

GIMM Model Basics

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GIMM Hands-on Modeling Workshop

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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
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What is it not for?

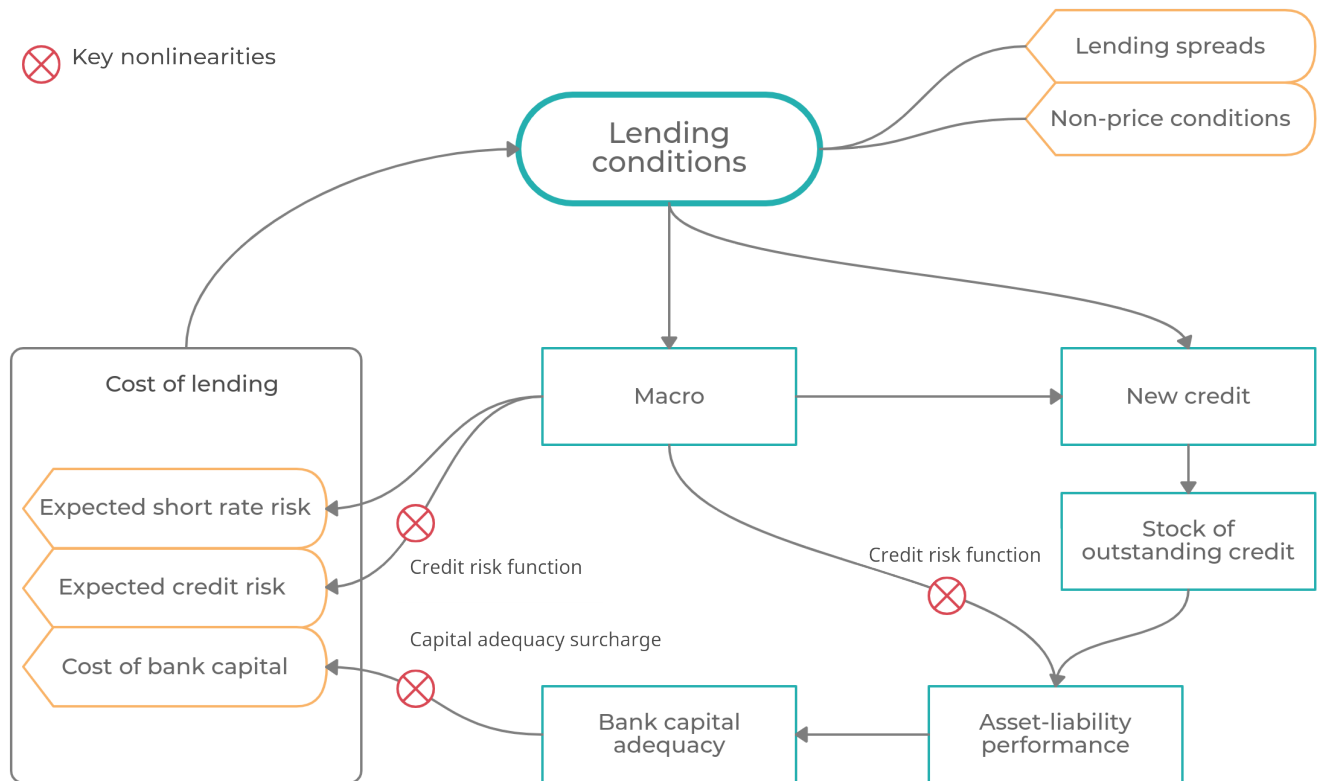
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- Forecasting
 - Statistical predictions
 - Deeply structural, research framework
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- Conceptual simulations, policy interventions
 - Gain insight into impact on the economy
 - Data-based projections, scenarios conditional on macroeconomic scenarios
 - Stress-testing exercises
 - Counterfactual simulations
 - Comparative static, analysis of equilibrium changes
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Bank balance sheet

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	<u>Assets</u>	<u>Liabilities</u>	
le_t	Net loans	Non-equity liabilities	d_t
$+ \sum l_t^k$	<i>Gross loans</i>	<i>Local currency</i>	$d_t^{\text{lc}} +$
$- \sum a_t^k$	<i>Allowances for credit losses</i>	<i>Foreign currency</i>	$d_t^{\text{fc}} +$
ona_t	Other net assets	Bank capital	bk_t

- All quantities explicitly tracked in LCU
 - Further decomposition possible
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Riskless loan portfolio

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Assume loan portfolio consists of infinite amount of identical loans:

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⋮ ☐

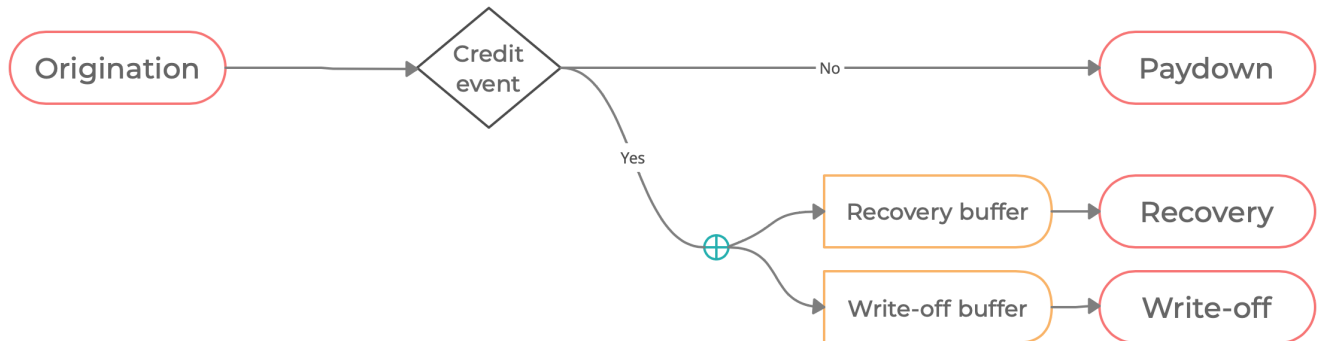
	Origination	Time 1	Time 2	...
Closing book value	l	$(1 - \theta)l$	$(1 - \theta)^2 l$...
Paydown		θl	$\theta (1 - \theta)l$...
Interest		$rl_0 l$	$rl_1 (1 - \theta)l$...
Total cash flow generated		$(\theta + rl_0)l$	$(\theta + rl_1) (1 - \theta)l_0$...

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.

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.

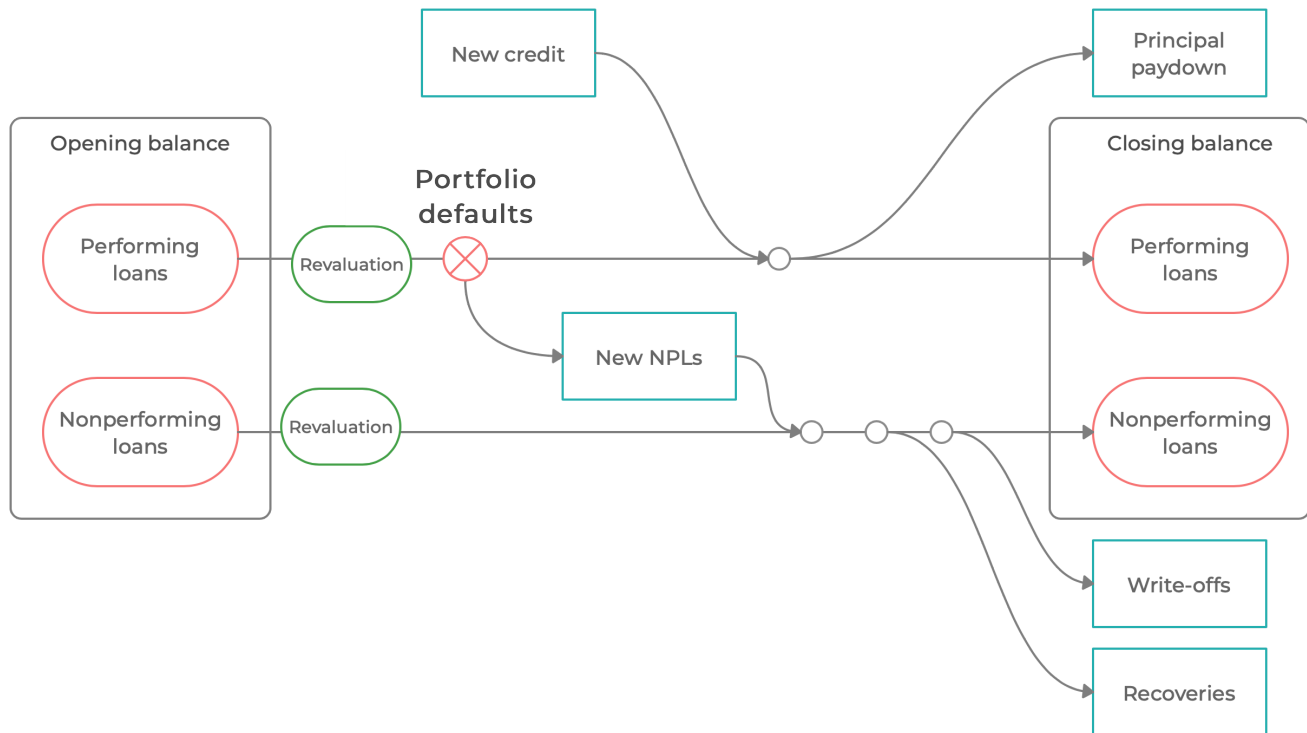
Portfolio division	Cash Flows	Credit event
Performing lp_t	Paydown, interest	(outflow) $ln_t^\Delta = q_t lp_t^0 \rightarrow$
Nonperforming recovery buffer lnc_t	Collections, repossession, resale	(inflow) $\rightarrow (1 - \lambda) ln_t^\Delta$
Nonperforming writeoff buffer lnw_t	None	(inflow) $\rightarrow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

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
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Stock-flow dynamics in loan portfolio

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

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

$$lnw_t = lnw_t^0 - w_t$$

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

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

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

Each loan segment is tracked separately.

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

- 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.

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

This part of the model is basically an Excel spreadsheet.

- 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
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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 :

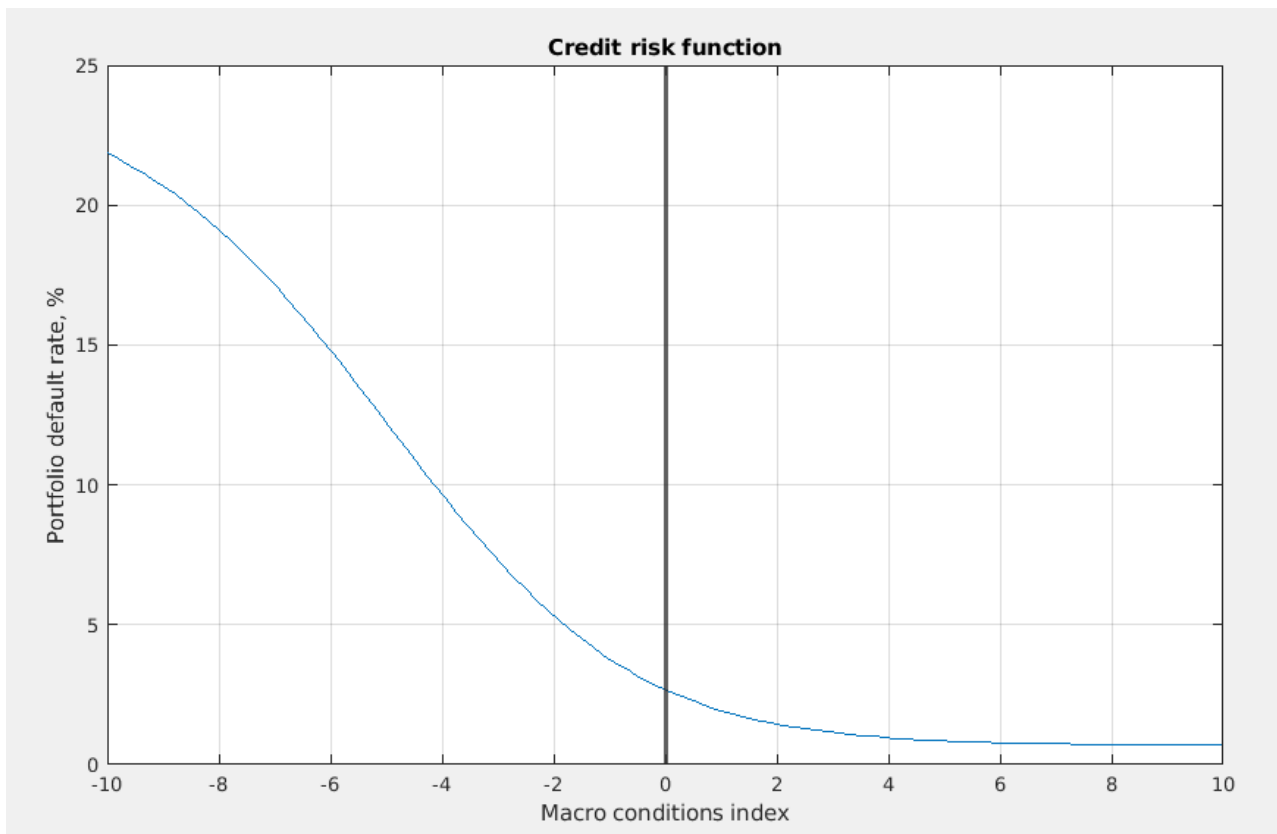
- $z_t = 0$ means normal (steady) macroeconomic and macrofinancial conditions
- $z_t > 0$ means good times
- $z_t < 0$ means bad times

The credit risk function determines

- the actual performance of the existing loan portfolio
 - the expected credit risk used in pricing new loans
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- key model feature
- very hard to estimate

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



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

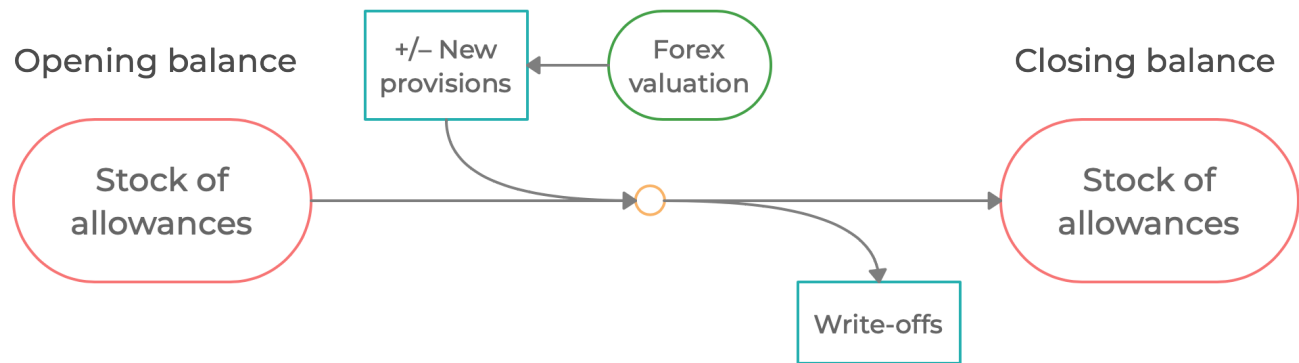
$$z_t^k = (\log y_t - \log \bar{y}_t) - c_1 \left(\left[\frac{l^k}{4 py fwy} \right]_t - \overline{\left[\frac{l^k}{4 py y} \right]}_t \right)$$

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

Open file `creditPerformanceShock.m`

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

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- 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

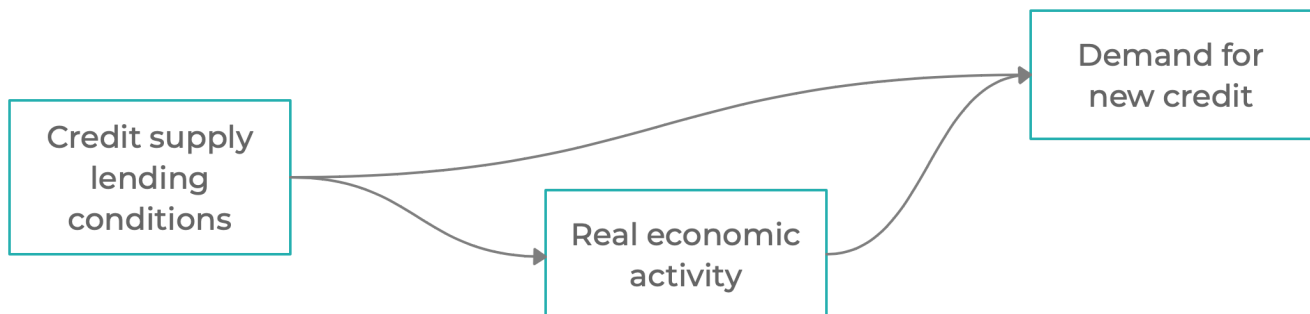
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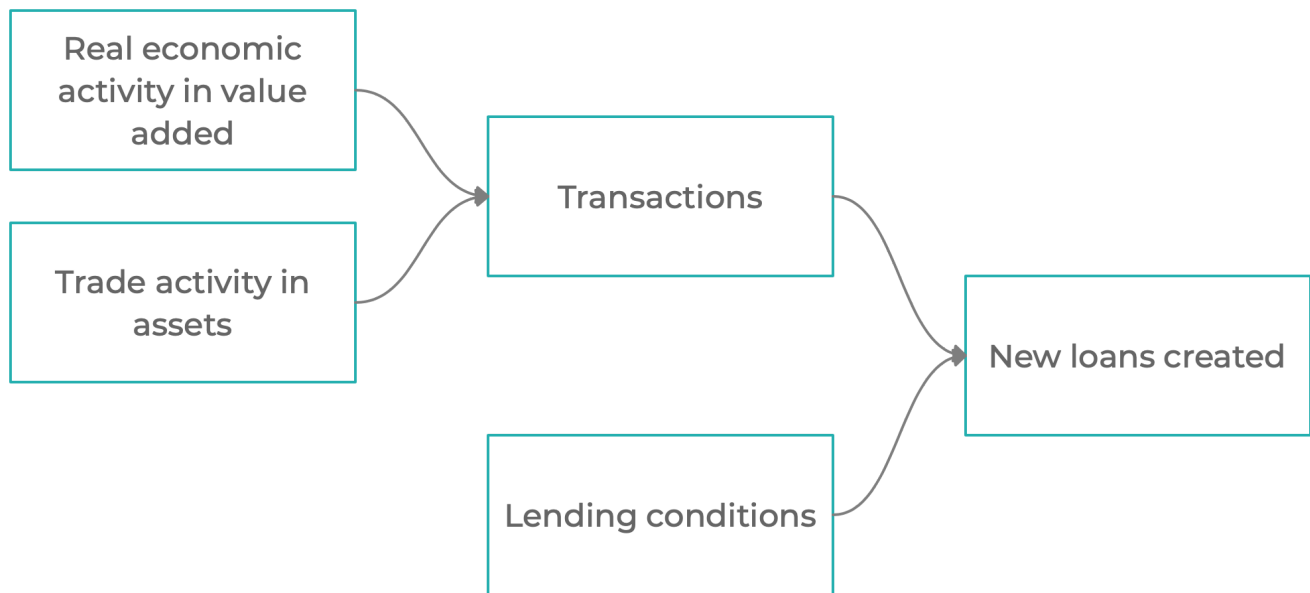
Again, please open file `creditPerformanceShock.m`

Reduced-form approach



Semistructural approach





Real-world lending conditions comprise

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

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

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.

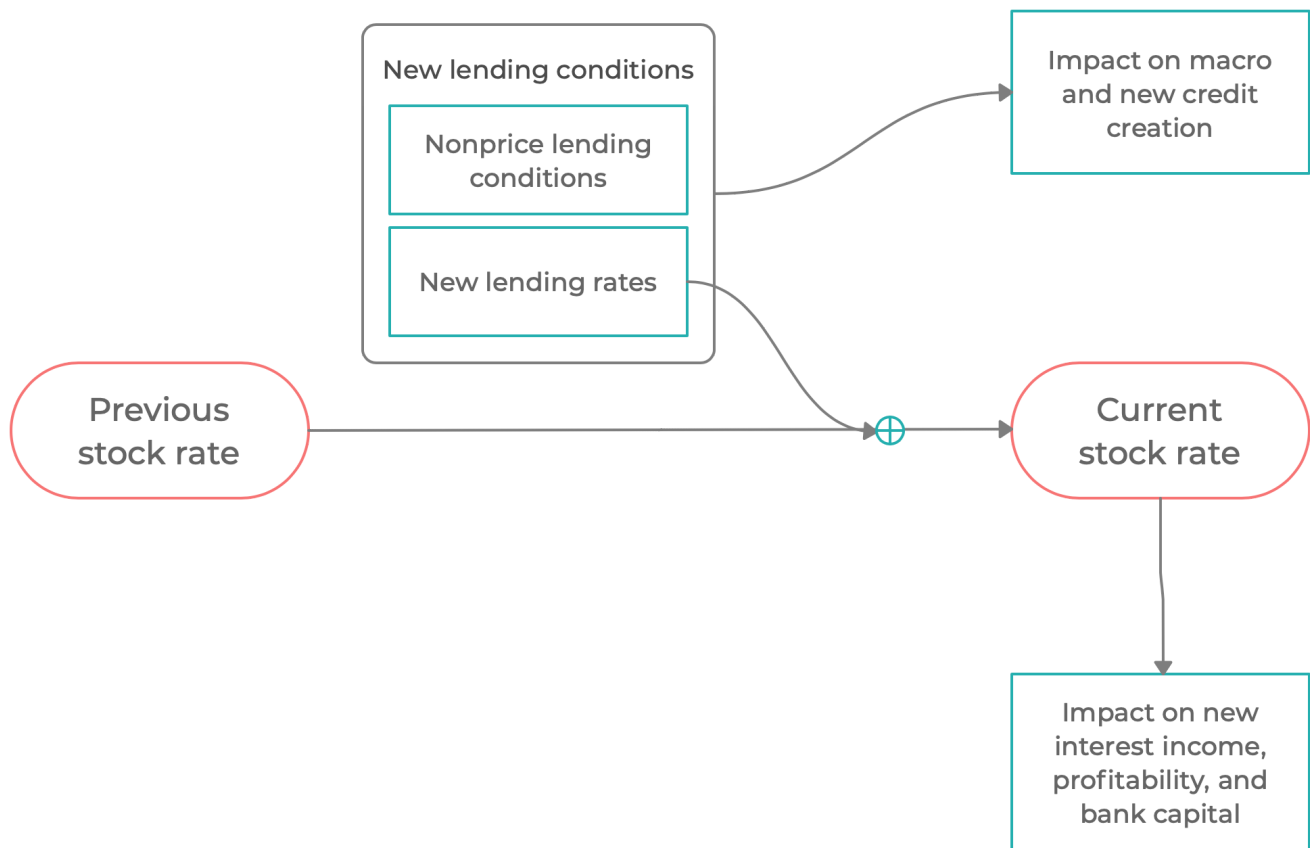
Let's revisit our simulation

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Again, please open file `creditPerformanceShock.m`

Interest rates - stocks vs flows

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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

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

where

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

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
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Let's revisit our simulation

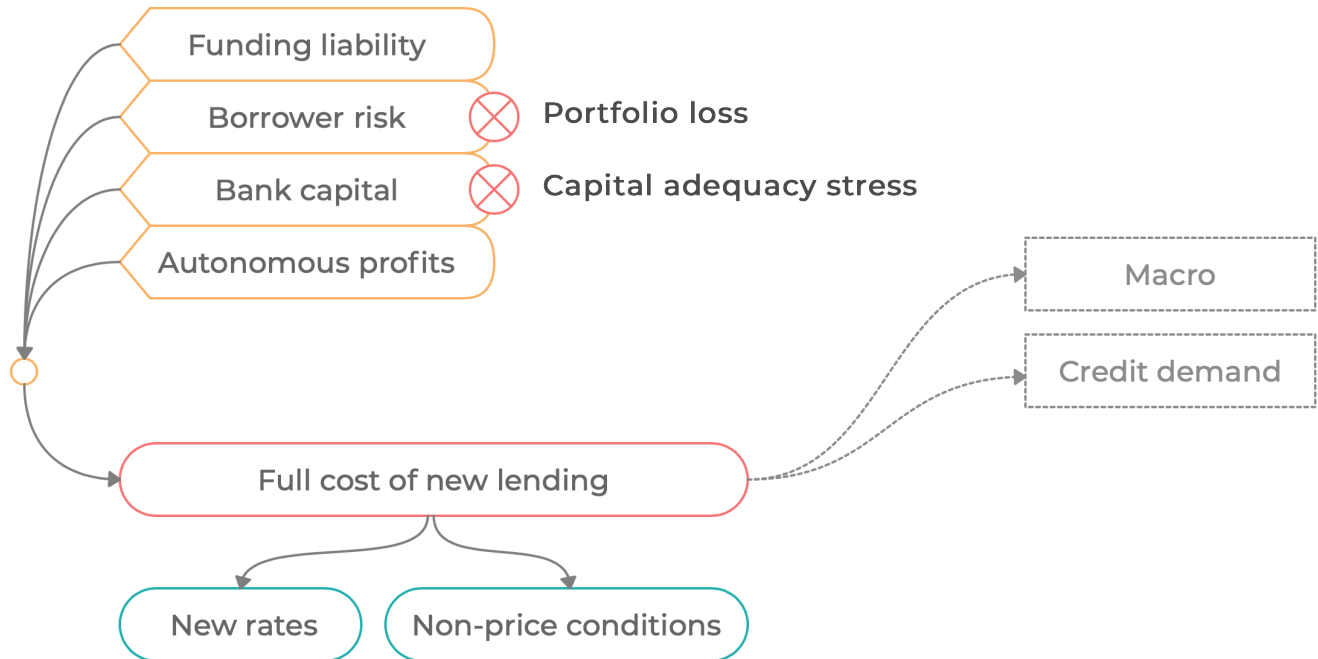
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Again, please open file `creditPerformanceShock.m`

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

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Short-term base rate

The short term base rate comprises

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

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

Forward-looking rate covering credit risk

The hypothetical lending rate covering the full credit is given by

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

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

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

Overall lending rate

Overall hypothetical lending rate reflecting all costs is given by

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

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)

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

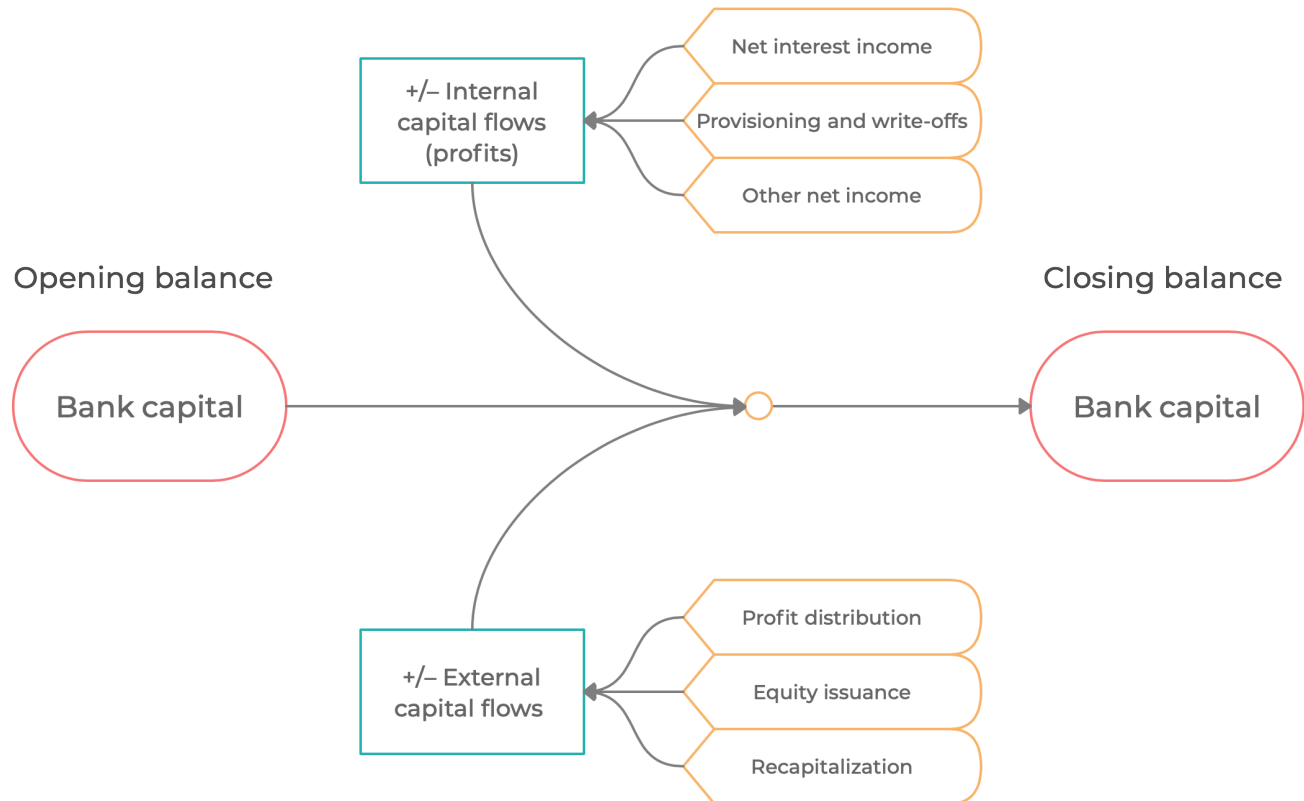
- hypothetical full-cost rate $rl_t^{\Delta\text{full}}$ enters the aggregate demand and credit demand equations, as it represents the true cost of credit for borrowers
 - observed market lending rate rl_t^{Δ} enters the bank profits calculations
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Let's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

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Again, please open file `creditPerformanceShock.m`

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.

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
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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 shocks

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

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
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Let's revisit our simulation

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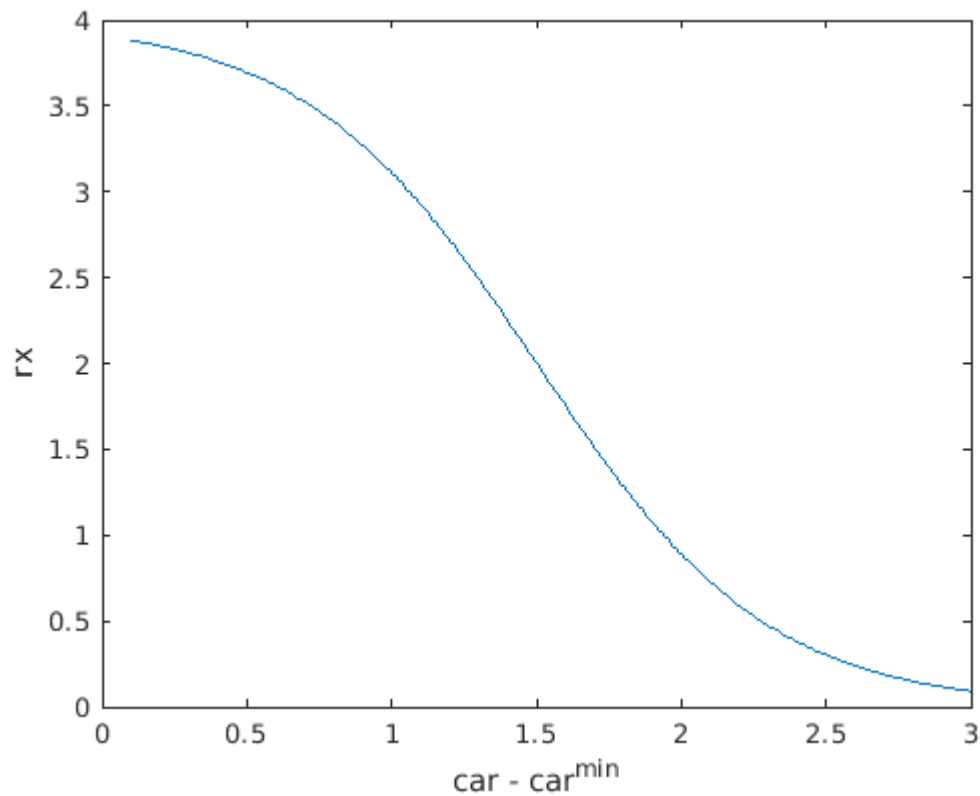
Again, please open file `creditPerformanceShock.m`

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
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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

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Again, please open file `creditPerformanceShock.m`

Let's revisit our simulation

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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.

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 issues are not the current focus of the framework.

Deposits always available, liquidity not an issue.

These are the key features of the model.

Let's examine it further - which scenario would be of interest to you?

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 equilibrium
- 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.

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`.
