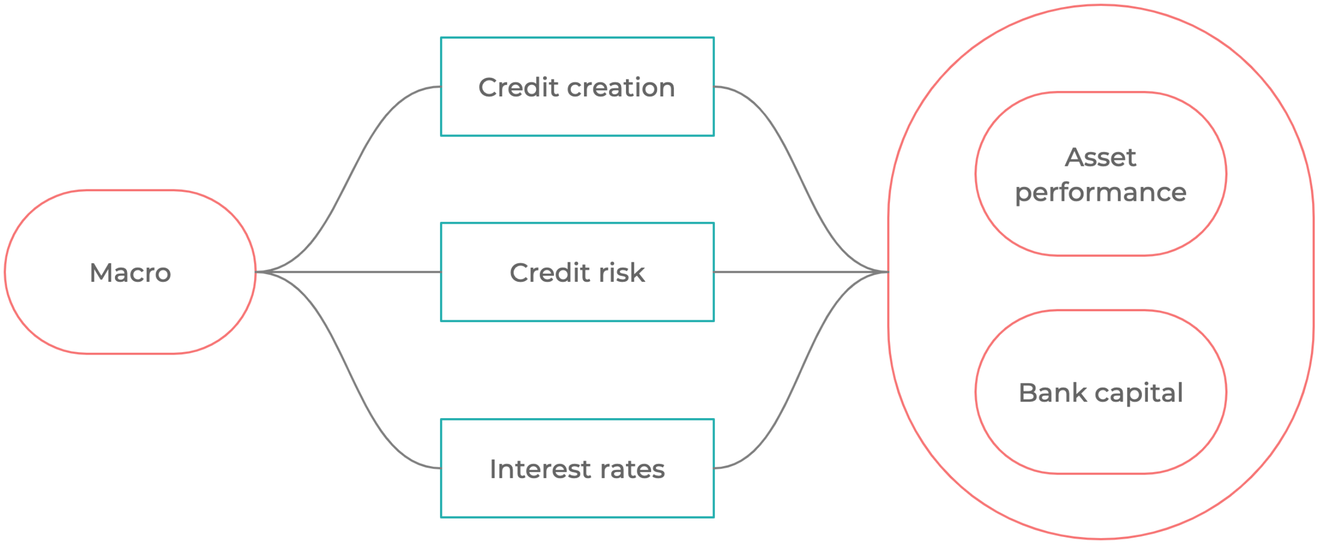
- Forecasting
- Statistical predictions
- Deeply structural, research framework

Use cases

- Conceptual simulations, policy interventions
  - Gain insight into impact on the economy
- Data-based projections, scenarios conditional on macroeconomic scenarios
  - Stress-testing exercises
- Counterfactual simulations
- Comparative static, analysis of equlibrium changes

Modules

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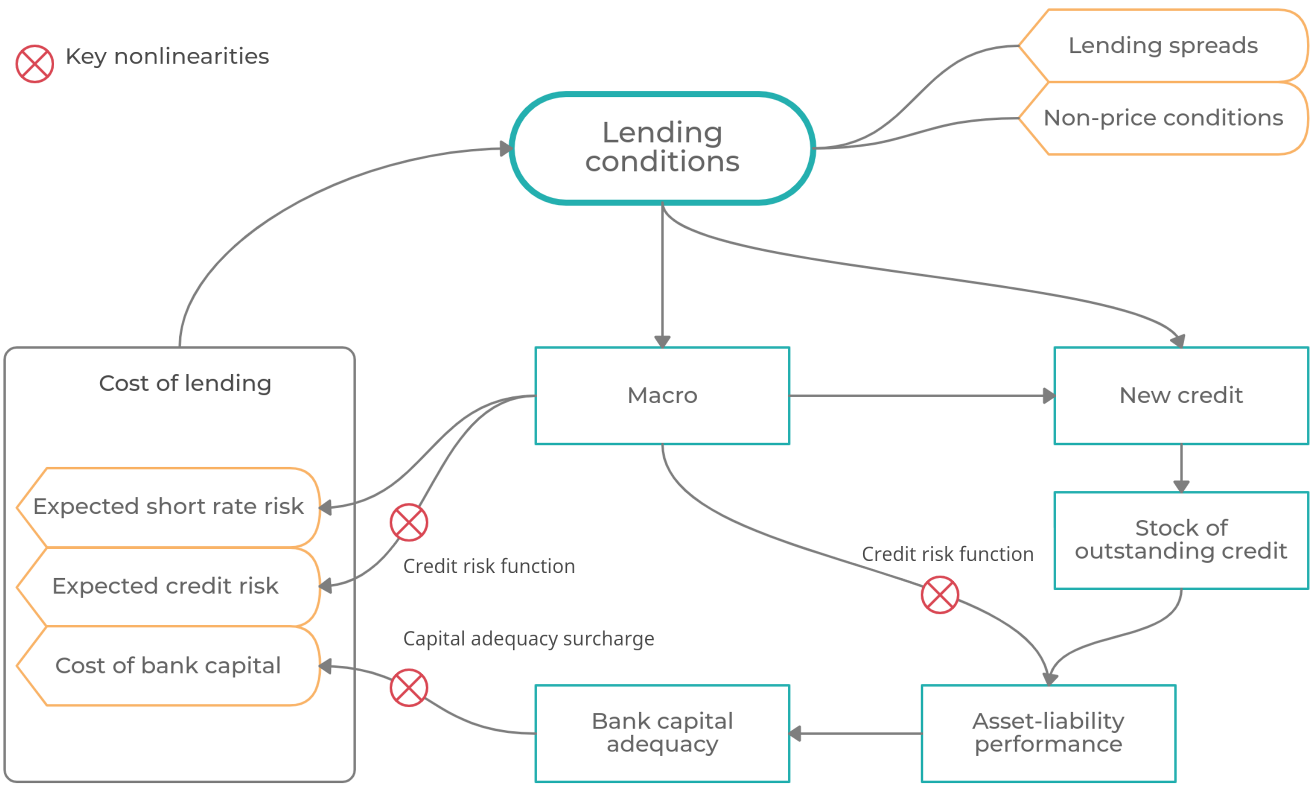
Big picture


Key nonlinearities
Lending conditions
Lending spreads
Non-price conditions
Cost of lending
Expected short rate risk
Expected credit risk
Cost of bank capital
Macro
New credit
Stock of outstanding credit
Credit risk function
Credit risk function
Capital adequacy surcharge
Bank capital adequacy
Asset-liability performance

Bank balance sheet

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	Assets	Liabilities	
le_t	Net loans	Non-equity liabilities	d_t
$+\sum l_t^k$	*Gross loans*	*Local currency*	$d_t^{\text{lcy}}\ +$
$-\sum a_t^k$	*Allowances for credit losses*	*Foreign currency*	$d_t^{\text{fcy}}\ +$
ona_t	Other net assets	Bank capital	bk_t

- All quantities explicitly tracked in LCU
- Further decomposition possible

Riskless loan portfolio

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Assume loan portfolio consists of infinite amount of identical loans:

	Origination	Time 1	Time 2	...
Closing book value	l	$(1-\theta)l$	$(1-\theta)^2 l$	...
Paydown		$\theta\, l$	$\theta\,(1-\theta)l$	...
Interest		$rl_0\, l$	$rl_1\,(1-\theta)l$	...
Total cash flow generated		$(\theta+rl_0)l$	$(\theta+rl_1)\,(1-\theta)l_0$	...

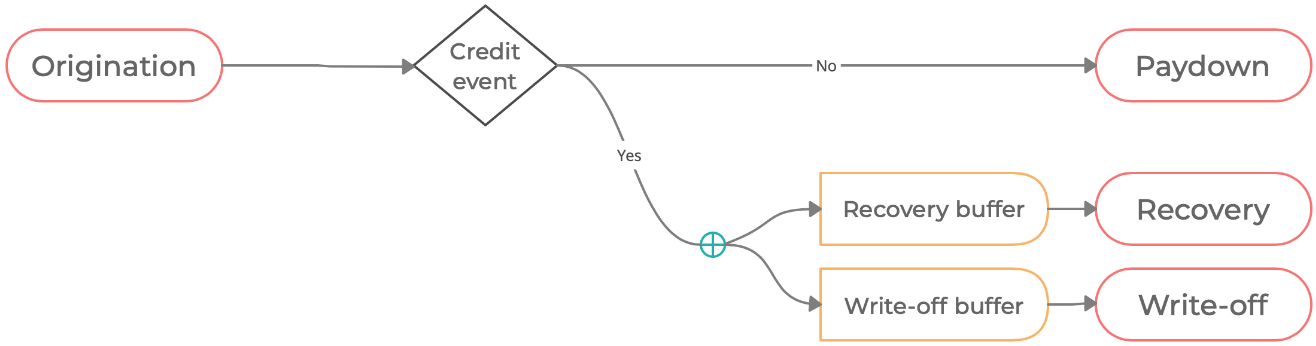
Parameter θ determines the average maturity of the loan portfolio, given as $\frac{1}{\theta}$.

$$l_t = (1-\theta)l_{t-1} + l_t^{\Delta}$$

where l_t^{Δ} is the gross production of new loans.

Credit risk

Each period, each loan faces a possibility of a credit event



Gross loans are classified either as **performing** or **nonperforming**:

$$l_t = lp_t + ln_t$$

NPLs break down into:

- lnc_t: recovery buffer (to be gradually recovered, i.e. generating cashflows)
- lnw_t: write-off buffer (to be gradually written-off),

$$ln_t = lnc_t + lnw_t$$

Split into the buffers takes place at the moment of the credit event, according to LGD parameter.

Evolution of loan portfolio

Portfolio division	Cash Flows	Credit event
Performing lp_t	Paydown, interest	(outflow) $ln_t^\Delta = q_t \ lp_t^0 \rightarrow$
Nonperforming recovery buffer lnc_t	Collections, repossession, resale	(inflow) $\rightarrow (1-\lambda) \ ln_t^\Delta$
Nonperforming writeoff buffer lnw_t	None	(inflow) $\rightarrow \lambda \ ln_t^\Delta$

where:

- ln_t^Δ is the amount of loans that become non-performing in time t
- q_t is the default rate
- λ is the LGD parameter

Stock-flow dynamics in loan portfolio

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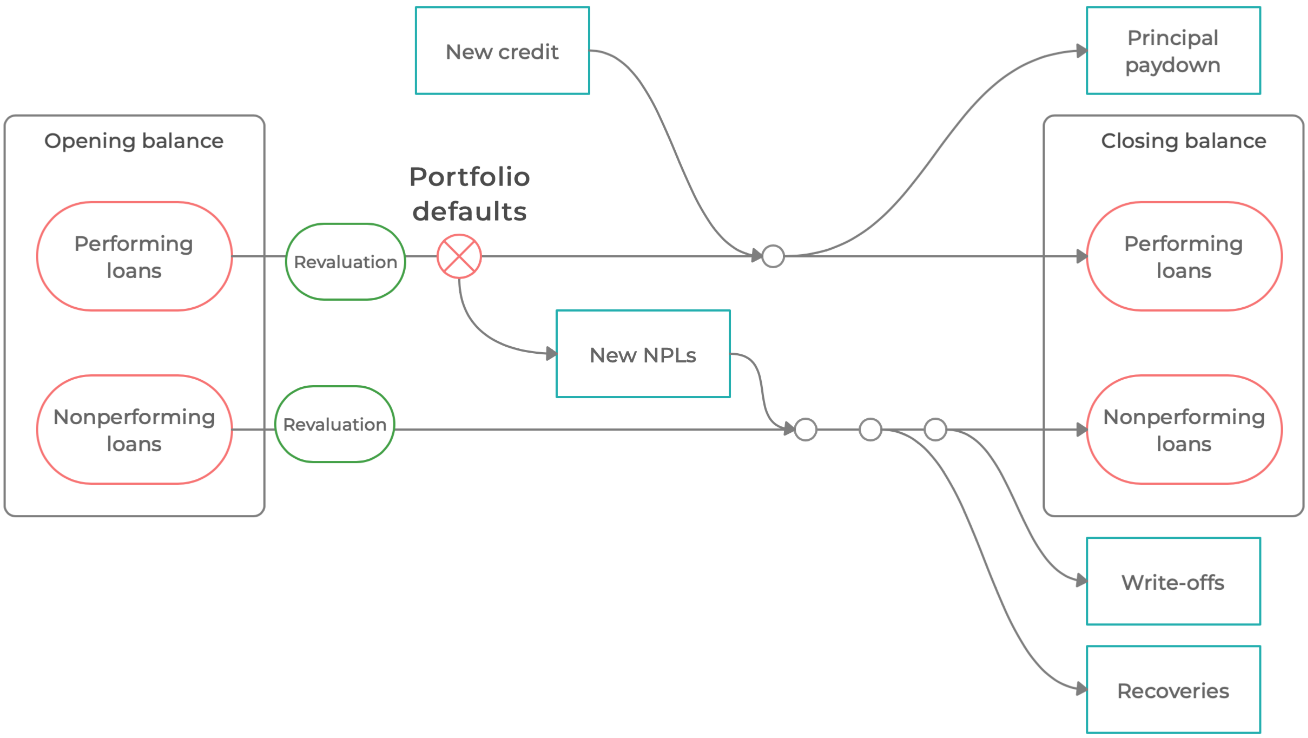


Let's ignore revaluation (FX rate effects) for the moment.

All equations in one place

Assuming no exchange rate valuation.

Performing loans

Closing balance rolled over from previous time $t-1$

$$lp_{t-1}$$

"Opening" balance at new time t: new information (defaults) arrives, adjust the balance for new information

$$lp_t^0 = lp_{t-1} - ln_t^\Delta$$

$$ln_t^\Delta = q_t \; lp_{t-1}$$

Throughout-period cash flows generated by the performing loans: paydown plus interest income

$$(\theta_{lp} + rl_{t-1}) \; lp_t^0$$

Closing balance after paydown and inclusive of new credit l_t^Δ

$$lp_t = (1 - \theta_{lp}) \; lp_t^0 + l_t^\Delta$$

Nonperforming loans: Recovery buffer

Closing balance rolled over from previous time $t-1$

$$lnc_{t-1}$$

"Opening" balance at new time t: new information (defaults) arrives, adjust the balance for new information

$$lnc_t^0 = lnc_{t-1} + (1 - \lambda) \; ln_t^\Delta$$

Throughout-period cashflow generated by the recovery buffer

$$rec_t \, lnc_t^0$$

Closing balance after recovery cash flows

$$lnc_t = (1 - \theta_{lnc}) \, lnc_t^0$$

Nonperforming loans: Write-off buffer

Closing balance rolled over from previous time $t-1$

$$lnw_{t-1}$$

"Opening" balance at new time t: new information arrives, adjust the balance for new information

$$lnw_t^0 = lnw_{t-1} + \lambda \, ln_t^\Delta$$

Throughout-period write-offs

$$w_t$$

Closing balance

$$lnw_t = lnw_t^0 - w_t$$

Portfolio segmentation

Total loan portfolio has K segments (subportfolios, subclasses), each differing in its

- risk parameters
- responsiveness to macroeconomic conditions
- share of foreign exchange denomination

$$l_t = l_t^1 + \cdots + l_t^K = \sum_{k=1}^{K} l_t^k$$

Each loan segment is tracked separately.

Equations presented above exist in K variants for each loan segment separately.

Exchange rate valuation

- all balance sheet items tracked in LCY value
- FX valuation effects can be potentially very large
- we allow for FX revaluation effects where and if needed

Not presented here, not included in the simple model version.

Model code

Let's have a look at file `loanPerformance.model` .

This part of the model is basically an Excel spreadsheet.

Credit risk

- link between real economy and bank asset performance
- expected credit risk gets (partially) priced in lending rates
- expected credit risk reflected in allowances
- banks hold excess capital to withstand unexpected increases in credit risk / worsening asset performance

Credit risk function

The credit risk function maps a macro conditions index (Basel II/III asymptotic single risk factor approach), z_t, into the actual portfolio default rate impact indicator, q_t

$$q_t = f(z_t)$$

Sign and location conventions for z_t:

- $z_t = 0$ means normal (steady) macroeconomic and macrofinancial conditions
- $z_t > 0$ means good times
- $z_t < 0$ means bad times

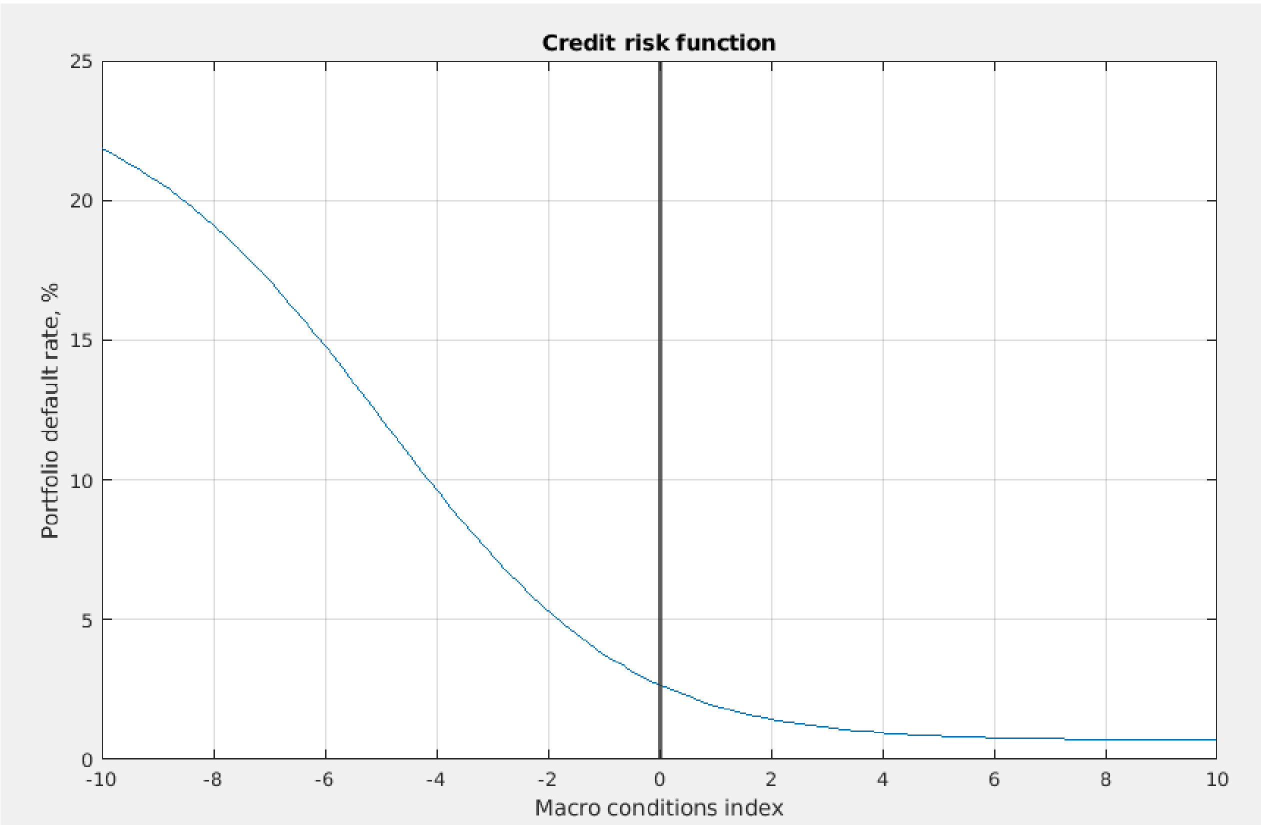
The credit risk function determines

- the actual performance of the existing loan portfolio
- the expected credit risk used in pricing new loans

Credit risk function, cont.

- key model feature
- very hard to estimate

$$f(z_t) = q_t = \underline{q} + \left(\overline{q} - \underline{q}\right)\left[\frac{1}{1 + \exp - \frac{z-\mu}{\sigma}}\right]^{\exp \nu}$$



Macro conditions index

Combines:

- current macro performance: output gap
- borrower vulnerability: annualized credit (loans) to GDP ratio
- other possible factors

Constructed in deviations from the long-run sustainability trends

$$z_t^k \;=\; (\log y_t - \log \overline{y}_t) \;-\; c_1 \left(\left[\frac{l^k}{4\, py\, fwy} \right]_t - \overline{\left[\frac{l^k}{4\, py\, y} \right]_t} \right)$$

Simulation

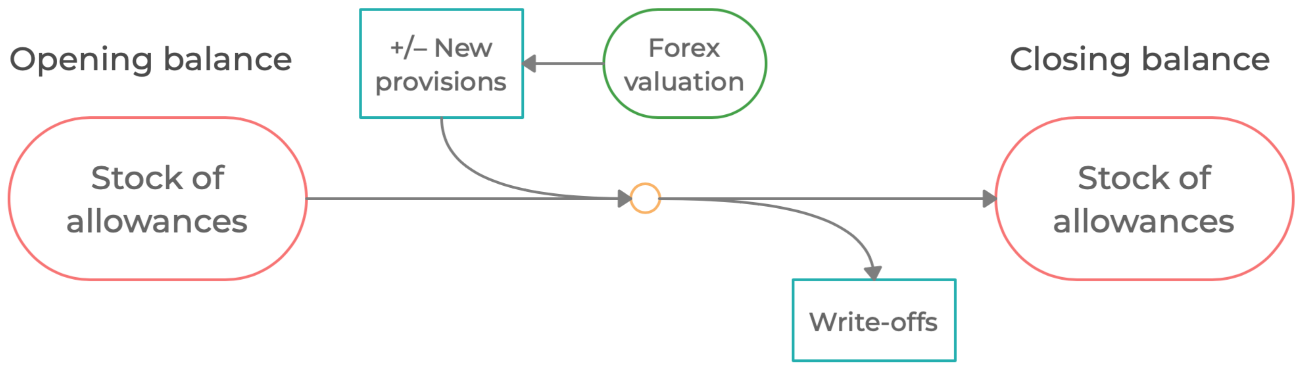
Let's have a look at all this in the model.

Open file `creditPerformanceShock.m`

Provisions, allowances

The allowances a_t (stock) are accumulated from provisions a_t^{Δ} (flows).

$$a_t = a_{t-1} - w_t + a_t^{\Delta}$$



Two types of allowances

- incurred loss (IL) based (backward-looking) allowances, ab_t
  - based on actual performance
- expected loss (EL) based (forward-looking) allowances, af_t
  - based on expected performance

The math for EL-based allowances is … long and complicated… Let's skip it for the moment and just note that:

- EL-allowances depend on expected credit risk over the lifetime of the loan

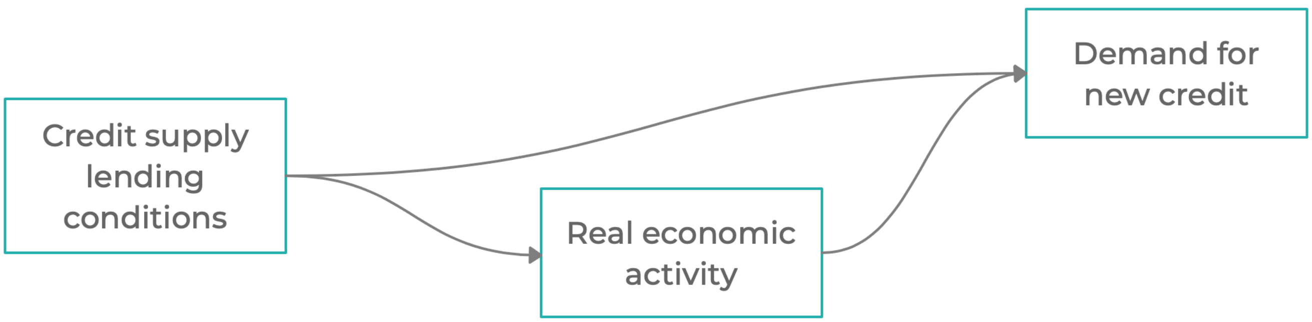
Let's revisit our simulation

Again, please open file `creditPerformanceShock.m`

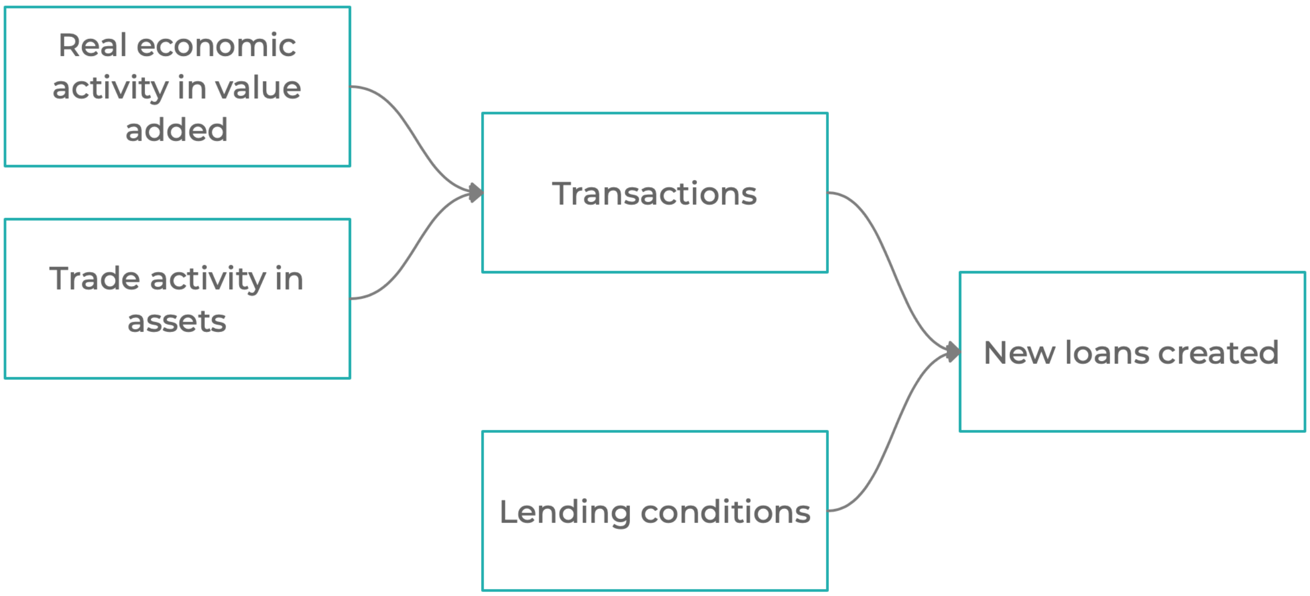
Credit creation

Reduced-form approach

Semistructural approach



Loan market equilibrium



Lending conditions

Real-world lending conditions comprise

- price conditions: lending rates
- non-price conditions: collateral requirements, insurance requirements, quantitative rationing

Demand for new credit

New credit is demanded to finance current period's transactions

$$l_t^{\Delta k} = vel_t^k \cdot trn_t^k \cdot \exp \varepsilon_{l\Delta,\, t}^k$$

where

- $l_t^{\Delta k}$ is new credit in segment k
- vel_t^k is the inverse velocity of new credit in segment k
- trn_t^k is the value of all the transactions that need financing in segment k
- $\varepsilon_{l\Delta,\, t}^k$ is a shock to the new credit in segment k

Demand for new credit, cont.

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$$trn_t^k = py_t \, y_t \; + \; c_1^k \; py_t \; y_t^{\mathrm{fws}}$$

$$\begin{aligned} vel_t^k &= c_0 \cdot vel_{t-1}^k + (1 - c_0) \cdot vel_{\mathrm{ss}}^k \\ &- \; c_1 \cdot \hat{r}_t^{\Delta full} \\ &+ \; c_2 \cdot \left(\left[\frac{l^k}{ny} \right]_t - \overline{\left[\frac{l^k}{ny} \right]_t} \right) \\ &+ \; \varepsilon_{vel^k, t} \end{aligned}$$

where:

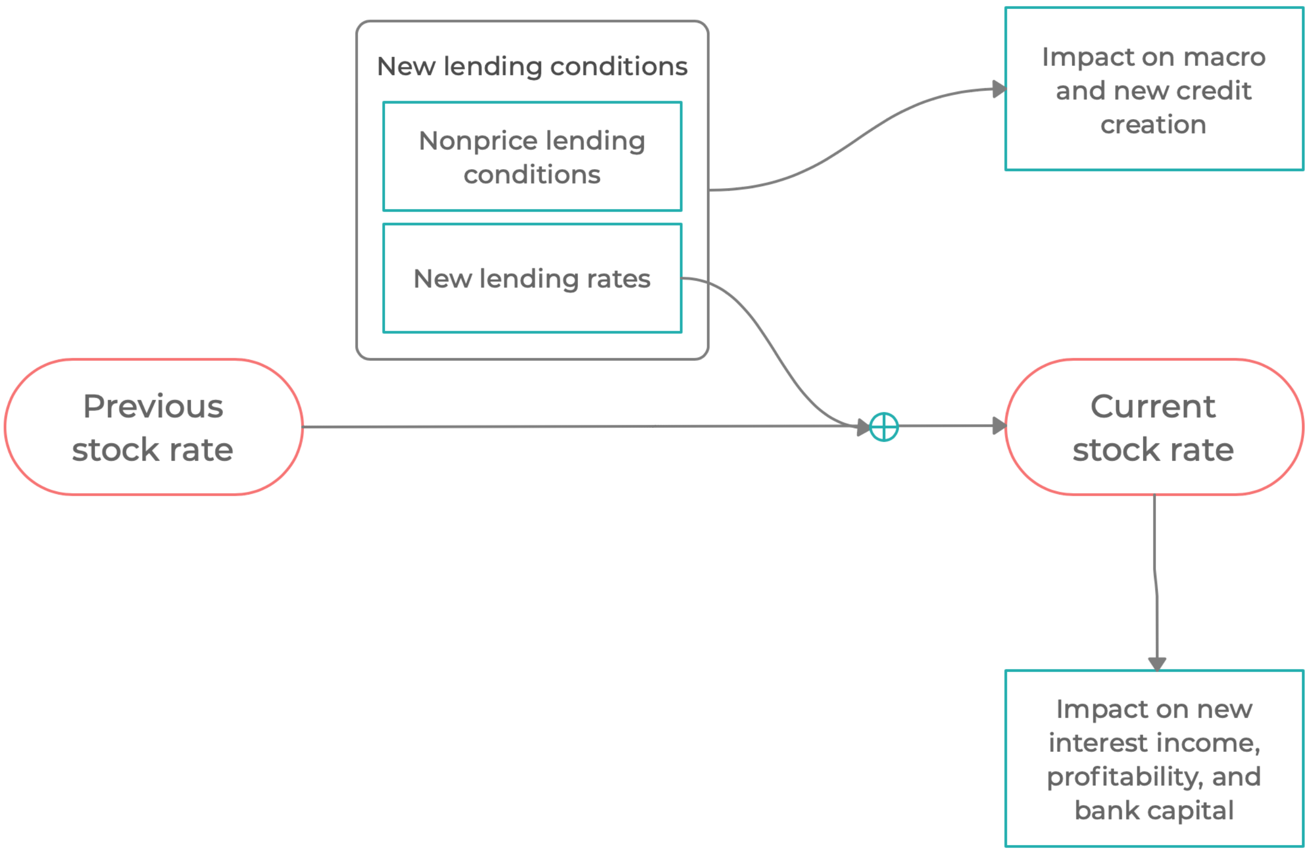
- $\hat{r}_t^{\Delta full}$ is a measure of lending conditions tightness
- $\left(\left[\frac{l^k}{ny} \right]_t - \overline{\left[\frac{l^k}{ny} \right]_t} \right)$ represents the current credit overhang over a sustainable level, expressed as a share of GDP; this concept is also known as the credit gap

Note that "credit trend" $\overline{\left[\frac{l^k}{ny} \right]_t}$ is **exogenous**.

Let's revisit our simulation

Again, please open file `creditPerformanceShock.m`

Interest rates - stocks vs flows



Stock loan rate vs new loan rate

Each period, banks set lending rate on loans issued in that period

$$rl_t^{\Delta}$$

The average loan rate on the **whole** loan portfolio is

$$rl_t = rl_{t-1} + \ \Omega_t \left(rl_t^{\Delta} - rl_{t-1} \right) + \epsilon_{rl,t}$$

where

$$\Omega_t = \frac{\psi_{rl} \left(1 - \theta\right) lp_t^0 + l_t^{\Delta}}{lp_t}$$

Parameter ψ_{rl} determines the average duration of interest rate fix:

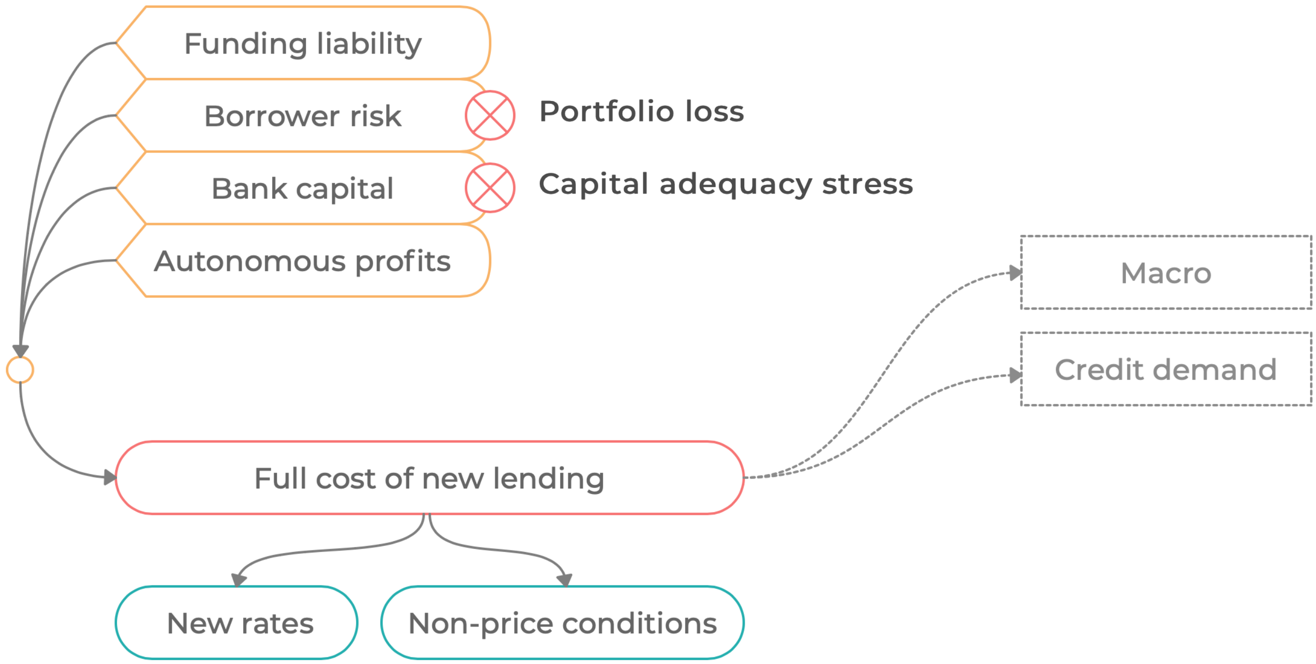
- $\psi_{rl} = 0$: a **fixed rate** loan, no interest rate reset
- $\psi_{rl} = 1$: fully **adjustable rate** loan, interest rate resets every period

Let's revisit our simulation

Again, please open file `creditPerformanceShock.m`

Note that banks cannot immediately reflect sudden increase in credit risk in higher interest rates for loans extended in previous periods.

Interest rate setting: overview



Short-term base rate

The short term base rate comprises

- the marginal cost of funding liabilities, rs_t
- an autonomous profit margin, $rl_t^{\Delta\mathrm{apm}}$

$$rl_t^{\Delta\mathrm{base}} = rs_t + rl_t^{\Delta\mathrm{apm}}$$

Forward-looking rate covering credit risk

The hypothetical lending rate covering the full credit is given by

$$rl_t^{\Delta\mathrm{full},1} = (1 - \Psi_1) \left[\frac{1 + rl_t^{\Delta\mathrm{base}}}{1 - \lambda\, q_{t+1}} \;+\; \Psi_1 \frac{1 + rl_{t+1}^{\Delta\mathrm{base}}}{1 - \lambda\, q_{t+2}} \;+\; \Psi_1^2 \frac{1 + rl_{t+2}^{\Delta\mathrm{base}}}{1 - \lambda\, q_{t+3}} + \;\cdots\; \right] + \epsilon$$

where

$$\Psi_1 = (1 - \psi_{rl,1})\,(1 - \theta)$$

is the effective discount factor applied on each future base cost.

Forward-looking rate covering cost of bank capital

The cost of bank capital (capital shortfall stress) is also reflected in loan pricing given by

$$rl_t^{\Delta\mathrm{full},2} = (1 - \Psi_2)\;\left[(1 + rx_t) + \;\Psi_2(1 + rx_t) + \;\Psi_2^2\,(1 + rx_{t+2}) + \;\;\cdots\;\right] + \epsilon_t^{rl\Delta\mathrm{full},2}$$

Overall lending rate

Overall hypothetical lending rate reflecting all costs is given by

$$1 + rl_t^{\Delta \text{full}} = (1 + rl_t^{\Delta \text{full},1}) \cdot (1 + rl_t^{\Delta \text{full},2})$$

Non-price lending conditions

The hypothetical full-cost rate $rl_t^{\Delta\text{full}}$ splits into

- a price component, i.e. the actually observed new lending rate;
- non-price conditions measured by an interest rate equivalent and passed on to borrowers)

$$rl_t^{\Delta} = rl_t^{\Delta\text{base}} \; + \; c_1 \left(rl_t^{\Delta\text{full}} - rl_t^{\Delta\text{base}} \right) + \; (1 - c_1) \left(rl_{\text{ss}}^{\Delta\text{full}} - rl_{\text{ss}}^{\Delta\text{base}} \right)$$

- hypothetical full-cost rate $rl_t^{\Delta\text{full}}$ enters the aggregate demand and credit demand equations, as it represents the true cost of credit for borrowers
- observed market lending rate rl_t^{Δ} enters the bank profits calculations

Let's revisit our simulation

Again, please open file `creditPerformanceShock.m`

Bank capital

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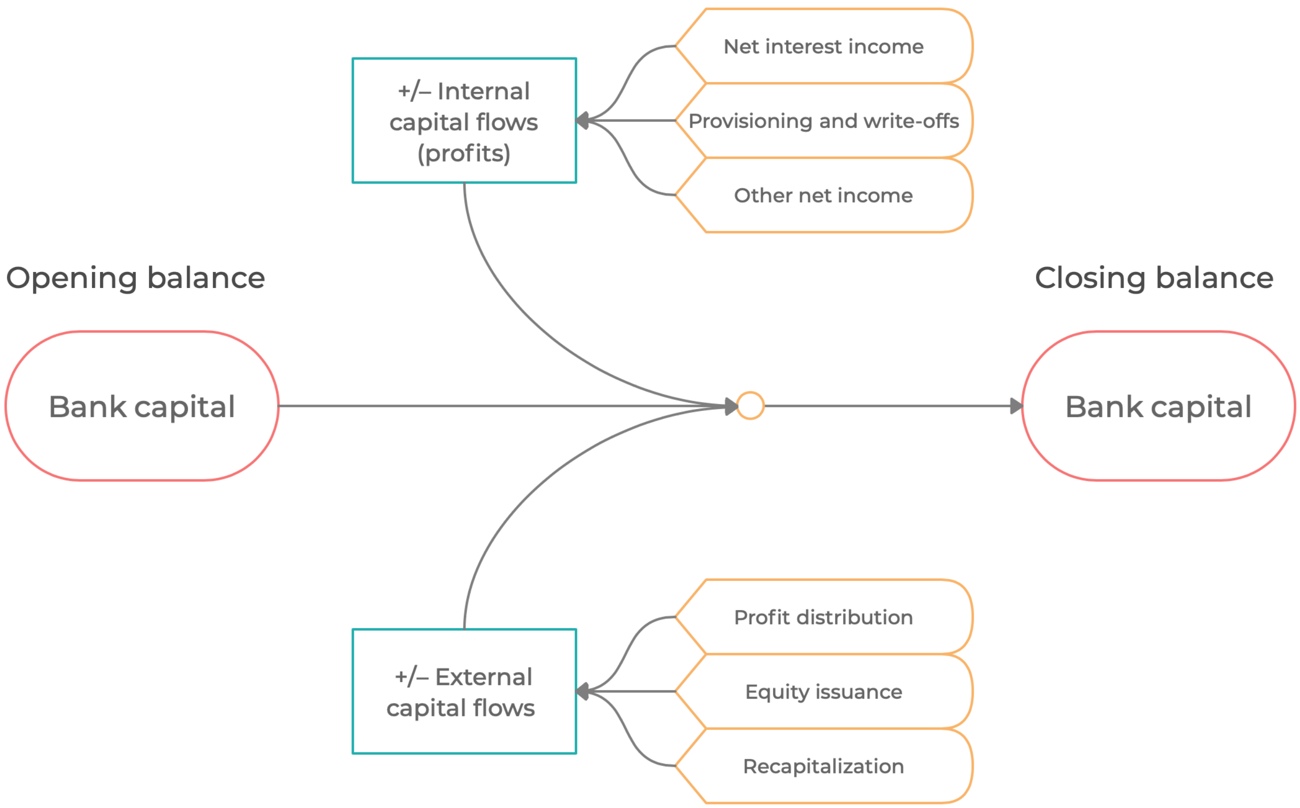
Key variable



$$bk_t = bk_{t-1} + prof_t + xcf_t$$

- bk_t is bank capital (balance sheet capital)
- $prof_t$ is an internal flow of capital (profit or loss, PnL) recorded on the closing balance of the balance sheets at $t-1$ and credit events throughout t
- xcf_t is an external flow of capital throughout t: dividends paid out (–), new equity issuance (+), equity withdrawals by parents (–), recapitalization flows (+), etc.

CAR:

Regulatory capital

$$regk_t = \left[\frac{regk}{bk}\right]_t bk_t$$

Standard capital adequacy ratio

$$car_t = \frac{regk_t}{riskw_t\ l_t}$$

- $riskw_t$ is the effective average risk weight, an exogenous variable

Equilibrium CAR

In the equilibrium (steady state), banks target a comfort level of CAR

$$car_t \longrightarrow car_t^{\text{tar}}$$

$$car_t^{\text{tar}} = car_t^{\text{min}} + car_t^{\text{exc}}$$

- car_t^{min} is the regulatory minimum including regulatory buffers
- car_t^{exc} is the excess capital target above the regulatory minimum to protect against unforeseen shocs

Why do banks not want to hold higher excess capital by themselves?

Profit and loss

Sums (almost) all developments on bank balance sheet:

- Interest income on loans (by segments)
- Income on other assets
- Interest expense on non-equity liabilities (by currency of denomination)
- Other income (proxy for fees, commissions, etc)
- Provisioning and write-offs
- Exchange rate valuation

Let's revisit our simulation

Again, please open file `creditPerformanceShock.m`

Macro-financial feedbacks

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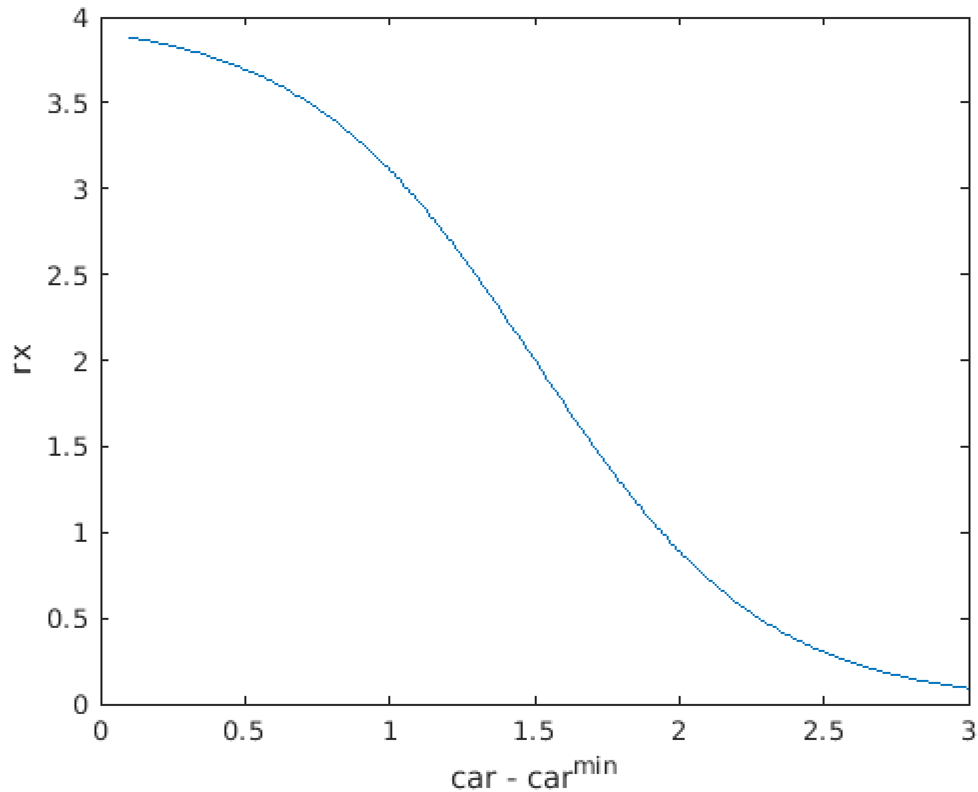
We have not yet discussed the **key issue**:
What do the banks do, when their capital declines below "optimal" level?

- Change composition of assets
- Reduce expenditures
- **Tighten lending conditions** - the only macroeconomically relevant action, the only one we consider

Capital risk surcharge

When car_t approaches regulatory minimum $car_t^{\min}$, capital shortfall triggers increase in capital adequacy risk surcharge rx_t:



Another key nonlinearity.

Let's revisit our simulation

Again, please open file `creditPerformanceShock.m

Let's revisit our simulation

Let me show you how to quickly set up a new simulation.

We will examine the impact of the shocks with and without the feedback mechanism.

Macroprudential policy

There is **none** in the model.

But we can represent a large number of policies:

- capital-based policies
- DTIs, LTVs, ...
- credit caps

We will see examples.

Funding side

Funding issues are not the current focus of the framework.

Deposits always available, liquidity not an issue.

Milestone

These are the key features of the model.
Let's examine it further - which scenario would be of interest to you?

Parameterization

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Estimation is very difficult.

We can employ various calibration strategies:

- Use other models - micro PD models, ...
- Match the model to data
  - Some parameters have directly observable real-world counterparts
  - Some parameters determine steady-state equilbrium
- Simulation exercises
  - Some parameters can be inferred by replicating interesting periods in data
  - Theoretical simulations, "smell-tests"
  - Comparison to other models

We have a calibration guide.

Simulating financial cycle

Financial cycle can arise for multiple reasons.

Overly-optimistic expectations are one of them.

In structural model, we can work with expectations explicitly.

Let's have a look at file `simulateFinancialCycle.m`.