

# **Bank balance sheets and asset performance**

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## Simplified aggregate bank balance sheets

The model explicitly describes balance sheet of the aggregate banking sector in the following form:

Assets		Liabilities	
$le_t$	Net loans	Non-equity liabilities	$d_t$
$+ \sum l_t^k$	+ Gross loans	+ Local currency	$+ d_t^{\text{lc}}$
$- \sum a_t^k$	– Allowances for CL	+ Foreign currency	$+ d_t^{\text{fc}}$
$ona_t$	Other net assets	Balance sheet capital	$bk_t$

- Bank loans can be denominated in local or foreign currency
- Non-equity liabilities  $d_t$  include deposits as well as other sources of financing.
- All allowances here assumed to be contra-assets, and netted against gross exposure values before risk weighting.

## MULTIPERIOD LOANS WITH GEOMETRIC PAYDOWN

# Motivation

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- Real-world loan portfolios include a whole range of loan durations (maturities)
- Stock-flow relationships between the stock of credit and new credit critical for the cost of deleveraging process
- Need to simplify to keep the model tractable, but still maintain key features of the real-world
- Assume a composite portfolio of loans with geometrically decreasing paydowns[]
  - Represents a mix of durations
  - Needs one single parameter
  - Has a recursive representation
  - Calibrated using Macaulay duration

## Lifetime of a single riskless pool

Each hypothetical loan follows the same life-cycle:

	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  $\theta$  determines the average maturity of the loan portfolio, and can be calibrated using e.g. Macaulay duration.

The effective interest rate on the stock of outstanding loans (stock rate),  $rl_t$  may vary over time and be disconnected from  $\theta$  in general.

# Calibrating loan duration

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Steady-state Macaulay duration

$$MD = 1 \cdot \frac{\theta + rl}{1 + rl} + 2 \cdot \frac{(\theta + rl)(1 - \theta)}{(1 + rl)^2} + \dots = \frac{1 + rl}{\theta + rl}$$

# Time evolution of a dynamic riskless loan portfolio

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**Dynamic** here means inclusive of the inflow of new loans.

Assuming no credit events and no exchange rate valuation, the loan portfolio evolves as:

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

where  $l_t^\Delta$  is the amount of new loans extended in time  $t$ .

Time  $t$  cash flows (paydown + interest) generated by the loan portfolio collected at  $t$ :

$$l_{t-1} (\theta + r)$$

## CREDIT RISK AND LOAN PERFORMANCE

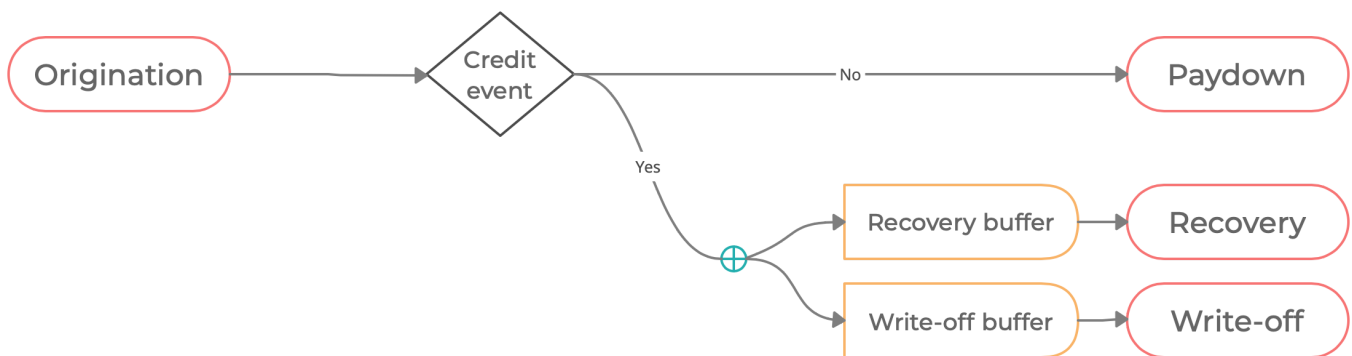


# Credit events

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- Introduce a theoretical structure that is simple enough to remain analytically tractable
- Make losses proportional not to the book value but the present value → simplify present value calculations (e.g. IFRS9 expected credit loss)[2]

**Static** snapshot of possible paths for a given loan



# Classification of gross loans

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

$$l_t = lp_t + ln_t$$

Non-performing loans break down into a recovery buffer (to be gradually recovered, i.e. generating cashflows),  $lnc_t$ , and a write-off buffer (to be gradually written-off),  $lnw_t$

$$ln_t = lnc_t + lnw_t$$

This is a simplification for modeling purposes. Do not think of individual loans as being classified as  $lnc_t$  or  $lnw_t$ ; rather the book value of each loan is split between these two categories on default. The recoverable amount is not known on default in real-world setting, but we simplify.

Total pool of loans generating cash flows

$$lc_t = lp_t + lnc_t$$

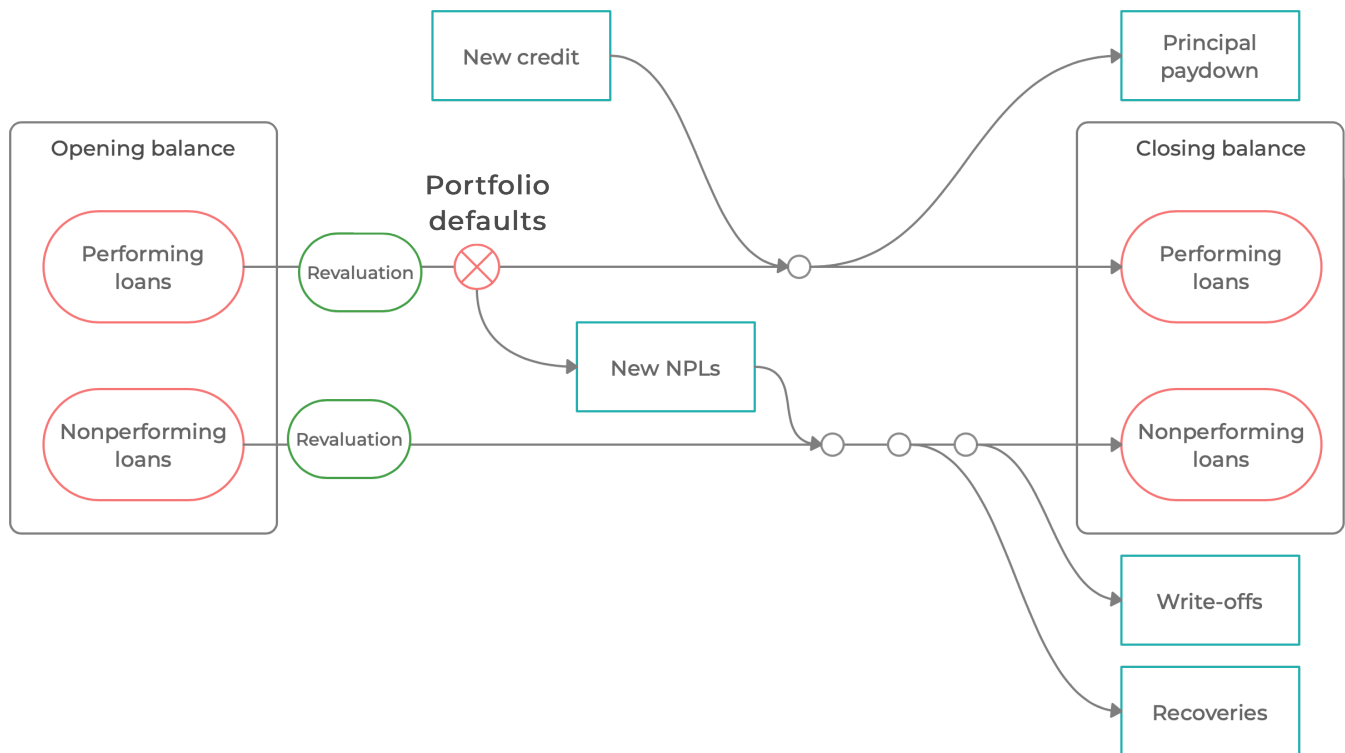
## Flows in gross loan portfolio

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

- $ln_t^\Delta$  is the amount of loans that experience a credit event and become non-performing in time  $t$
- $q$  is the share of performing loans experiencing a credit event (default)
- $\lambda$  is parameter governing the share of the newly non-performing loans which falls into the write-off buffer  $lnw_t$

# Stock-flow dynamics in risky loan portfolio



# Time evolution of dynamic risky loan portfolio

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Assuming no exchange rate valuation in all that follows below

## Performing loans

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

$$lp_{t-1}$$

Balance after **new information** 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

$$(\theta_{lp} + r)lp_{t-1}$$

**Closing** balance after paydown and inclusive of new credit  $l_t^\Delta$

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

## Nonperforming loans: Recovery buffer

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

$$lnc_{t-1}$$

Balance after **new information** 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

$$rec_t lnc_t^0$$

The recovery rates are mimicked by hypothetical paydowns  $\theta_{lnc}$  (may be different from  $\theta_{lp}$ ) and interest payments; this assumption is to

- distribute the collections, repossession of collateral and/or resale over time

- preserve the net present value equal the current book value (that is why we include the interest payments) as a simplifying assumption

$$rec_t = \theta_{inc} + rl_{t-1}$$

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  $t - 1$

$$lnw_{t-1}$$

Balance after new information 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

$$lnw_t = lnw_t^0 - w_t$$

## PROVISIONING AND WRITE-OFFS

# Provisioning

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The stock of allowances,  $a_t$ , is determined by expected credit losses; the balancing item here is the impact of changes in allowances on period profit/loss after correction for write-offs

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

- $a_t$  is the stock of allowances for expected credit losses
- $w_t$  is period write-offs (flow)
- $a_t^\Delta$  is the impact of new provisions (flow) on period profit/loss



## Write-off process

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Write off a certain proportion of the exiting buffer each period

$$w_t = \omega \ln w_{t-1}$$

- $\omega \in (0, 1)$  is a parameter determining the speed of the write-off process
- $\ln w_{t-1}$  is the write-off buffer balance at the close of last period

## SEGMENTATION AND VALUATION

# Portfolio segmentation

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Consider total gross loans consisting of a number  $K$  of 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.

# Exchange rate valuation

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For practical modeling:

- We introduce an effective (nominal) exchange rate that would be sufficiently representative of movements on foreign currency denominated asset classes
- All balance sheet quantities will be expressed (reported, tracked) in *local currency units* independently of their currency of *denomination*

## Parameterizing foreign currency denomination

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For each loan segment, we define the steady-state degree of foreign exchange denomination (exposure) by  $\sigma_k \in [0, 1]$ :

$$\sigma_k = \frac{l_t^{k,fcy}}{l_t^k}$$

- $\sigma_k = 0$  means fully home currency denomination
- $\sigma_k = 1$  means fully foreign currency denomination
- $0 < \sigma_k < 1$  means mixed currency denomination

The loan portfolio segment  $l^k$  is adjusted for exchange rate valuation whenever crossing a time period using the following exchange rate valuation impact indicator (depending on the parameter  $\sigma_k$ )

$$j_t^k = (1 - \sigma_k) + \sigma_k \frac{e_t}{e_{t-1}} = 1 + \sigma_k \left( \frac{e_t}{e_{t-1}} - 1 \right)$$

# Time evolution of foreign currency denominated loan segments

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Closing balance from previous time  $t - 1$

$$lp_{t-1}^k$$

Balance after new information at a new time  $t$ : new information arrives including the new level of the exchange rate adjust the balance for new information

$$\begin{aligned} ln_t^{\Delta k} &= j_t^k q_t lp_{t-1}^k \\ lp_t^{0k} &= j_t^k lp_{t-1}^k - ln_t^{\Delta k} \end{aligned}$$

Period cash flows generated by the portfolio: paydown plus interest income

$$(\theta_{lp}^k + r_{t-1}^k) lp_t^{0k}$$

Closing balance after paydown and inclusive of new lending

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

# Open net foreign positions

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Part of the non-equity liabilities is denominated in foreign currency:

$$d_t = d_t^{\text{lcy}} + d_t^{\text{fcy}}$$

The banks can have open net foreign positions, expressed as a share of capital:

$$d_t^{\text{fcy}} = \sum_{k=1}^K l_t^k \cdot \sigma_k + onfx_t \cdot bk_t$$

and  $onfx_t$  is an exogenous process around its steady-state value

$$onfx_t = \rho_{onfx_t} onfx_{t-1} + (1 - \rho_{onfx_t}) onfx_{ss} + \varepsilon_{onfx_t,t}$$

1. For instance, Rudebusch and Swanson (2008) Examining the bond premium puzzle with a DSGE model. JME 55 (2008), S111--S126 ↩
2. For instance, Duffie and Singleton (1999) Modeling Term Structure of Defaultable Bonds. *The Review of Financial Studies*, 12(4). ↩