Stress Testing and Calibration of Macroprudential Policy Tools

LUCY GORNICKA AND LAURA VALDERRAMA

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Outline

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Motivation

Statistical versus structural approach

Statistical approaches are limited to measure real estate risk

- Limited data on tail events
- Changes in regulatory policy
- Benign cyclical conditions

A structural approach can be more reliable, flexible, and transparent

- It links the loan default process to risk concentrations that accumulate in the upturn (indebtedness indicators, house price developments, interest rate changes, etc.)
- It can accommodate structural features of the real estate market
- It is explicit about modeling assumptions and amenable to counterfactual analysis

Key model features and contributions

- Contribution: The paper investigates major loan loss events and informs the calibration of macroprudential policy to enhance banking system resilience

- Forward-looking: The approach applies stress testing techniques to provide a measure of credit risk by *risk bucket* under adverse conditions

- Scenario design: The model is applied to scenarios whose severity is linked to the level of risk (DSGE with exogenous shocks), or to assessments on near term likelihood (GDP ‘at risk’)

- Calibration: The model informs the adequacy and calibration of macroprudential instruments for real estate risk:
  - Amortization requirements and sectoral CCyB
  - LTV and DSTI caps

- The paper presents two applications: Mortgage market in Switzerland and Austria

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The Model

Modeling approach

It builds on RBNZ’s TUI model of mortgage lending risk, adds modeling enhancements

Main behavioral assumption: “Double trigger” theory of default:

- **Financial distress (liquidity constraint)**: the borrower is unable to service the loan due to financial difficulties (e.g. unemployment, lower income, higher rates)
  - The borrower cannot repay the debt on time

- **Economic default (negative equity)**: the net value of the collateral is less than the outstanding value of the loan
  - The borrower cannot pre-pay the loan

Semi-structural approach

- Structural process
- Estimation/calibration of parameters
- Simulation using current regulatory environment/counterfactual analysis

Financial distress

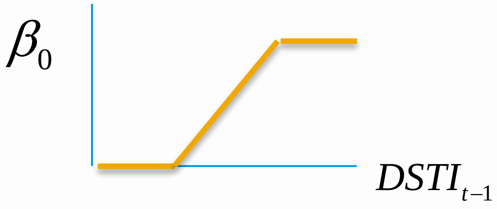
$$\Pr(FD_{i,t}) = \beta_0(DSTI_{i,t-1}) \times D_{i,t} + \beta_1 \times \Delta DSTI_{i,t}{}^{\gamma} + \beta_0(DSTI_{i,t-1}) \times (\beta_2 U_{t-1} + \beta_3 \Delta U_t{}^{\alpha})$$

Risk drivers

- Macroeconomic conditions: aggregate shocks (interest rates, income, RE prices)
- Loan characteristics: type, tenor, rollover rate, overcollateralization
- Borrower characteristics: idiosyncratic shocks (unemployment/demographic)
- Regulatory environment: amortization requirements, borrower-based measures
- ❖ The impact on bank resilience depends on the availability of buffers

Predictors of illiquidity

- Demographic shock D
- Changes in debt-servicing capacity DSR_t (income shocks, interest rate shocks, house price shocks)
- Changes in the unemployment rate U_t
- ❖ The impact of idiosyncratic shocks (D, U_t) on financial stress is non-linear
  - ❖ β_0 is a non-linear function of $DSTI_{t-1}$



Economic default

The house price decline is sufficiently large, so that the loan becomes undercollateralized and early mortgage termination is not feasible:

$$\widetilde{HP}_{i,t} - C < NPV\left(L_{i,t}, r_t^{type,M}, r_t^f, T_{i,t}\right)$$

$$NPV_t\left(L_t\right) = L_t + \sum_{j=0}^{T-1} \frac{r_t^{type,M} L_t \left(1 - \frac{j}{T}\right)}{\left(1 + r_t^f\right)^j}$$

The NPV of the loan reflects:

- the outstanding principal
- the amount of foregone interest payments which rise with the size of the interest rate shock

Default event

The probability of default of borrower *i* is defined by:

$$PD_i = \Pr(FD)_i \times \Pr(ED)_i$$

The conditional LGD is driven by the discounted sale price of the repossessed collateral.

The sale occurs at *t*+*s* and proceeds net of transaction costs are discounted at a rate reflecting the risk premium of the foreclosed asset.

$$LGD_{i,t} = NPV(L_{i,t}, r_t^{type,M}, r_t^f, T_{i,t}) - (1-\delta) \times \frac{\widetilde{HP}_{i,t+n}}{\left(1 + r_t^f + spread\right)^n}$$

We use Monte Carlo simulations to simulate PDs and LGDs for LTV-vintage buckets of mortgages:

- Each bucket is assumed to have 10,000 mortgages
- Within a bucket we draw a house price for each mortgage from a normal distribution of prices (idiosyncratic risk)
- We simulate each bucket 2,000 times

Granular projections

The model generates 2-year bank-specific forecasts for stressed PDs, LGDs, and loss rates (which are then annualized):

- *By risk bucket LTV*. This allows identifying high risk buckets to inform the calibration of macroprudential instruments.
- *By vintage s.* This allows detecting high risk issuances to assess the effectiveness of macroprudential implementation (new issuances; outstanding stock)
- *By portfolio*. This allows forecasting credit losses by weighting the distribution of outstanding mortgages across risk buckets and vintages

Characteristics of mortgage markets in CH and AT

	Switzerland	Austria
Data by risk bucket	✓	✓
Vintage disclosure		✓
Real estate crisis	✓	
Typical mortgage	fixed	floating
Typical maturity	Rollover 1-10y	25y
Interest only	✓	
Margin call	✓	
Structural changes	✓	
Binding sectoral CCyB	✓	
Binding amortization requirement	✓	
Non-binding guidance		✓
Toolkit LTV, DTI, DSTI, tenor		✓

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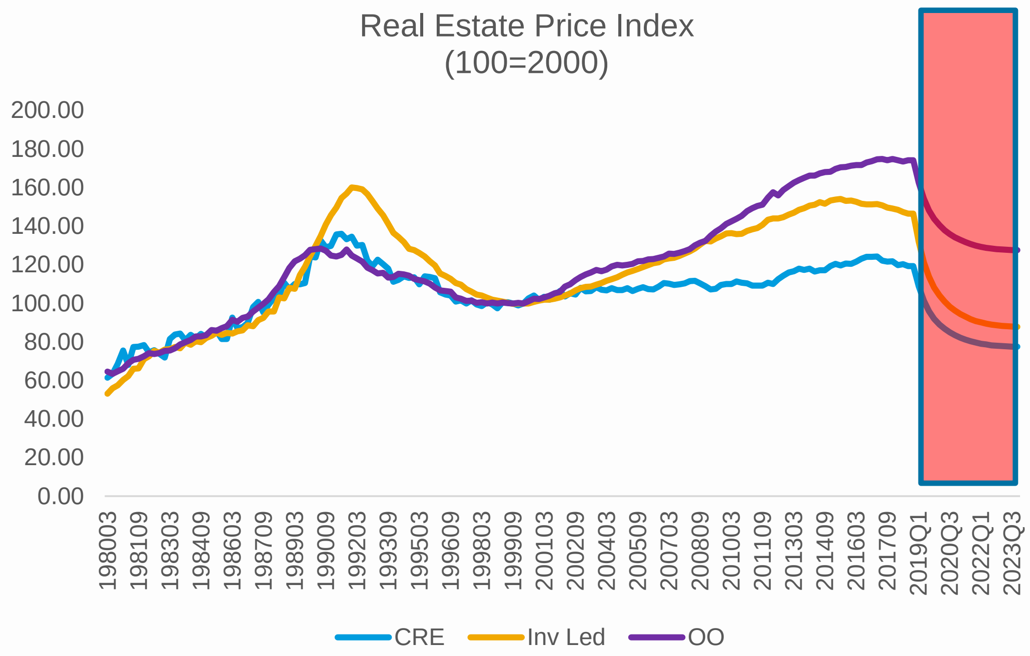
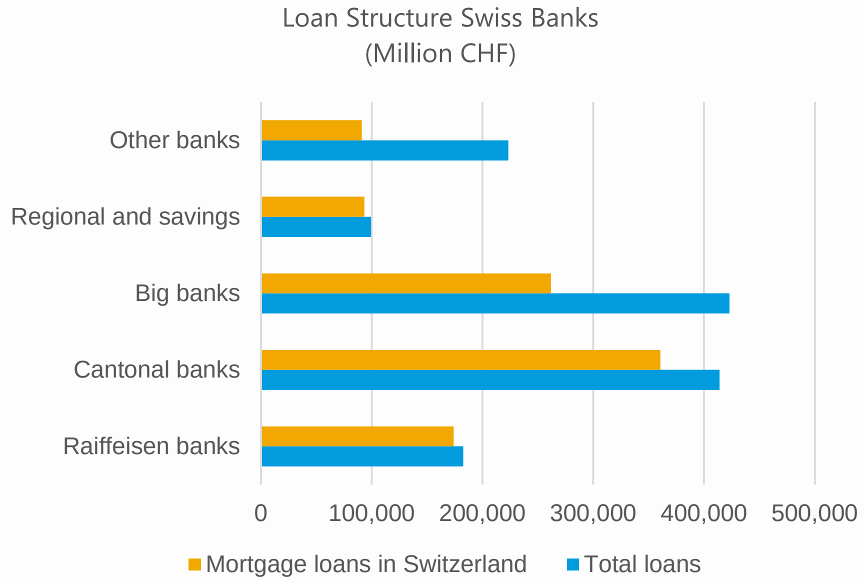
Application I:
Stress Testing and Adequacy of Tools in Switzerland

Strong price dynamics and high exposure





Peak-to-trough	Owner occupied	Investment	CRE
Historical	-17%	-31%	-23%
5-year adverse scenario	-27%	-40%	-35%

Banking system	OO	Investment	CRE
Share of mortgage loans	50%	30%	20%

Regulatory framework

Switzerland became the first country to activate the Basel CCyB in Feb 2013.

Structural shifts

- In 1995, borrowers were allowed to draw on their pension contributions to cover down payments
- In July 2012, the LTV ratio must be reduced to at most two-thirds within at most 20 years (mandatory amortization), and home buyers must provide at least 10 percent of the house value as “hard equity”
- In June 2014, the tenor of mandatory amortization was shortened to 15 years

Amortization requirements depend on LTV at origination and vintage

- “First mortgage”: interest-only
- “Second mortgage”: amortization rate linked to maximum amortization period

$$L_{i,s}^{first} = \frac{2}{3} HP_{i,s}$$

$$L_{i,s}^{second} = L_{i,s} - \frac{2}{3} HP_{i,s}$$

Margin call

- Banks have the option to request a margin call if the value of the collateral is insufficient to meet self-regulation rules

Scenario for Switzerland

Variable	Cumulative percentage change over two years (baseline)	Cumulative percentage change over two years (adverse)
Real disposable income	3.6%	-4.4%
Real house price level	0%	-25.4%
Unemployment rate	-0.11%	1.4%
Mortgage rate	1.25%	3.8%

The table shows the cumulative changes in key macroeconomic variables that affect mortgage default and losses. The paths are projected using a DSGE model. The scenario implies a deviation of real GDP from its baseline level by 7.7 percent in 2020, with a 3.3 standard deviation move in two-year cumulative real GDP growth rate.

Model inputs

Supervisory templates and SNB statistics: LTV, LTI matrices by bank

We segment the mortgage portfolio by LTV bucket and vintage

For each segment, we control for the share of loans of different types (fixed, floating; rollover rates; maturity)

$$DSTI_{i,s} = \frac{A_{i,s} + I_{i,s}^{type}}{Income_{i,s}}$$

$$A_{i,s} = \begin{cases} \dfrac{L_{i,s}^{second}}{20} & if \ \ s < 2014 \\ \dfrac{L_{i,s}^{second}}{15} & if \ \ s \geq 2014 \end{cases}$$

$$I_{i,t}^{fixed,5y} = \begin{cases} r_{i,s}^{fixed,5} \cdot L_{i,t} & t < s+5 \\ r_{i,s+5}^{fixed,5} \cdot L_{i,t} & s+5 \leq t < s+10 \\ r_{i,s}^{fixed,5} \cdot L_{i,t} & s+10 \leq t \end{cases}$$

$$I_{i,t}^{floating,1y} = \left\{ r_t^{floating,1y} \cdot L_{i.t} \right\}$$

Margin call

- The amortization schedule is updated each period according to the following rule:

$$A_{i,t} = \max\left(\frac{\left(L_{i,s} - (t-s)A_{i,s}\right) - \frac{2}{3}HP_{i,t}}{T_{i,t}}, \frac{L_{i,s} - \frac{2}{3}\cdot HP_{i,s}}{T_{i,s}} \right)$$

- A margin call is triggered when the decline in the value of the collateral leads to a violation of the amortization requirement
- It is satisfied within the remaining duration of the contract

Vintage analysis

- We reconstruct vintages flows from supervisory data showing current PiT LTV distribution on stocks
- From average inflow/outflow rates we compute the amount of mortgages *issued* in past vintages
- For each vintage, we split loans into first and second mortgages and match the *calculated* outstanding mortgages from each vintage (applying the regulatory amortization schedule) to the *reported* outstanding stock in 2018
- We distribute LTV shares by vintage under two assumptions
    - *Baseline assumption*: Same distribution of PiT LTV for each vintage
    - *Alternative assumption*: Same distribution of LTV at origination for each vintage

From LTV at origination to PiT LTV

- We have information on the PiT LTV shares of the *stock* of mortgages $\{\beta_b\}_{b=1}^{5}$
- We assume a candidate distribution of mortgage shares at issuance $\{\hat{\alpha}_b\}_{b=1}^{5}$
- For each LTV bucket, we compute the ‘second mortgage’ and apply the amortization rule

$$LTV_{s,t,b}^{PiT} = \frac{\left(1 - \sum_{i=1}^{t-s} A\left(LTV_{s,b}^{orig}, s, i\right)\right) \cdot L_{s,b}}{HP_s \cdot \prod_{k=1}^{t-s}\left(1 + g_{s+k}\right)}$$

- We compute share of outstanding mortgages with PiT LTV=b at time *t* as

$$\hat{\beta}_{b,t} = \sum_{s=t_0}^{t} \gamma_s \cdot \sum_{k=1}^{5} \hat{\alpha}_k \cdot \mathrm{I}_{s,t,b,k} \qquad \mathrm{I}_{s,t,b,k} \equiv \mathrm{I}\left[LTV_{s.t,b}^{PiT} \in b_k\right]$$

- We solve the multiple equation system, back out the value of $\{\alpha_b\}_{b=1}^{5}$, and compute the PiT LTV distribution by vintage

Calibration

- Calculate average PD over 1990-92, assuming LGD= 35% → PD=2.6%
- Estimate the share of borrowers in distress, calibrating the share of economic default → 13.2%
- Allocate financial distress due to ΔDSTI and Δu (80%; 20%)
- Compute the aggregate sensitivity of $\Pr(FD)_i$ to changes in the average DSTI in 1989-92
- Calculate the aggregate sensitivity of $\Pr(FD)_i$ to changes in unemployment in 1989-92

→ $\beta_1 = 0.21$

→ $\beta_3 = 0.66$

- Calibrate D to match expected default rates in 2018

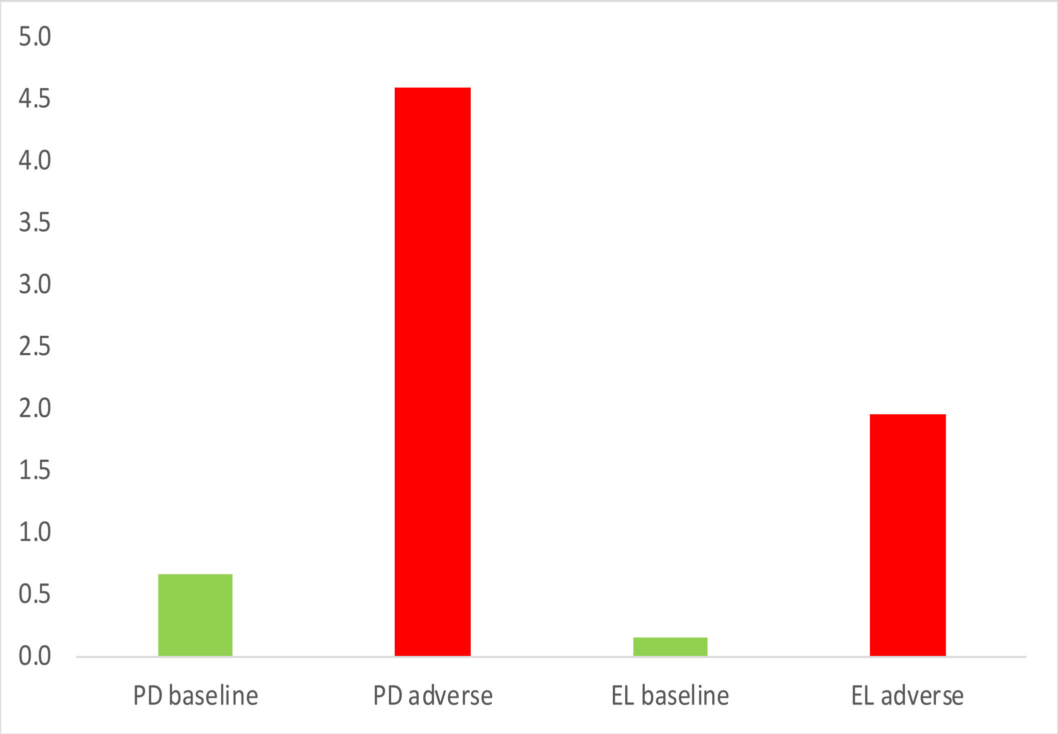
Stress test results

- The average annualized default rate reaches 4.6 percent in 2019-20 with the average LGD at 32.4 percent.

- The loss rate of mortgage claims rises to 1.95 percent leading to a 1.50 percentage points decline of the banking system CET1 ratio.

- Default rates are concentrated in the top RHS quadrant of the LTI LTV matrix. Loss rates range between 3.3 percent and 11.2 percent for LTI buckets higher than 7.

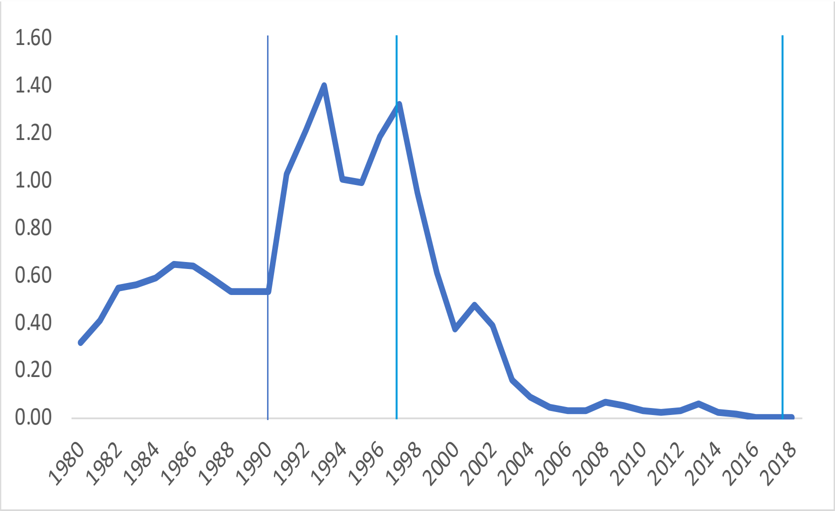
PD and Expected Loss Rate (EL)
(Percent)



Backtesting

The model is validated against ‘bad times’, ‘good times’, and current ‘benign conditions’

Mortgage loss rate
(Percent)



1989-1991	Loss Rate
Predicted	1.01
Observed	1.03

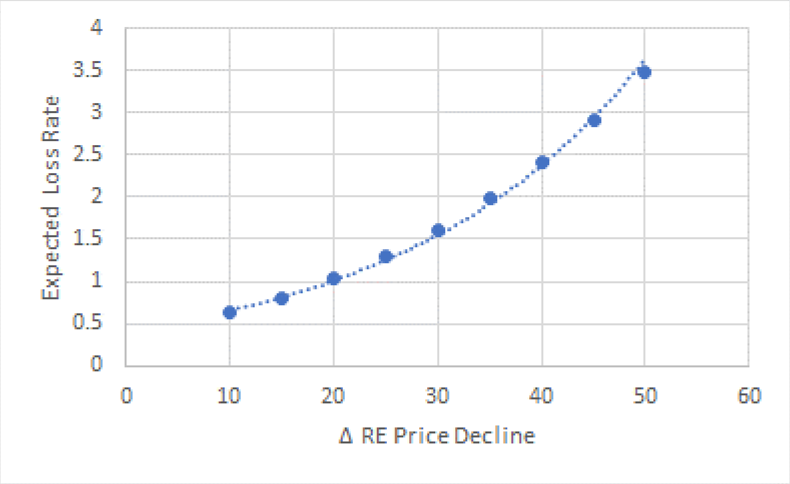
1997-1999	Loss Rate
Predicted	0.61
Observed	0.83

2019-20 baseline	Loss Rate
Predicted	0.15
IRB estimate	0.16

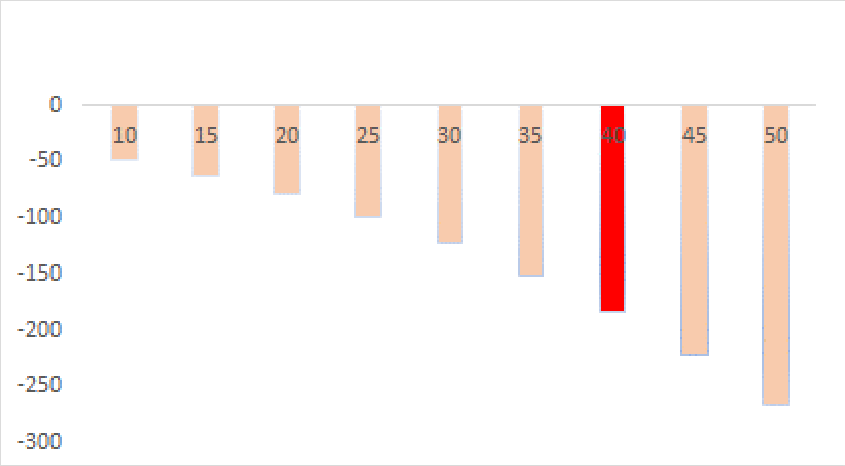
Sensitivity test – Real Estate Prices

Exponential effect on loss rates and CET1 depletion from larger real estate price corrections. Assume adverse conditions and IR=3%

Expected loss rate
(Percent)



CET1 depletion
(Percent)

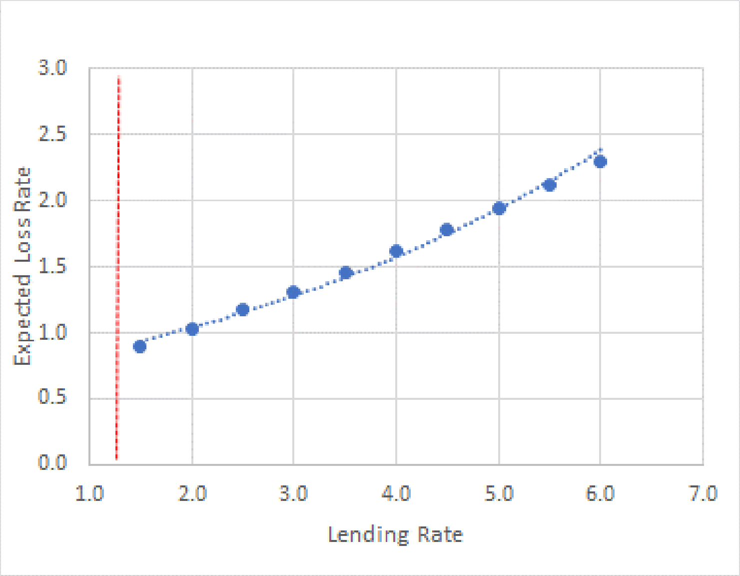


ΔRE=-40% triggers EL=2.4%, and ΔCET1=-184bps

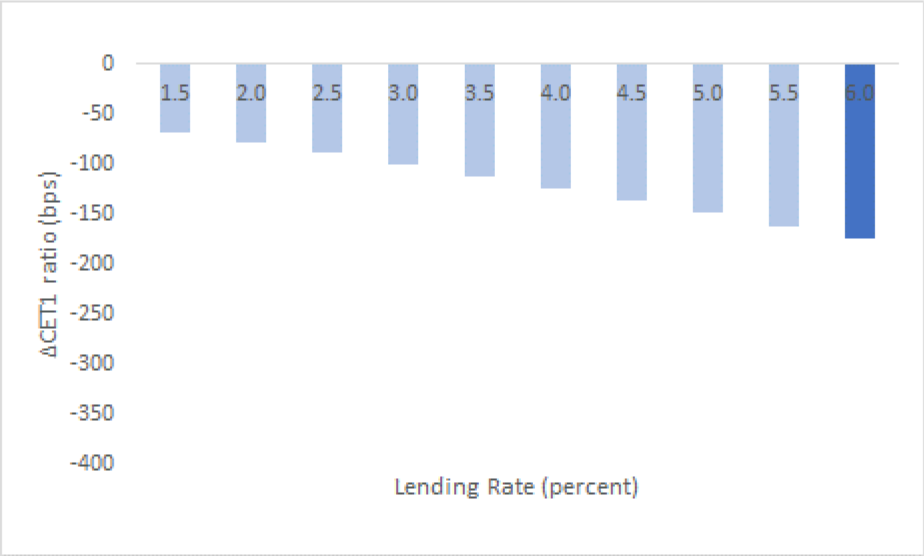
Sensitivity test – Interest Rates

More linear effect on loss rates and CET1 impact from wider shocks to interest rates. Assume adverse conditions and ΔRE=-25.4%

Expected loss rate (Percent)



CET1 depletion (Percent)

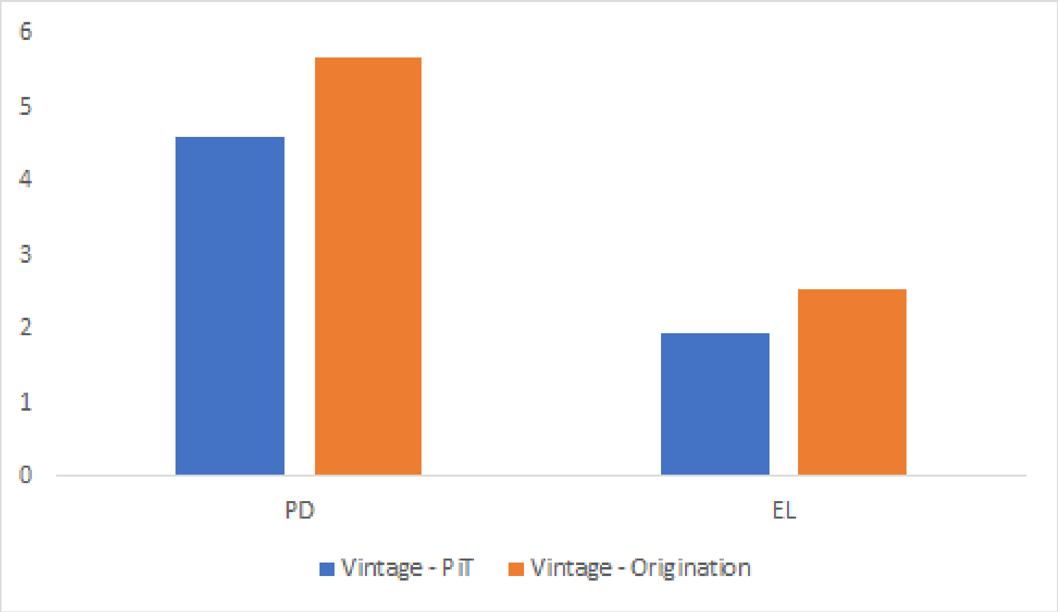


An IR=6% triggers EL=2.3%, and ΔCET1=-175bps

Robustness checks

- Vintage distribution
  - LTV PiT vs LTV at origination
  - PD increases from 4.6 to 5.7 percent
- Margin call (switched off):
  - PD declines from 4.6 to 4.3 percent
  - CET1 ratio increases by 60 bps

PD and Expected Loss rate (Percent)



Macroprudential Policy Assessment

- CCyB=2% of risk-weighted positions secured by residential property situated in Switzerland

- CET1 depletion by 149 basis points represents 3.3 times the size of the CCyB, assuming a risk weight density of 30% or 3.0 times netting out provisions

- Counterfactual analysis: Change in the maximum amortization period for second mortgage

- Offsetting effects
  - Illiquidity condition (-)
  - Negative home equity (+)
  - Margin call (lower probability, higher impact)

- Result: if the maximum amortization period in 2014 had been lowered to 10 years (rather than to 15), the PD would decrease from 4.6 to 4.5 percent in 2019-20 (CET1 impact of 10 bps)

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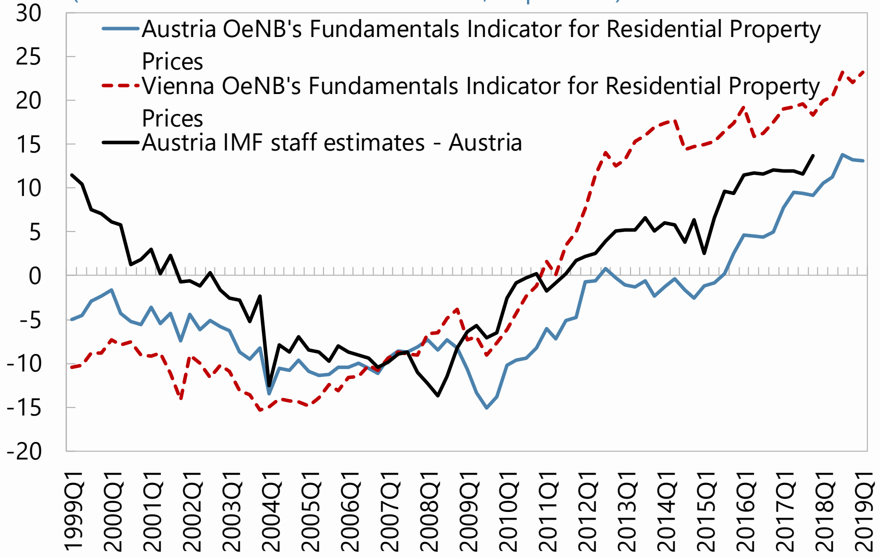
Application II:
Calibration of Borrower-Based Limits in Austria

Strong price dynamics in the real estate market

- The authorities issued a guidance on "sustainable lending standards" in September 2018

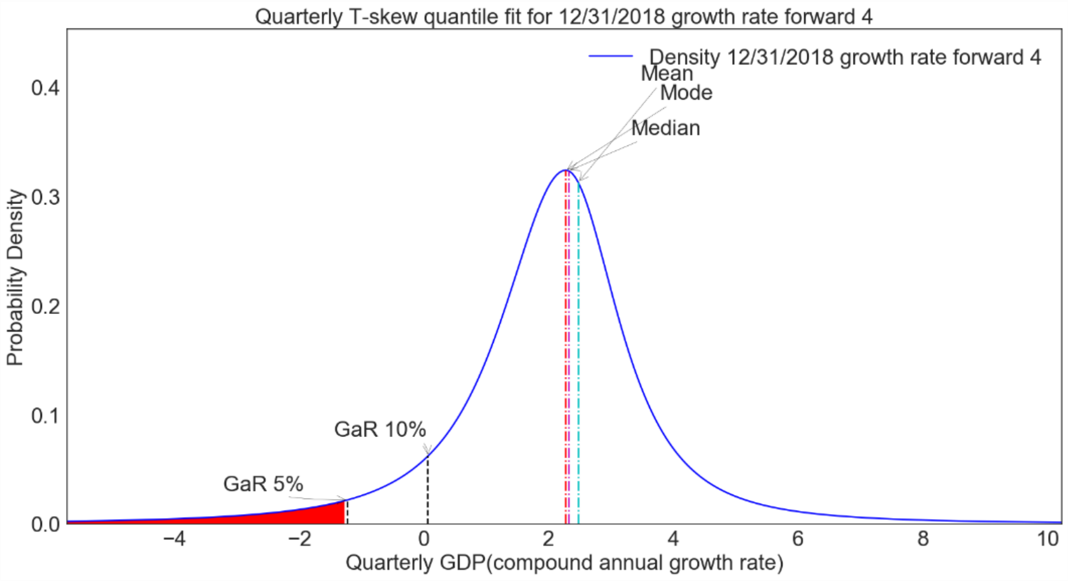
- The share of new mortgage loans with high risk profile has (so far) not declined since the guidance was issued

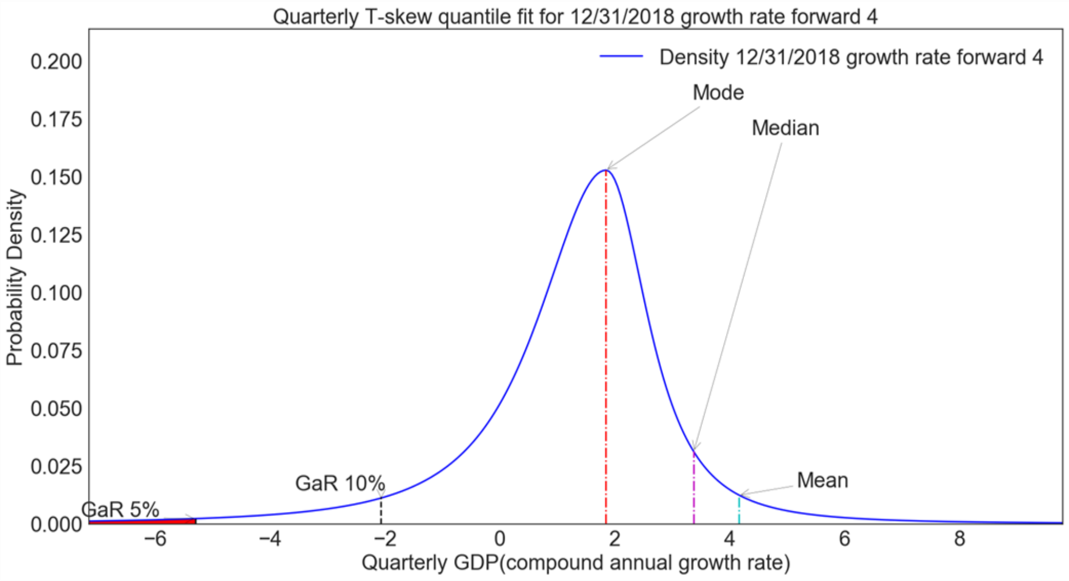
Indicators for House Price Valuation
(deviation from fundamental value, in percent)



Sources: OeNB, IMF staff calculations.

Tail-risk: Growth at Risk (GaR) and House Price at Risk (HaR)





Scenario for Austria

Variable	Cumulative percentage change over 2 years
Real disposable income	-2.5%
Real house price level	-11%
Unemployment rate	1.9%
Real rate on housing loans	1.4%

- The change in unemployment rate is estimated based on the past relationship with GDP growth.
- The change in the interest rate on housing loans is calibrated based on evidence from past recessions.

Supervisory data

- The dataset captures over 80 percent of the new mortgages and provides information on the distribution of new loans by LTV, DSTI and DTI (as well as joint LTV-DSTI and LTV-DTI distributions)

- A total of 9 LTV buckets and 33 vintages on quarterly basis (2010Q4-2018Q4)

- No need to reconstruct many mortgage vintages (for mortgage volumes from before 2010Q4 assume characteristics similar to the 2010-2011 vintages)

Introduction of borrower-based limits

We assume macroprudential limits are introduced *n* quarters before the tail risk materializes

- During the *n* quarters the new borrower-based measures are binding and affect the LTV, DSTI, and DTI distributions of new flows of mortgages, while some of outstanding loans mature.
- We assume "bunching" of new loans just below the regulatory limits.

During the *n* quarters, HH income and RE prices grow at the median values from the GaR and HaR models (no change in u or lending rate)

In the absence of macroprudential measures, new mortgage flows are similar to average flows (in terms of volume, LTV, DSTI and DTI distributions) observed in Q1-Q4 2018

Policy simulations

We set *n=8* and consider the following regulatory interventions:

- LTV limits,
- DSTI limits,
- combined LTV and DSTI limits,

DSTI limits affect the debt service ratio in the “distress” formula, and the LTV distribution (joint distributions from the dataset).

For each of interventions we consider two alternatives:

- Hard limits
- Hard limits with speed limits

Results: No macroprudential limits

Without macroprundetial policy actions annualized credit losses reach 1.6% on new mortgage flows over 2 years.

	Whole mortgage portfolio			New mortgage vintages		
	PD	LGD	EL	PD	LGD	EL
Tail risk event	1.9	26.6	0.8	3.9	34.0	1.6
Sensitivity analysis						
With fin wealth	1.6	28.5	0.7	3.4	33.7	1.5
dR=2%	3.4	32.0	1.5	6.9	40.0	3.1
dHP=-20%	2.3	29.2	0.9	4.5	37.7	2.0

Results: Impact of macroprudential limits

New mortgage vintages

		hard limits					speed limit of 20%				
LTV	none	80.0	none	80	80	90	80.0	none	80	80	90
DSTI	none	none	40	30	40	40	none	40	30	40	40
PD	3.9	2.7	3.2	1.3	2.2	2.7	3.3	4.0	2.3	3.3	3.7
LGD	34.0	31.9	31.8	31.8	31.8	32.1	32.9	34.1	32.9	32.9	33.4
EL	1.6	1.0	1.3	0.5	0.8	1.0	1.3	1.6	0.9	1.3	1.5

- DSTI limits of above 30% are not very effective (the average DSTI is below 30% *across* vintages and LTV buckets)
- Joint LTV-DSTI caps with a ‘speed limit’ of 20 percent, or a tighter joint LTV-DSTI ‘hard limit’ match expected losses with the "old" part of the portfolio.

Thank you