The Eurace 2.0 model

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Disclaimer:

The views are those of the presenter and do not necessarily reflect those of the IMF.

We agree with:

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We develop a Macro-Financial Agent-Based Model: not abstract, realistic, featuring endogenous cycles (instability), and a role for policy to influence the cycle.

Objective

Develop a model that helps policy makers answer questions such as:

1. Do capital- and borrower-based MPRU instruments help reduce financial and business cycle variance?
   - Comparative efficacy of instruments?
   - Trade-off between growth and stability (mean and variance)?
   - Transmission channels?
   - Actual quantitative, initial state-dependent impacts?
2. Static vs. dynamic use of tools
   - What macro-financial indicators to link to?

Why an ABM?

- Recourse to shocks in NK models very dis-satisfactory → not explaining cyclical sequence of booms and recessions
- Critique about DSGE models very explicit (Blanchard 2016a/b, Stiglitz 2017, …)
- Rational expectations (Muth 1961): neat but extremely implausible
- Bounded rationality more plausible (Simon 1955, Tversky & Kahnemann 1974): heuristics are economical and effective
- Agent heterogeneity: distributional effects of policy

OUTLINE

1. Literature perspective
2. Selected model features
3. Exemplary simulation results
4. Conclusions + Way forward

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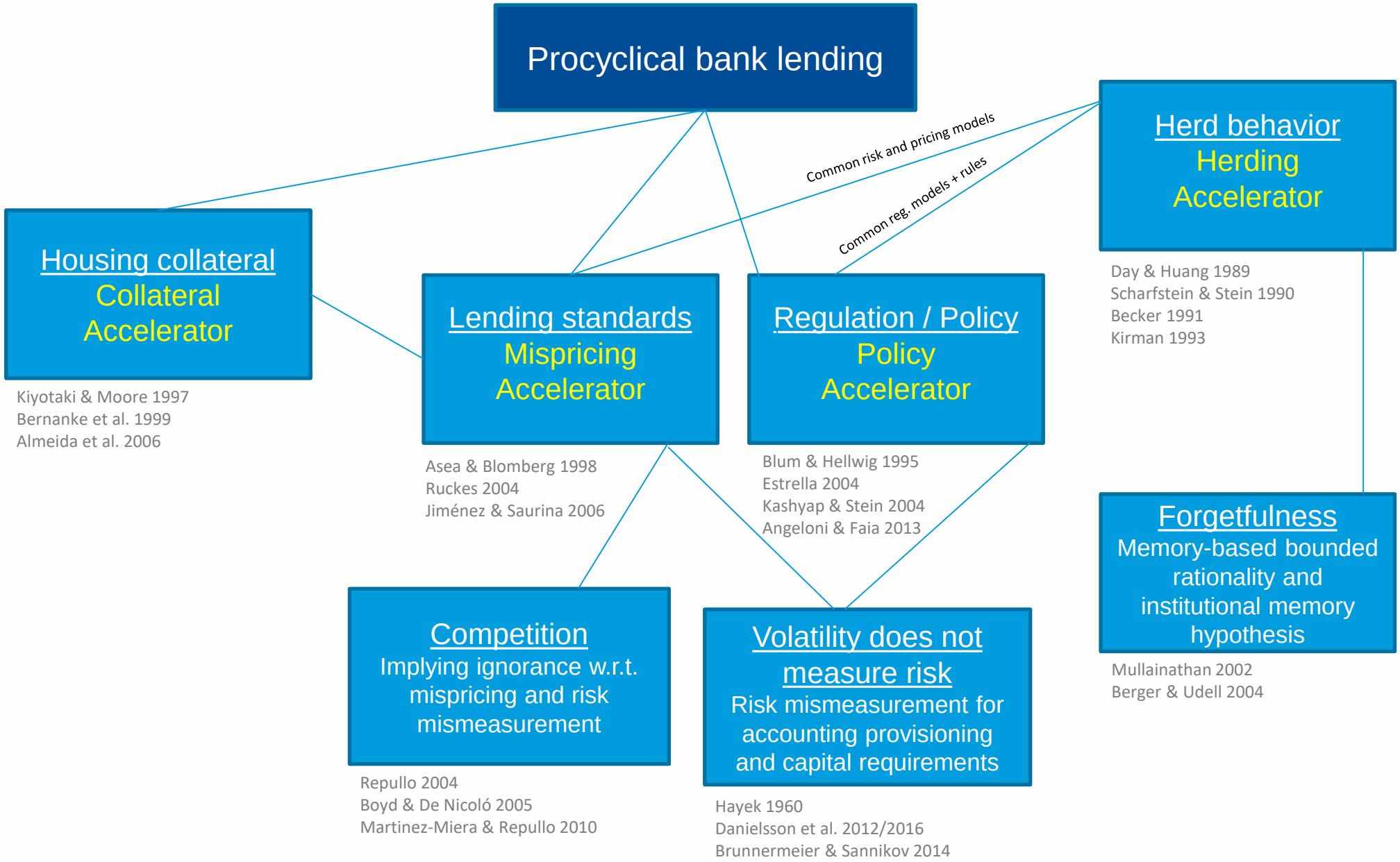
Literature perspective



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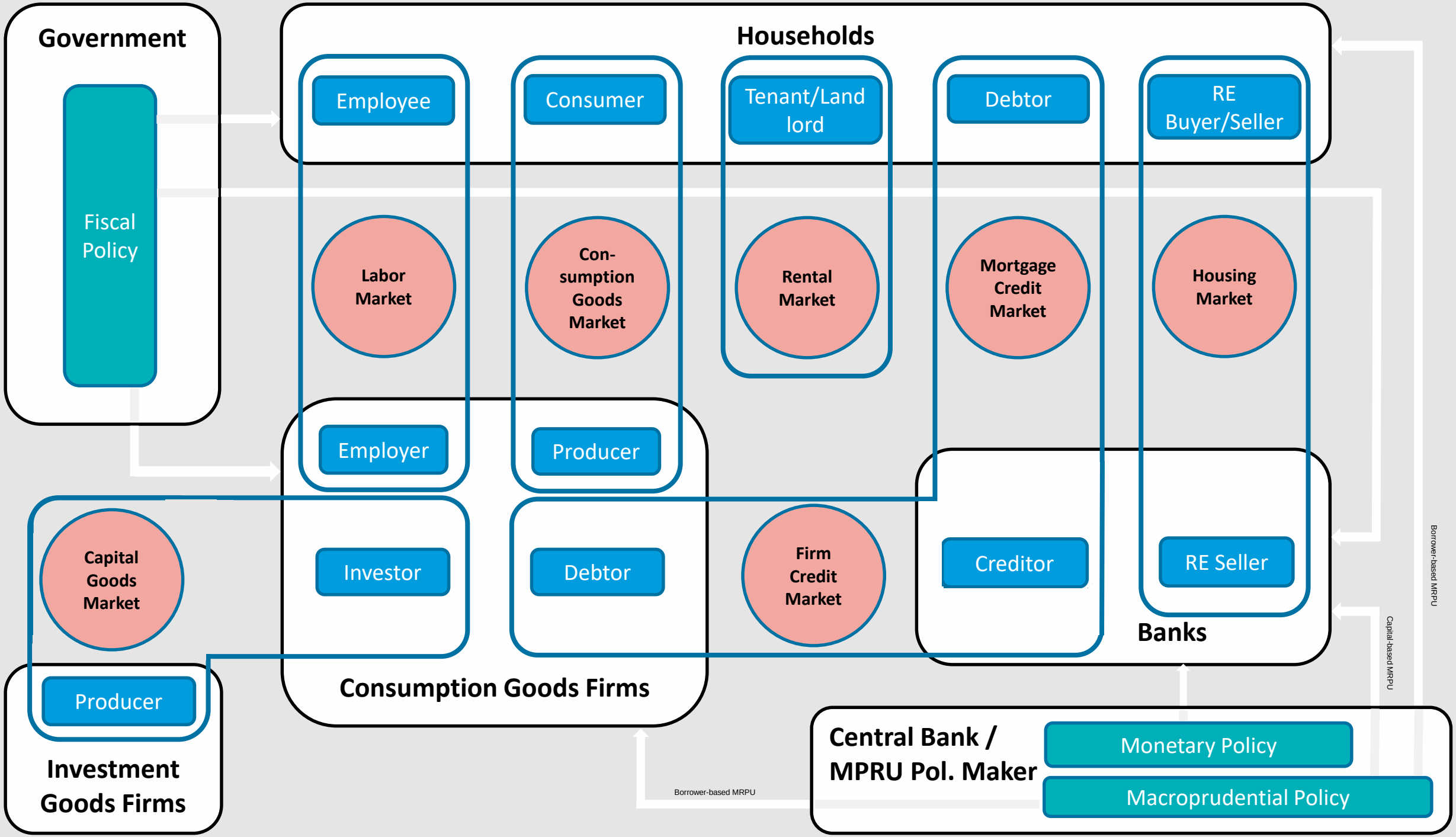

Government
Fiscal Policy
Households
Employee
Consumer
Tenant/Land lord
Debtor
RE Buyer/Seller
Labor Market
Con-sumption Goods Market
Rental Market
Mortgage Credit Market
Housing Market
Employer
Producer
Capital Goods Market
Investor
Debtor
Firm Credit Market
Creditor
RE Seller
Banks
Consumption Goods Firms
Producer
Investment Goods Firms
Central Bank / MPRU Pol. Maker
Monetary Policy
Macroprudential Policy
Borrower-based MRPU
Capital-based MRPU
Borrower-based MRPU

Integrated balance sheets

Agent	Assets		Liabilities	
Households (h=1...H)	T^h	tangible assets (real estate)	MORT	mortgage loans
	M^h	liquid assets (deposit at bank)		
	S^f	equity stake in firms		
	S^b	equity stake in banks	E^h	equity
	SBOND	sovereign bonds		
Consumption goods firms (f1=1...F1)	T^{f1}	tangible assets (physical capital)	FLOAN	loans
	M^{f1}	liquid assets (deposit at bank)	E^{f1}	equity
Investment goods firms (f2=1...F2)	T^{f2}	tangible assets (physical capital)	E^{f2}	equity
	M^{f2}	liquid assets (deposit at bank)		
Banks (b=1...B)	sum(MORT)	mortgage loans	sum(M^h)	deposits from households
			sum(M^{f1})	deposits from cons. good firms
	sum(FLOAN)	loans to consumption good firms	sum(M^{f2})	deposits from investment good firms
	GLOAN	loans to government	M^G	deposits from government
	SBOND	sovereign bonds	BLOAN	loan from central bank
	M^b	reserves (deposit at central bank)	P	loan loss reserve
			E^b	equity
Government (G)	M^G	liquid assets (deposit at bank)	GLOAN	loans
			SBOND	sovereign bonds
			E^G	equity
Central Bank (CB)	M^{CB}	liquid assets	sum(M^b)	liquid assets from banks (reserves)
	SBOND	sovereign bonds	E^{CB}	equity
	BLOAN	loans to banks		

Component 1/13: Bank funding cost module – Why?

… because changes in bank funding costs due to (policy-induced) changes in bank capital structure and bank-external conditions are important to properly capture the impact of MPRU policies.

Component 1/13: Bank funding cost module

$$i_{b,h,t}^{loans} = WACF_{b,t} + spread_t(borrower\ risk)$$

Fully structural, function of borrower PDs and LGDs. For firms and mortgage loans separately. Borrower-specific spread.

$$WACF_{b,t} = i_t^{base} + spread_t\ (bank\ risk)$$

Empirically micro-founded bank panels for deposit rates, cost of debt and equity embedded in the ABM. Bank-specific.

$$i_t^{base} = i_t^{pol} = \mathrm{f(capacity\ util.\,, inflation\ gap)}$$

Taylor rule. Capacity utilization and inflation gap structurally endogenous in the ABM. Economy-wide base rate.

Component 1/13: Bank funding cost module (ctd)

Cost of deposits and debt

- Empirical bank (agent) panel model
- Controls for market price of risk and sovereign risk (ignored in ABM though)

$$r_{bt}^{D} = \max\{\alpha_b^{D,*} + \beta^D R_{b,t-1} + \gamma^D R_{b,t-1}^2 + \delta^D RW_{b,t-1} + \eta^D r_t^{CBF}, 0\}$$

Cost of central bank funding

- Empirical Taylor rule: function of inflation gap and capacity utilization

$$r_t^{CBF} = \max\{r^* + \alpha_\pi(\pi_{t-1} - \pi^*) + \alpha_u u_{t-1}, 0\}$$

Cost of equity

- Empirical bank (agent) panel model of cost of equity (CAPM-based)
- Define CAPM-based rate as dividend pay-out rate in the model

$$r_{bt}^{Div} = \max\{\alpha_b^{Div,*} + \beta^{Div} R_{b,t-1} + \gamma^{Div} R_{b,t-1}^2 + \delta^{Div} RW_{b,t-1}, 0\}$$

Weighted average cost of funding (WACF)

$$f_t^b = \frac{12}{3} \times \sum_{s=1}^{3} \frac{IE_{t-s}^{b,total}}{L_{t-s}^b}$$

CoF panel model: Empirical micro-foundation

$$r_{bt}^{comp} = c + \alpha_b + \beta R_{bt} + \gamma R_{bt}^2 + \delta V_{bt} + \eta r_t + \theta ms_t + \psi \ln(trx_t) + \xi \ln(cds_{bt}^{sov}) + \epsilon_{bt}$$

Variable	Name	Description	Expected coefficient sign
r_{bt}^{comp}	Cost of debt, deposits or capital	LHS variable, cost of funding components. CAPM-implied cost of capital.	
R_{bt}	Capital ratio	Consolidate bank level, not risk weighted. Either CET1/TA or TE/TA.	- on linear term, + on squared term
V_{bt}	Asset volatility	Either aggregate risk weight (REA/TA) or asset volatility derived from Merton model.	+
r_t	Policy rate	ECB main refinancing rate	+
ms_t	Money market spread	3-month Euribor minus policy rate	+
trx_t	iTraxx Financials	iTraxx Senior Financial to control for market price of risk	+
cds_t	Sovereign CDS	5Y sovereign CDS to control for presence of implicit / explicit guarantees	+

CoF panel model: Empirical micro-foundation

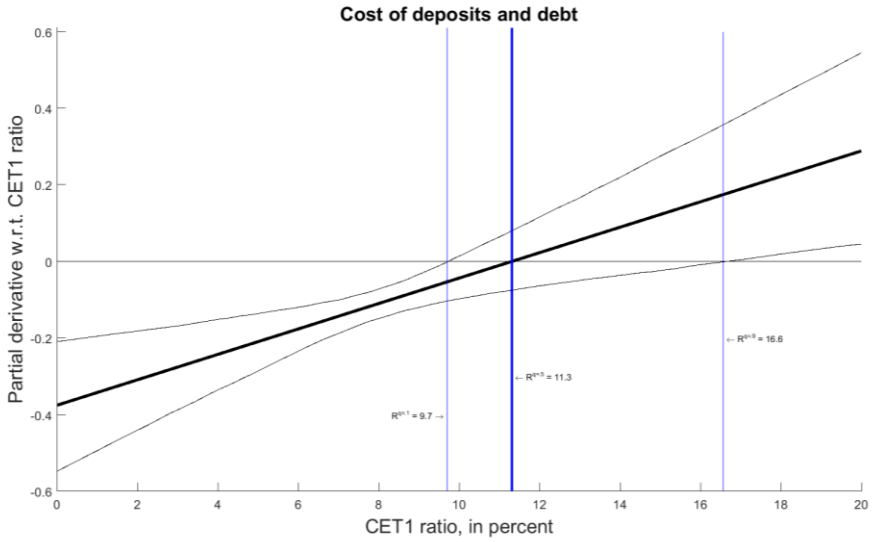
$$r_{bt}^{comp} = c + \alpha_b + \beta R_{bt} + \gamma R_{bt}^2 + \delta V_{bt} + \eta r_t + \theta ms_t + \psi \ln(trx_t) + \xi \ln(cds_{bt}^{sov}) + \epsilon_{bt}$$

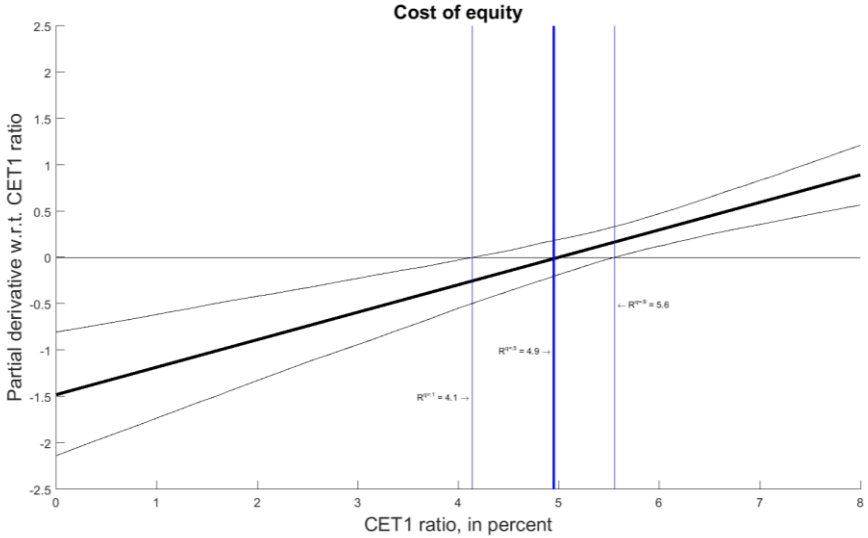
While this eq. does not as such capture the reverse relationship (funding cost → solvency), this reverse relation is captured in a fully structural manner in the ABM. That is, the impact of changing funding costs implies a change in interest expenses (incl. dividends) which feed directly through to changes in bank capital.

[it's this reverse relation that is captured in an econometric simultaneous eq. system for example in Schmitz et al. (2017) and Aldasoro and Park (2018)]

Component 1/13: Bank funding cost module (ctd)

Partial derivative w.r.t. unweighted capital ratio





$$\frac{\partial r}{\partial R} = \beta + 2\gamma R$$

	Cost of deposits+debt		Cost of equity	
	Lin. R	Quad. R	Lin. R	Quad. R
R	-0.13 (0.00)	-0.37 (0.00)	0.14 (0.35)	-1.48 (0.01)
R^2		0.02 (0.04)		0.15 (0.00)
Aggregate risk weight	0.19 (0.04)	0.26 (0.03)	0.60 (0.03)	0.60 (0.03)
Policy rate	1.21 (0.00)	1.16 (0.00)		
Money market spread	0.65 (0.00)	0.66 (0.00)		
LN(ITRXSENFIN)	0.20 (0.18)	0.25 (0.11)	-0.58 (0.31)	-0.45 (0.43)
LN(SOVCDS)	0.22 (0.06)	0.18 (0.15)	1.55 (0.00)	1.59 (0.00)
Obs.	784		1,044	
Adj. R2	0.87	0.89	0.48	0.51
W. mean dep. variable	2.55		11.70	
W. STD dep. variable	1.01		2.70	

We use the combined cost of deposits and debt for steering deposit expenses of banks in the ABM since the model does not contain money market / wholesale funding sources (on purpose).

Component 2/13: Mortgage loan market – Why?

… because borrower-based measures (LTV/DSTI/LTI/DTI caps) operate on new loan business, hence new loan origination feature is needed.

And: Mortgage credit matters a lot from an economic perspective (Claessens et al. 2010, Schularick & Taylor 2012, Jorda et al. 2013, Jorda et al. 2016, etc.).

Component 2/13: Mortgage loan market

Mortgage loan application process

Joint draw for DSTI, LTV, M

Multivariate distribution based on HFCS (with caps or without); debt service implied since income of household is given.

Interest rate setting

Bank sets spread over own funding cost to reflect borrower-specific risk (lifetime PD and LGD) to cover EL and earn positive spread on average.

Imply principal loan amount and repayment schedule

Given maturity M, borrower interest rate and debt service, principal is implied. Imply lifetime schedule.

Imply max value of house

Given a draw of an LTV and implied L, value of house is implied.

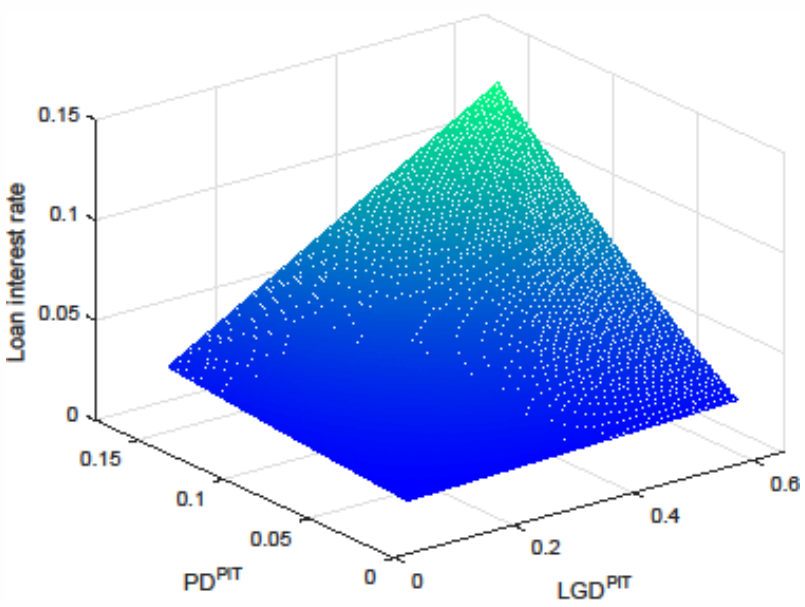
HH own funds

Required residual own funds suffice or not, for contract to be signed or not.

Component 2/13: Mortgage loan market

Loan pricing

Set loan rate (i_t) such that expected life-time loss of a loan is covered, for the bank to earn at least its funding cost (f_t) plus a self-set profit margin (μ_t) on top.



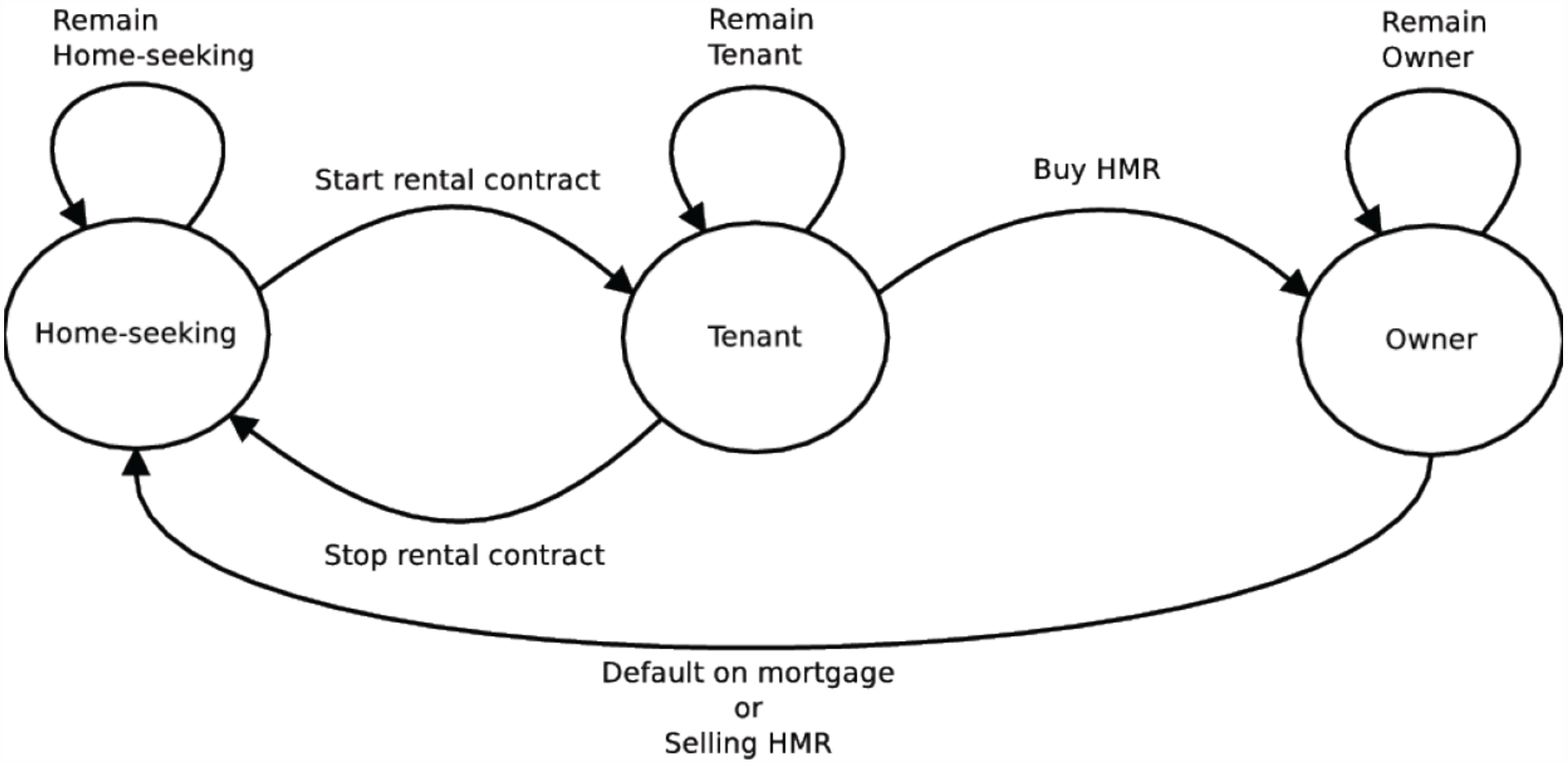
$$
\begin{aligned}
(1+f_t+\mu_t)^m &= \left(1+i_t^h\right)^m \left(1-PD_{t,t+m}^h\right) + \left(1-LGD_t\right) PD_{t,t+m}^h \\
\Leftrightarrow i_t^h &= \left[\frac{(1+f_t+\mu_t)^m - \left(1-LGD_t\right) PD_{t,t+m}^h}{\left(1-PD_{t,t+m}^h\right)}\right]^{\frac{1}{m}} - 1
\end{aligned}
$$

Component 3/13: Housing market

- HHs have inherent motive to own a house
- Purchase possible only with mortgages
- Approach housing market if mortgage contract is feasible and debt service no more expensive than current rent (conditional on current quality)
- Double-auction market
- Buy-To-Let (BTL) gene for pre-defined subset of HHs: aim to own additional housing units to rent out
- Secondary housing market only: no new construction
- Rental and house price index in the model: for policy to link to them

Component 3/13: Housing market

Involving voluntary and involuntary transitions.



Component 4/13: Buy-to-Let investors

Adaptive price expectation rules

Two conditions to hold for attempt to buy OP (to rent out)

Capital gain objective & **Rental yield objective**

$$E_t\left(V_{t+H}\right) > \gamma_1 V_t$$

$$\sum_{h=1}^{H} \frac{E_t\left(RI_{t+h}\right)}{A_{t+h}} > \gamma_2$$

$$E_t\left(V_{t+H}\right) = \exp\left(\ln\left(V_t\right) + H \times q_t\right)$$

$$\text{where} \quad q_t = \frac{1}{S}\sum_{s=1}^{S} \ln\left(\frac{p_{t-s}}{p_{t-s-1}}\right)$$

$$E_t\left(RI_{t+H}\right) = \exp\left(\ln\left(RI_t\right) + H \times q_t\right)$$

$$\text{where} \quad q_t = \frac{1}{S}\sum_{s=1}^{S} \ln\left(\frac{CPI_{t-s}}{CPI_{t-s-1}}\right)$$

Condition to hold for attempt to sell

Avoid capital loss

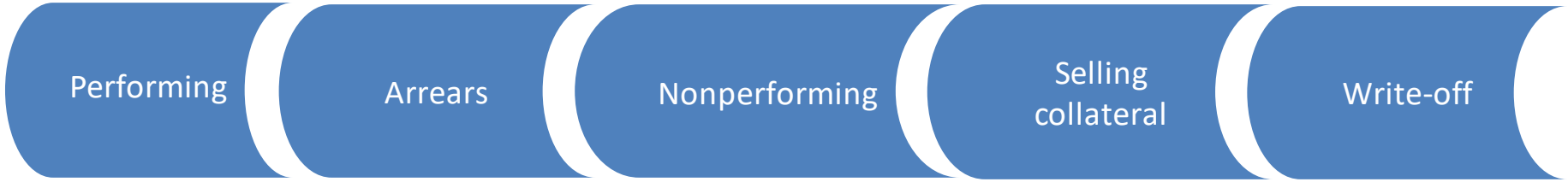
$$E_t\left(V_{t+H}\right) < V_t$$

Component 5/13: Banks' loan loss reserve management

Expected loss (EL) a function of point-in-time PDs, LGDs, and EAD, for firms and HH mortgages in the ABM.

IFRS9 philosophy in a simplified manner: Expected loss instead of incurred loss for LLR built up for performing loans.

Event line built into the model:



Remaining components 6-13

6. Risk weighted asset dynamics: IRB REA formulas embedded
7. Seizure of housing collateral by banks and re-sale in secondary market
8. Solvency-based bank defaults
9. Balance sheet initialization for households with household survey data and banks
10. Household consumption and savings rules, including household assets
11. Consumption goods firms: production planning, capital/labor management, vintage choice, pricing
12. Capital goods firms: development of vintages, pricing
13. Sovereign: tax rules and unemployment benefits

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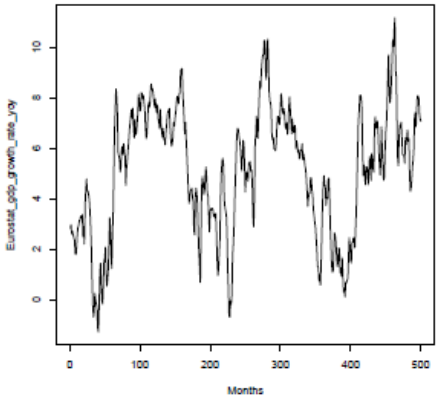
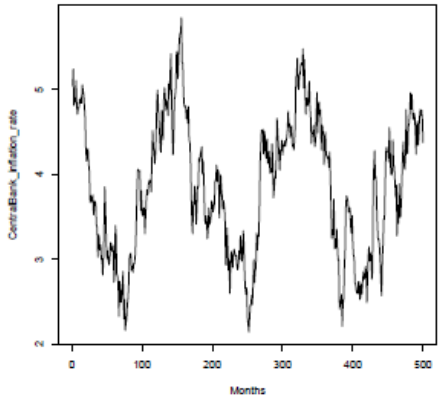
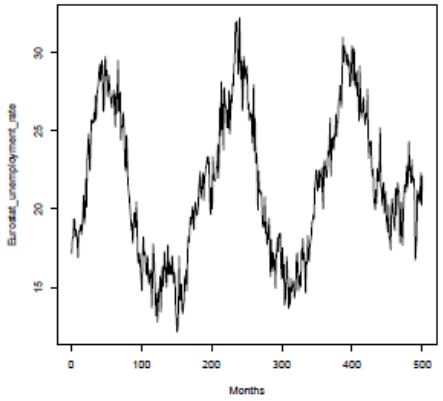
Baseline: Endogenous cycles



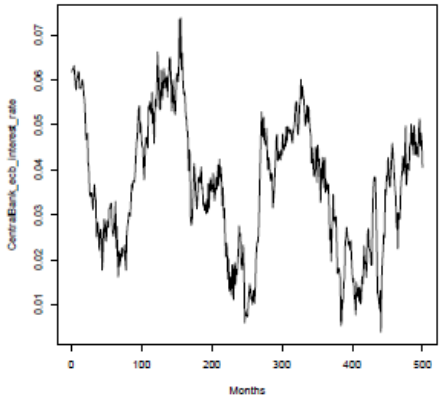
(a) GDP growth YoY



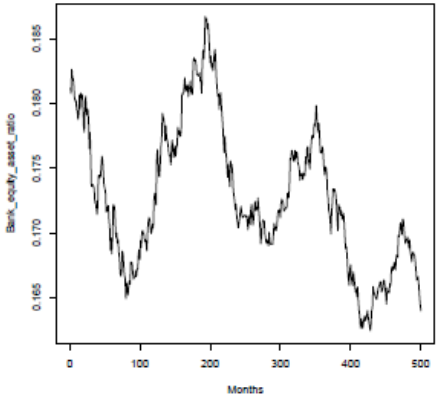
(b) Price inflation YoY



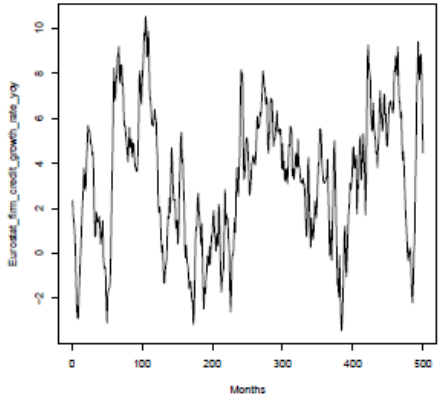
(c) Unemployment rate



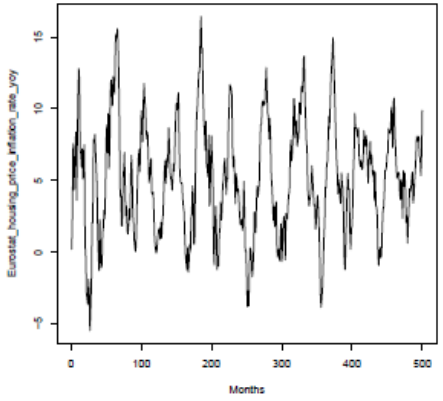
(d) Policy rate



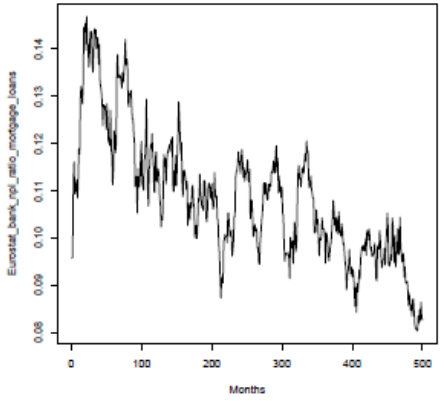
(e) Banks' E/A ratio



(f) Firm credit growth YoY



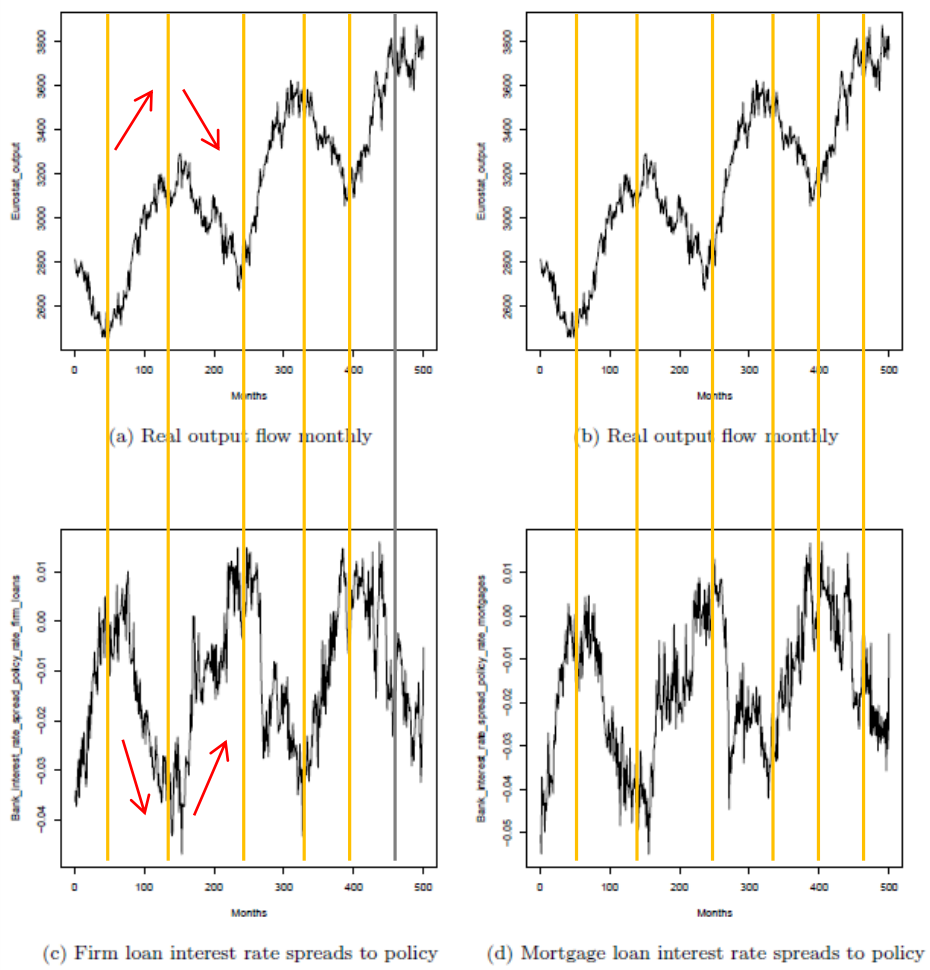
(g) House price inflation



(h) NPL ratios

Countercyclical pricing

Model outcome vs. empirical data

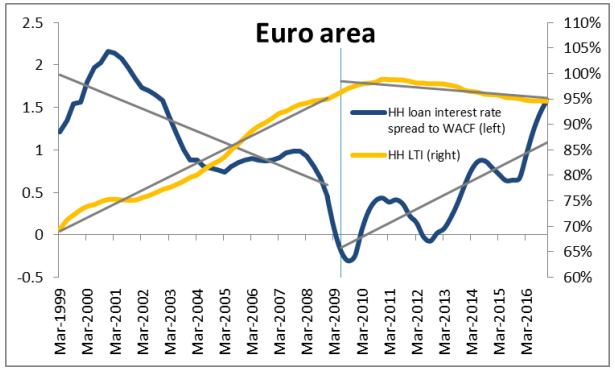


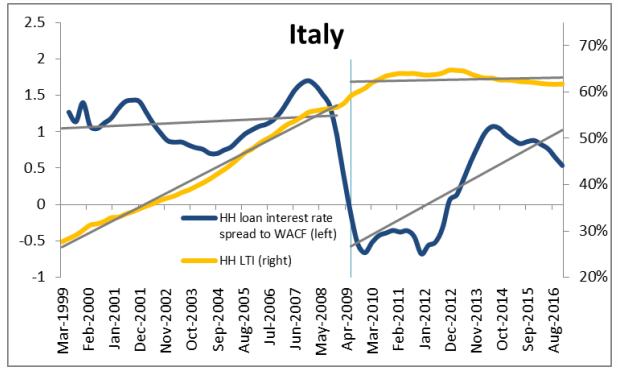
(a) Real output flow monthly

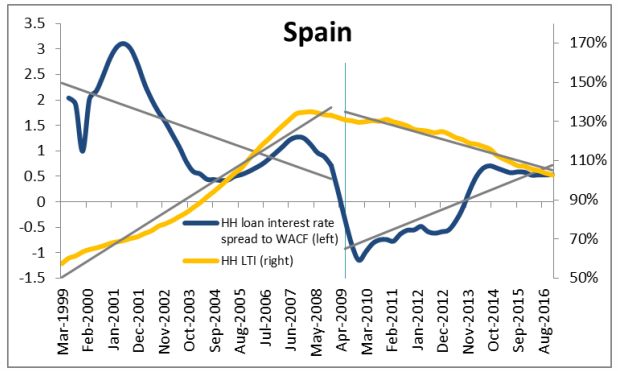
(b) Real output flow monthly

(c) Firm loan interest rate spreads to policy

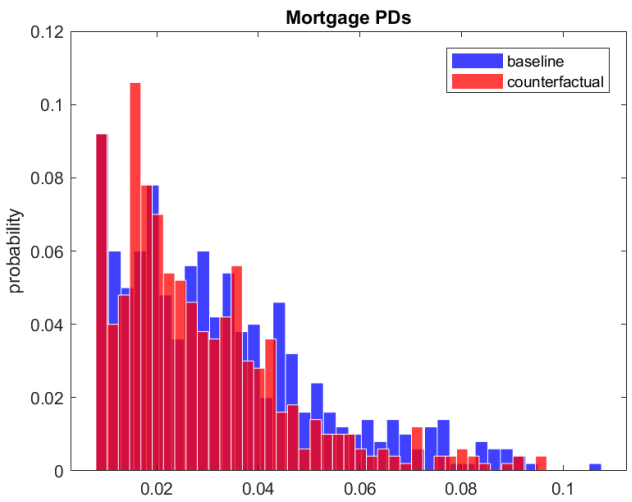
(d) Mortgage loan interest rate spreads to policy







LTV cap at 70%


Mortgage PDs
baseline
counterfactual
probability
0.12
0.1
0.08
0.06
0.04
0.02
0
0.02
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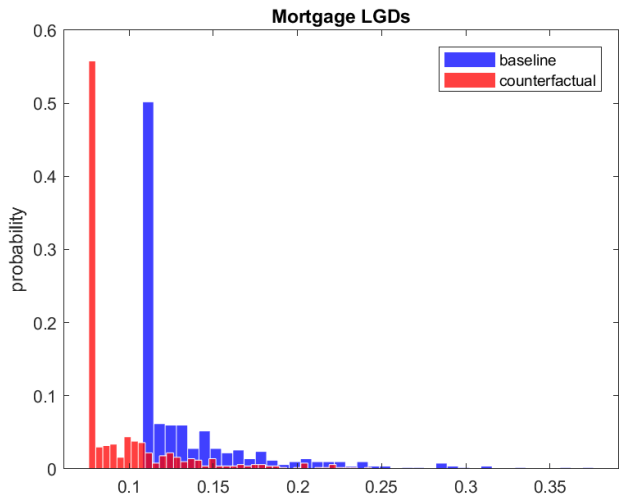
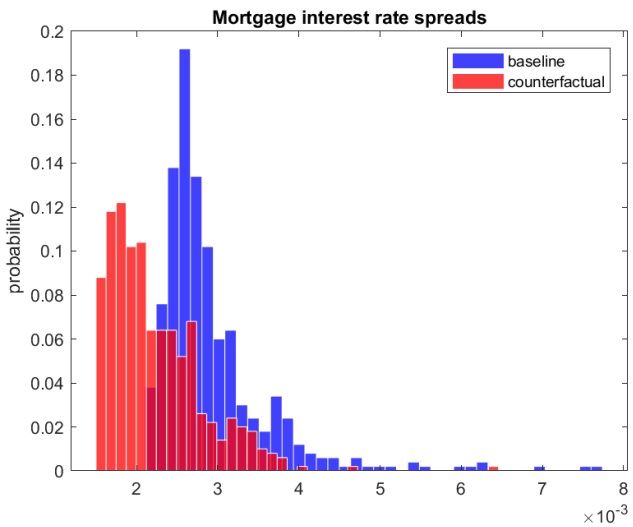
0.06
0.08
0.1


Mortgage LGDs
baseline
counterfactual
probability
0.6
0.5
0.4
0.3
0.2
0.1
0
0.1
0.15
0.2
0.25
0.3
0.35


Mortgage interest rate spreads
baseline
counterfactual
probability
0.2
0.18
0.16
0.14
0.12
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0.08
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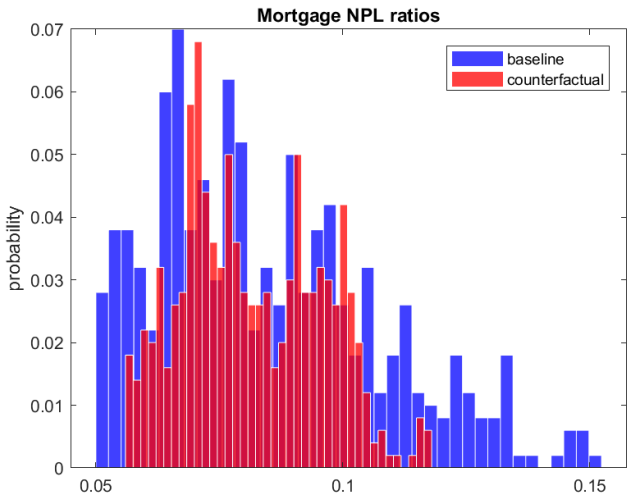
Mortgage NPL ratios
baseline
counterfactual
probability
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0.06
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0.05
0.1
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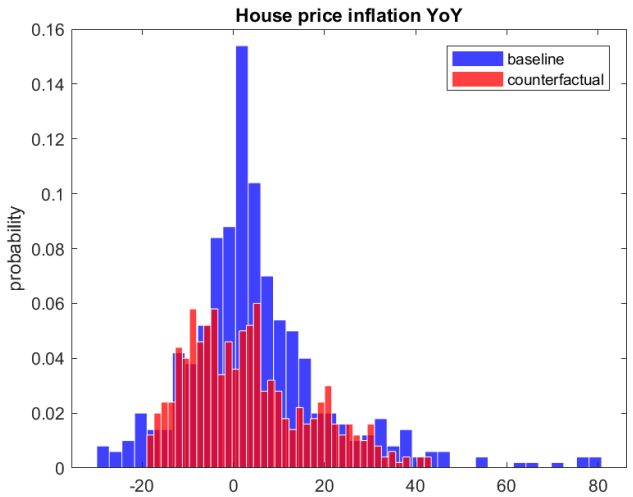
House price inflation YoY
baseline
counterfactual
probability
0.16
0.14
0.12
0.1
0.08
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-20
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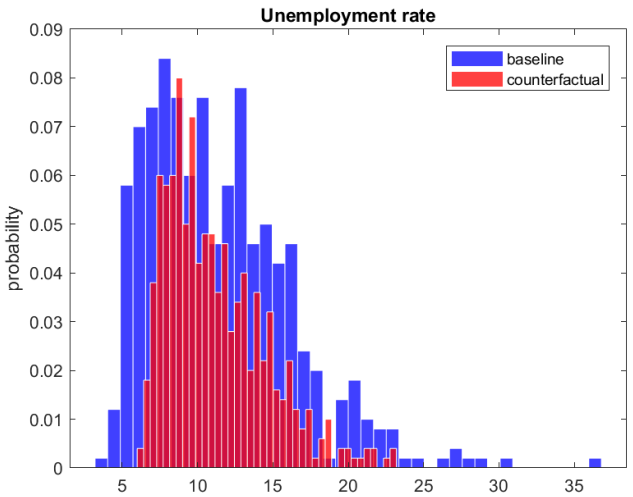
20
40
60
80


Unemployment rate
baseline
counterfactual
probability
0.09
0.08
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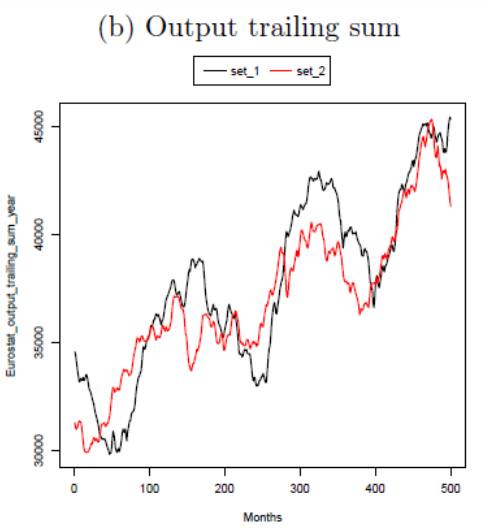
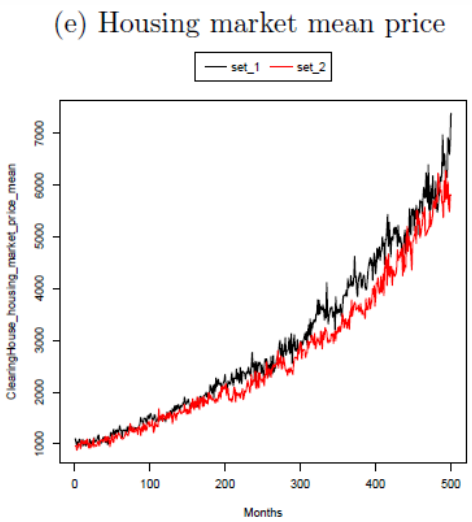
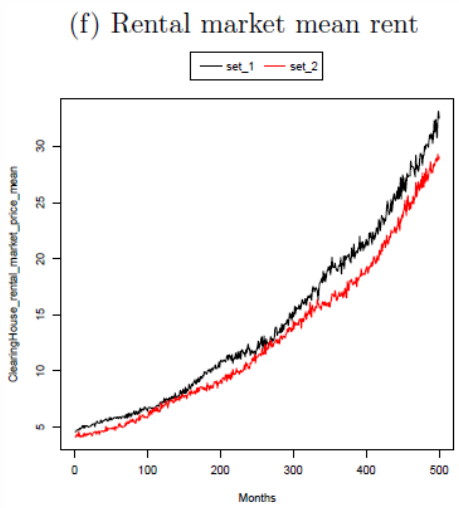
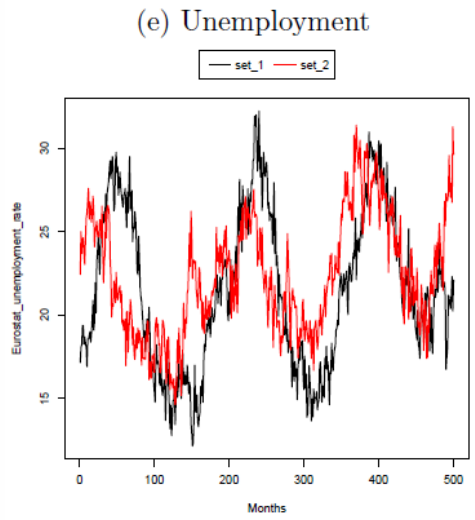
25
30
35

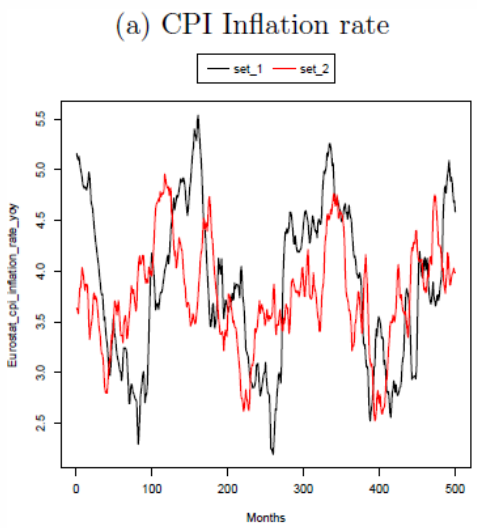
Switch off OP business











Reduction in business and financial cycle variance.

OUTLINE

1. Literature perspective
2. Selected model features
3. Exemplary simulation results
4. Conclusions + Way forward

Conclusions

Model with self-evolving endogenous leverage, business and financial cycles, without recourse to exogenous (off-model) shocks.

Capital-based MRPU policy able to compress cycle under two conditions:

1. Banks to hold voluntary excess buffers above regulatory minima.
2. Assumptions underlying MM theorem to not hold.

Conclusions

Borrower-based policy has a more direct bearing. LTV caps work primarily through reducing borrowers' LGDs (DSTIs more through PDs).

Model without strategic default structures, as meant to capture European structure. Otherwise, LTVs may have stronger bearing on PDs as well.

Point-in-time risk measures that banks use to price risk, to provision and compute RWs not forward-looking enough

→ Mispricing Accelerator / Variance does not measure risk
→ IFRS9 promising in principle (but…)
→ Countercyclical regulation to counter pro-cyclical effects of passive risk-based regulation

Way forward

Two steps toward finalizing the model structure:

1. Implement target capital ratio mechanism for banks: to render capital-based MPRU more potent. Define break-even capital ratios (self-estimated) as targets (approx. 10-12%).

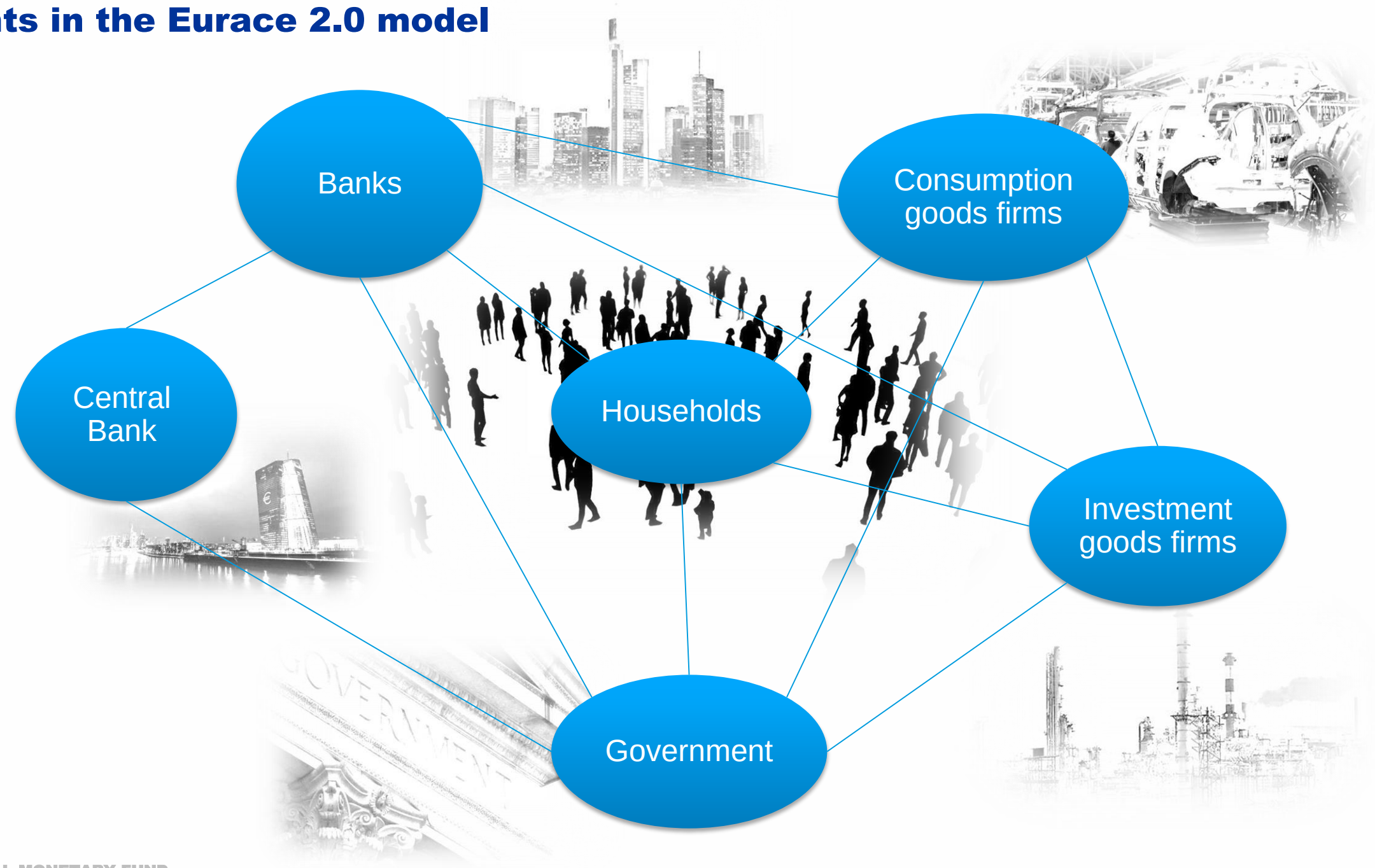
2. Make labor market a bit more inflexible: to increase correlation of firm PDs with the cycle.

Then: Estimate the model (a project in itself)

Then: Outcome of counterfactual policy simulations can be interpreted also quantitatively.

Background Slides

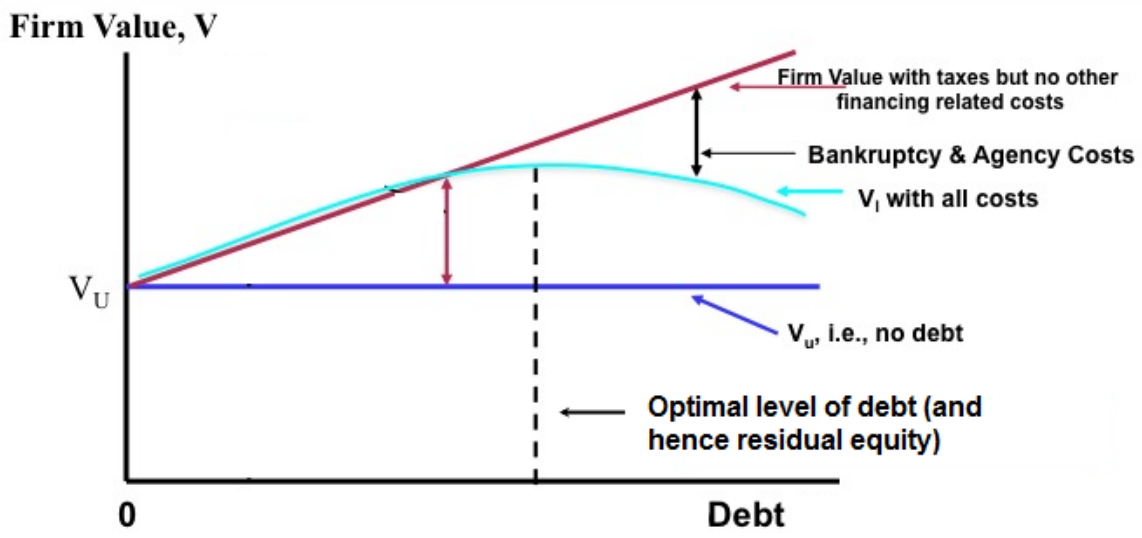
Agents in the Eurace 2.0 model



Component 1/13: Bank funding cost module (ctd)

Trade-off theory of capital structure

- Kraus and Litzenberger 1973 and Myers 1984: banks choose debt amounts vs. residual net worth in a way to balance costs and benefits → trade-off between tax benefit and bankruptcy costs
- Marginal benefit of more debt (due to tax benefits) vanishes with higher levels of debt (more risk); effect of higher risk will dominate at some pt.



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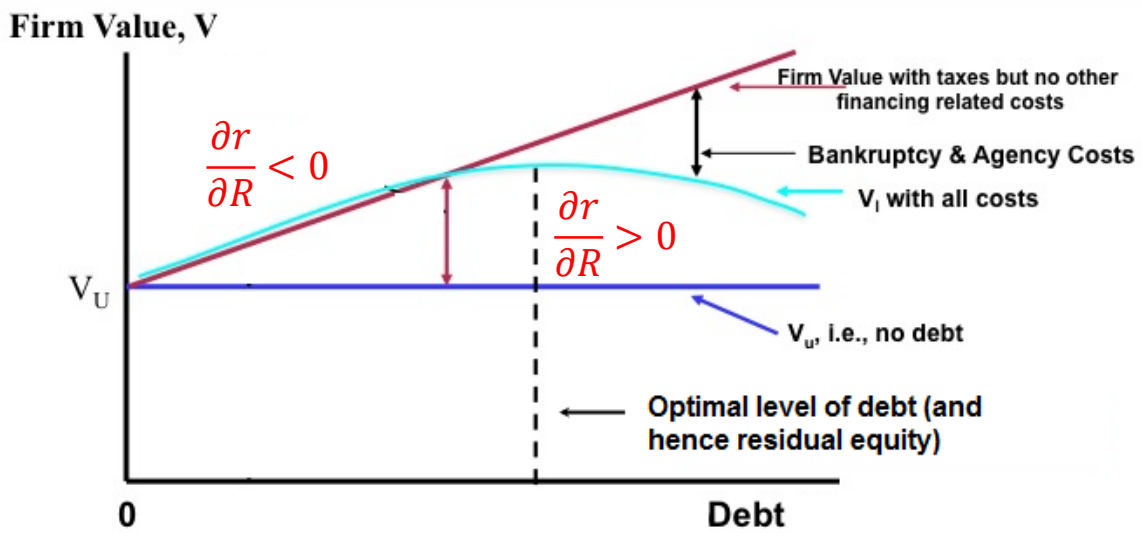


We link to this theory: <u>not</u> via use of capital structure measures on LHS (as all literature in this field it seems) <u>but through lense of cost of funding</u>!

Component 2/13: Mortgage loan market (ctd)

Nonlinear repayment schedule: constant annuity, fixed rate contracts

Principal implied by interest rate (*i*) and duration (*M*):

$$L_0^{b,h} = \frac{12A^h\left(\left(1+i^{b,h}/12\right)^M - 1\right)}{i^{b,h}\left(1+i^{b,h}/12\right)^M}$$

Principal outstanding each period:

$$L_s^{b,h} = L_0^{b,h}(1+i^{b,h}/12)^s - \frac{12A^h[(1+i^{b,h}/12)^s - 1]}{i^{b,h}}, \forall s = 0, ..., M$$

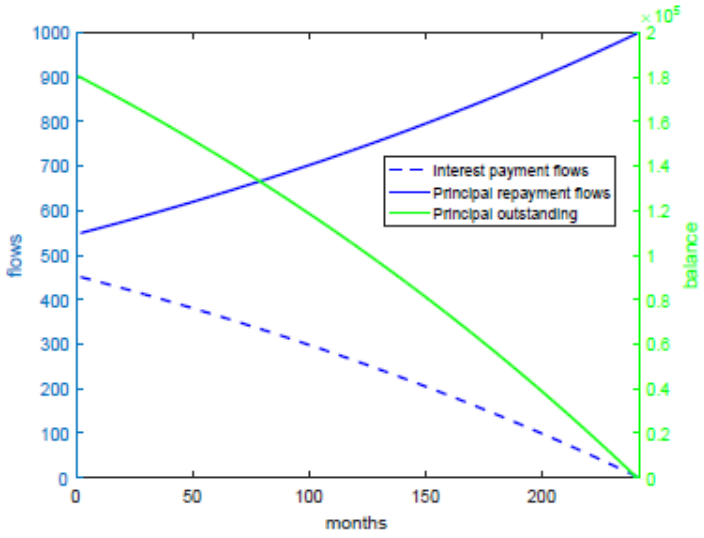
Monthly interest payment flows:

$$a_s^{b,I} = \frac{i^{b,h} \times L_{s-1}^{b,h}}{12}, \forall s = 1, ..., M$$

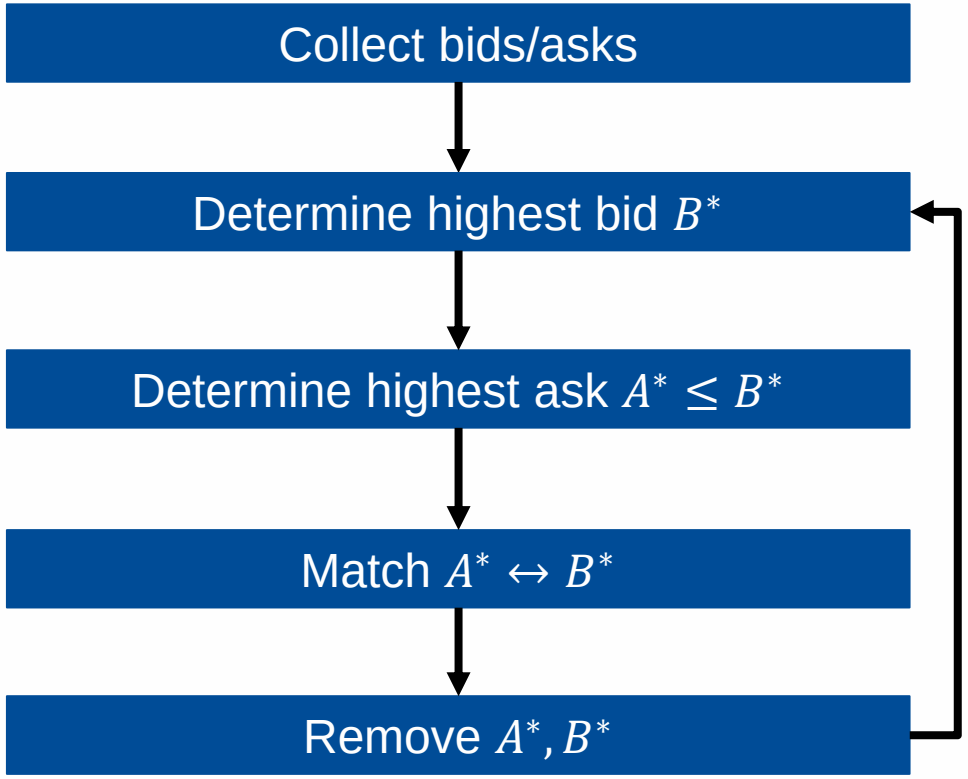
Monthly repayment flows:

$$a_s^{b,P} = A^h - a_s^{b,I}, \forall s = 1, ..., M$$

Example: Duration 20 years. Monthly annuity EUR 1,000. Annual effective interest rate 3%. Principal loan amount at EUR 180,311.

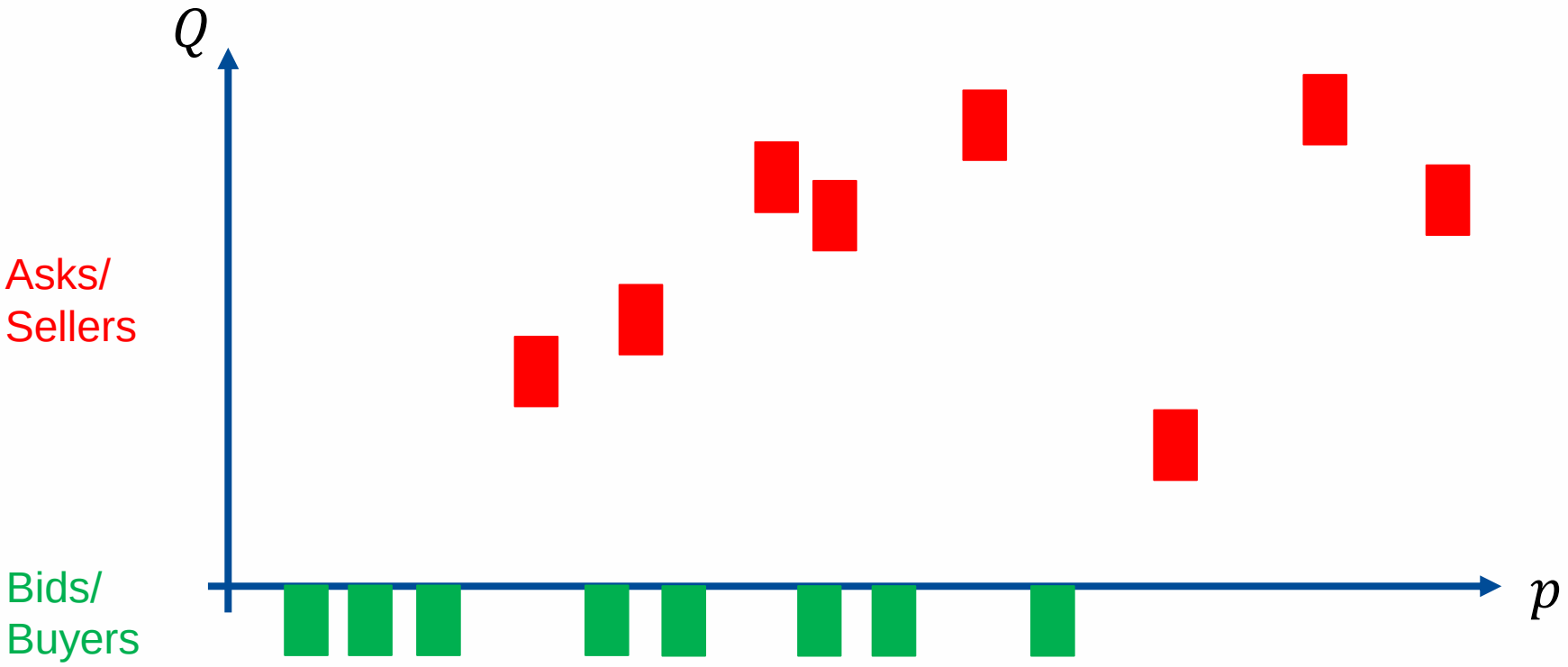


Component 3/13: Housing market



Repeat until all bids processed or unable to find $A^* \leq B^*$

Housing/Rental Market Mechanism (ctd)



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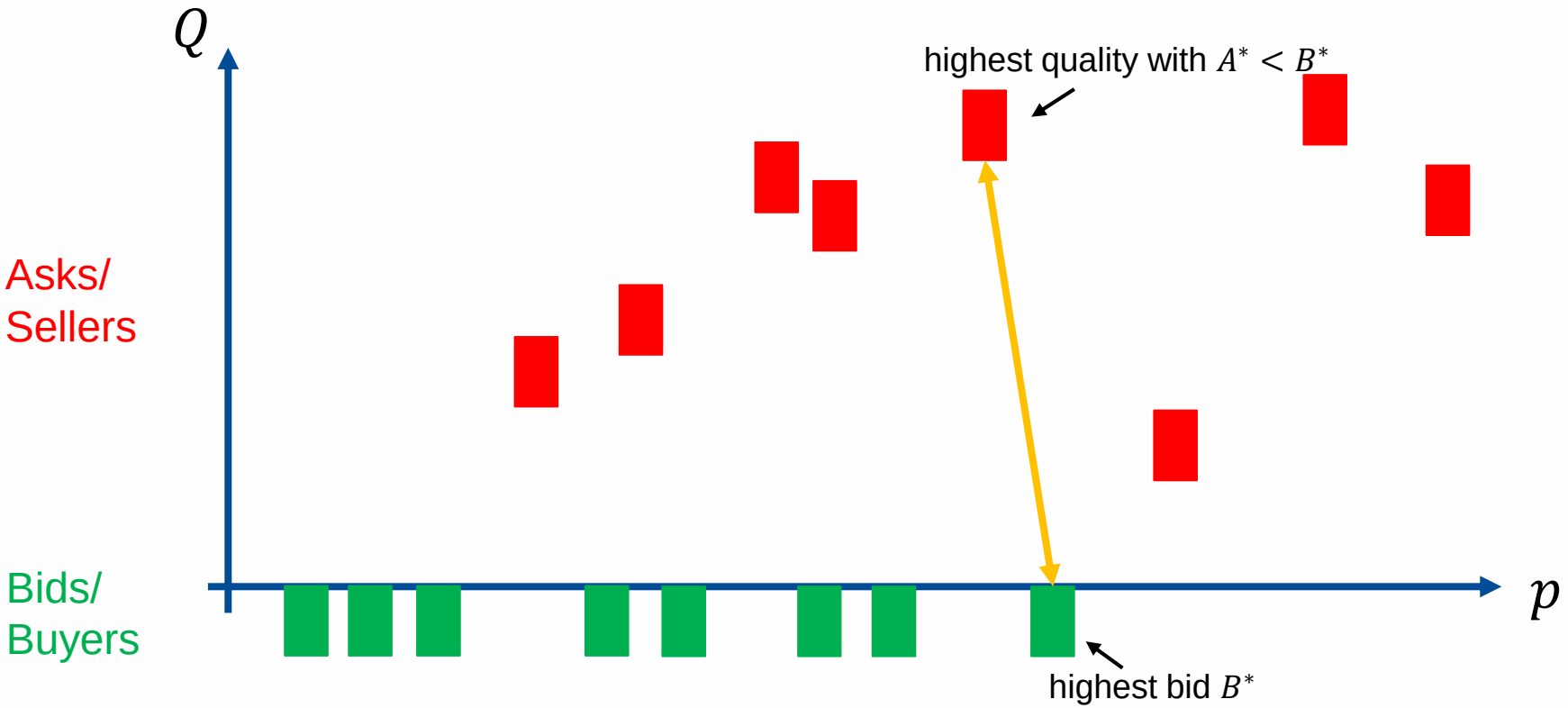

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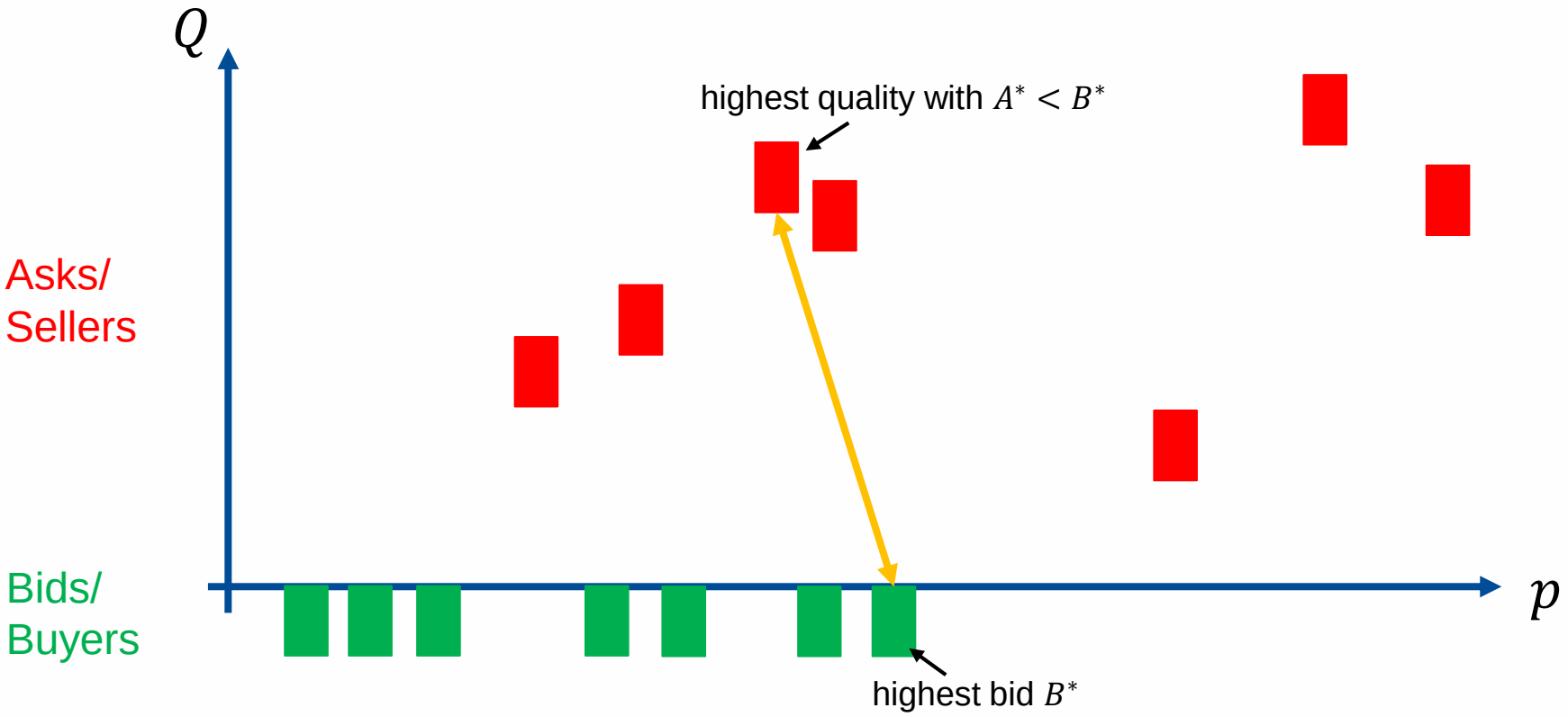

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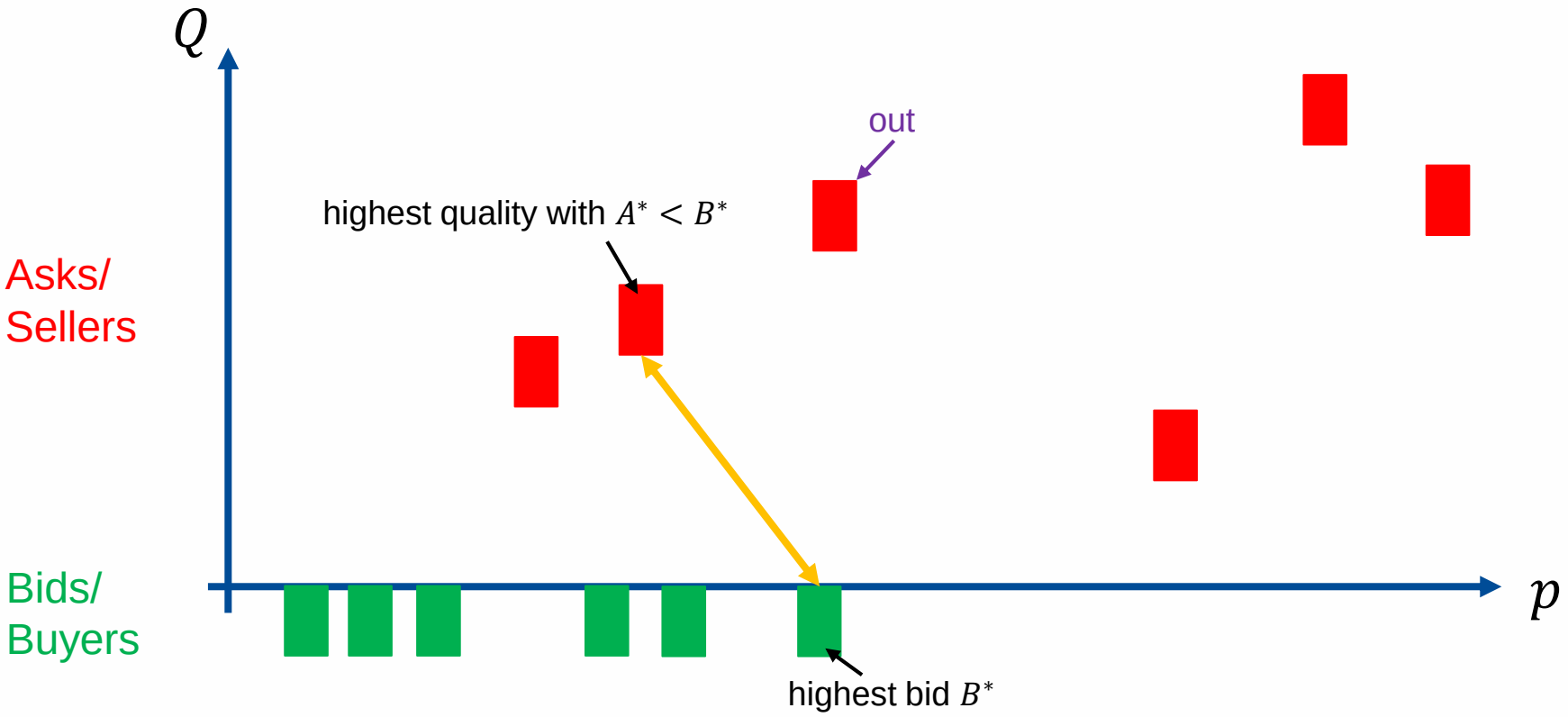

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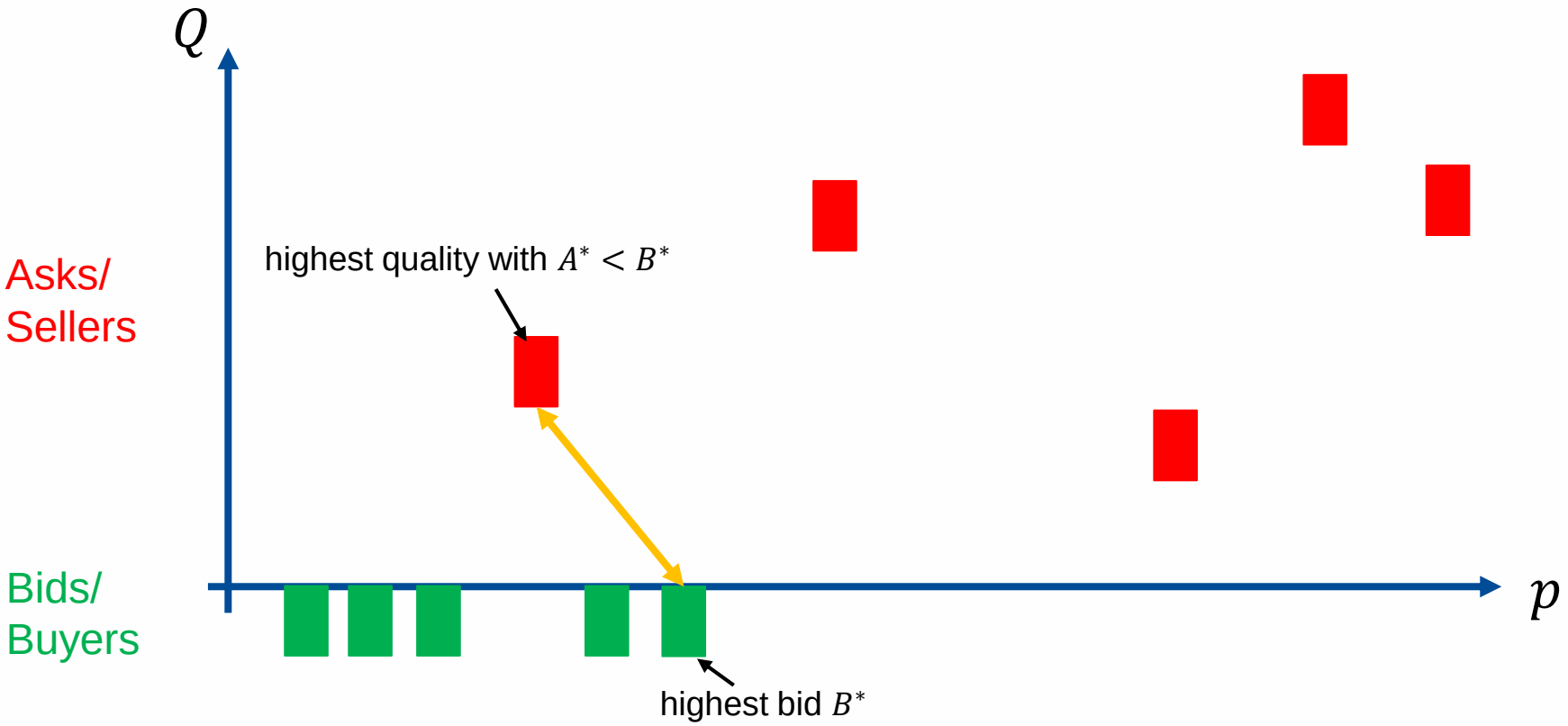

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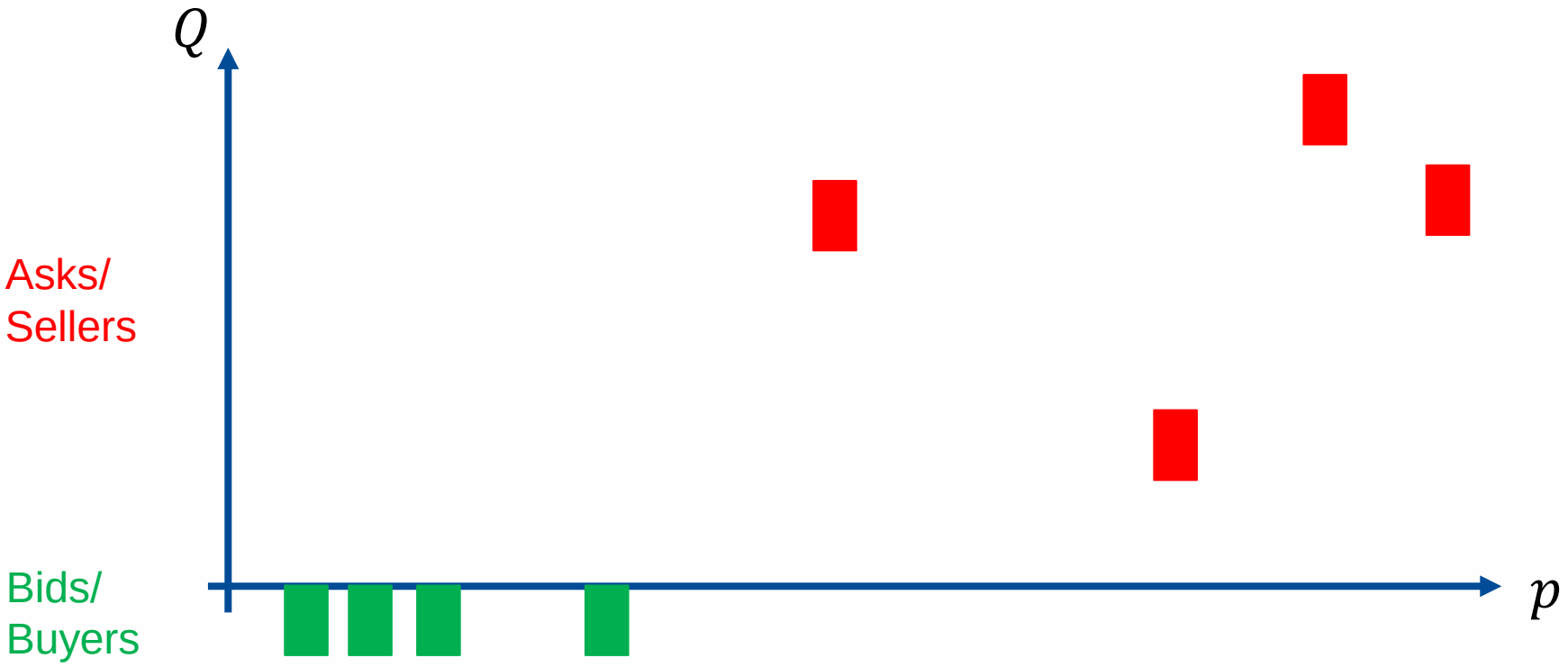
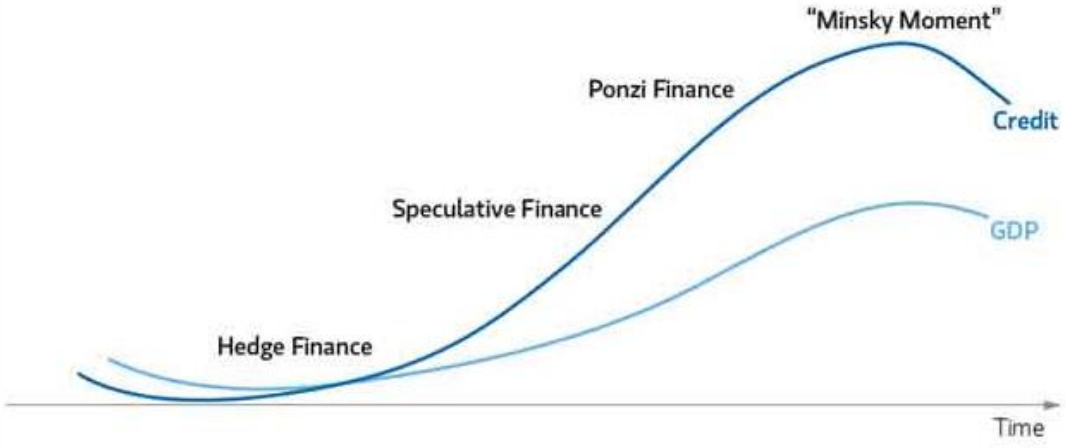


Self-evolving business and financial cycles: A narrative



Boom: credit available, collateral values rising due to rising demand (through credit), optimism, adaptive/extrapolative expectations, PDs and LGDs falling because of use of PiT measures, LLR of banks too small (not reflecting risk), hedge finance for firms: profits cover annuity

Nearby turning point: leverage reaches its limits, some firms have entered speculative finance (interest still covered by profits but principal not), Ponzi finance, small disturbances (endogenous) may cause first firms/HHs to default

At/after turning point: firms go bankrupt, HHs get unemployed, HHs default on their mortgages, banks face losses (underprovisioned at this time because of too low PDs/LGDs before), value of collateral falls due to excess supply and lack of demand in the housing market, loan interest rate spreads rise since still based on variance-model philosophy just as during boom

Nearby trough of recession and forward: share of NPLs beyond the peak now coming down (write-offs), bank BS more healthy, NPLs no drag on credit creation potential anymore, PDs and LGDs meanwhile down because default wave abades, credit spreads down, positive supply impulse, more demand, all up again

Eurace vs. Eurace 2.0 model

Eurace project: model development, final in Nov. 2009 → **Applications with the model since 2009** → **Eurace 2.0** → **Eurace 2.0 policy applications**

EU Commission project: Consortium of experts from universities in Italy, France, Germany, UK.

Policy applications since then: Focus largely on fiscal policy and regional/labor market policies.

Significant additional development, adding:

1. A properly designed banking system
2. Mortgage credit to households
3. Housing and rental market

Primary focus: Capital- and borrower-based macroprudential (MPRU) policy assessment.

Interplay of MPRU with monetary policy.

Eurace vs. Eurace 2.0 model

Current / almost final

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Eurace vs. Eurace 2.0 model

Near future

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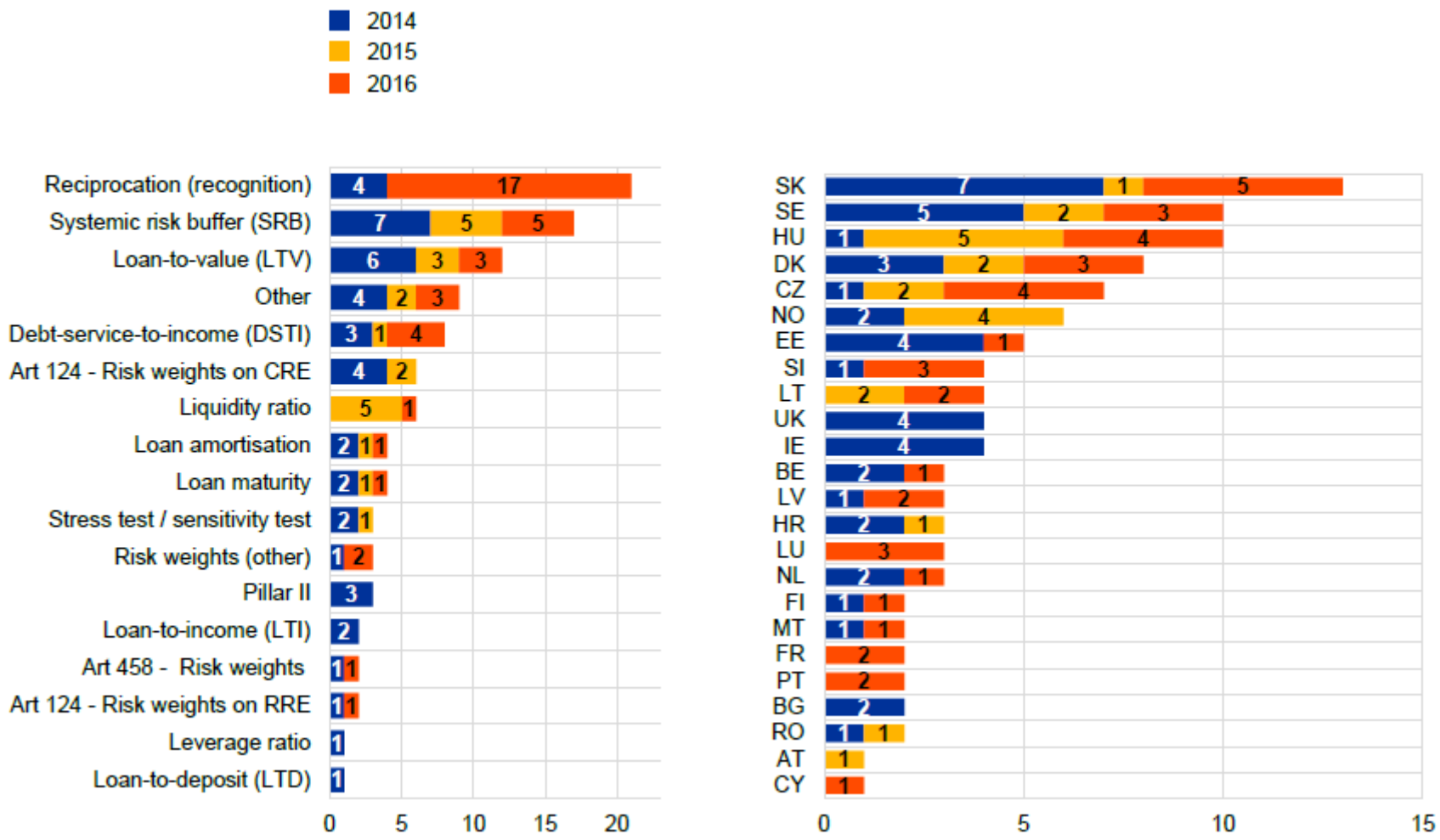
Number of macroprudential measures taken in the EU in 2014-16

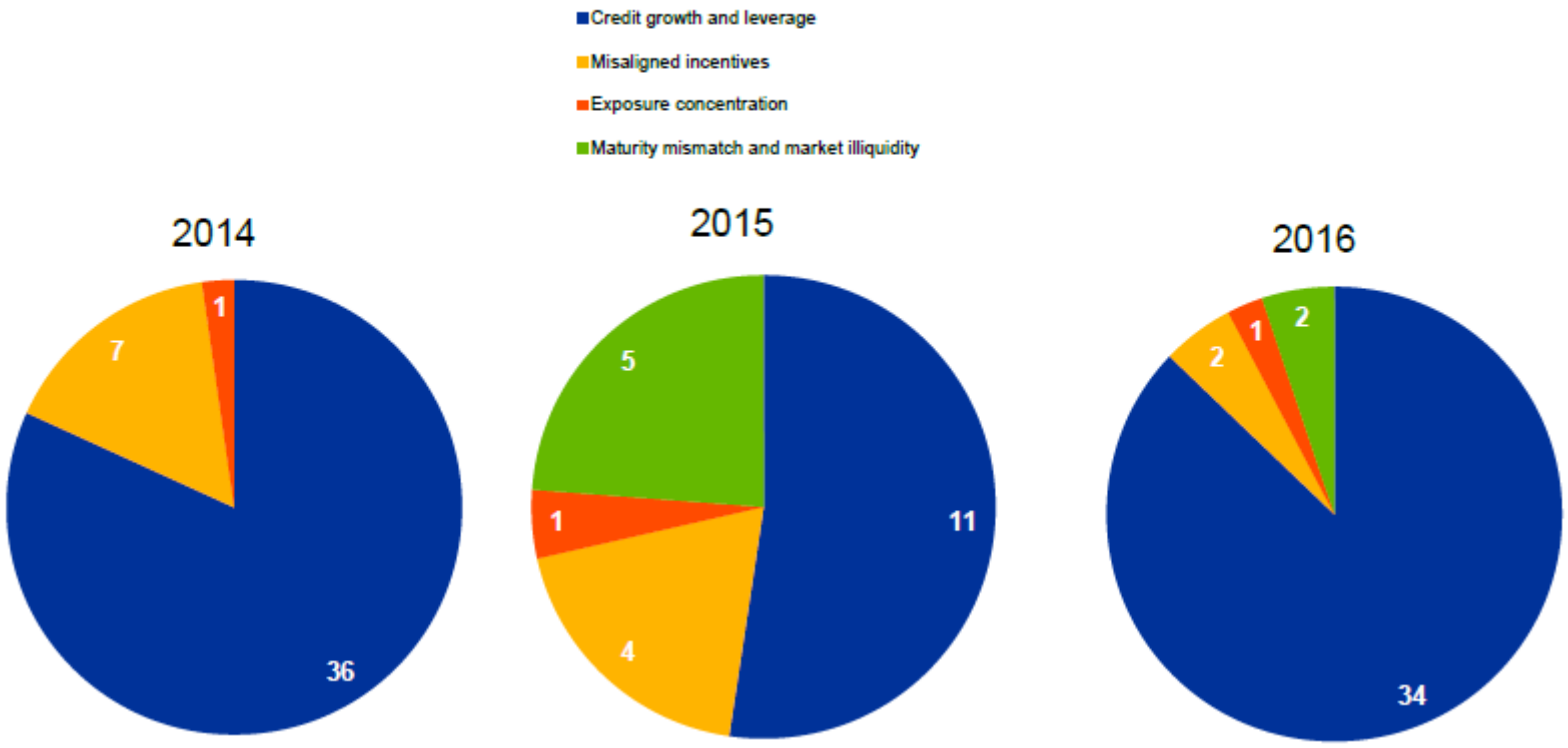
(Number of measures by measure type (left panel) and by Member State (right panel))



Source: ESRB 2017.

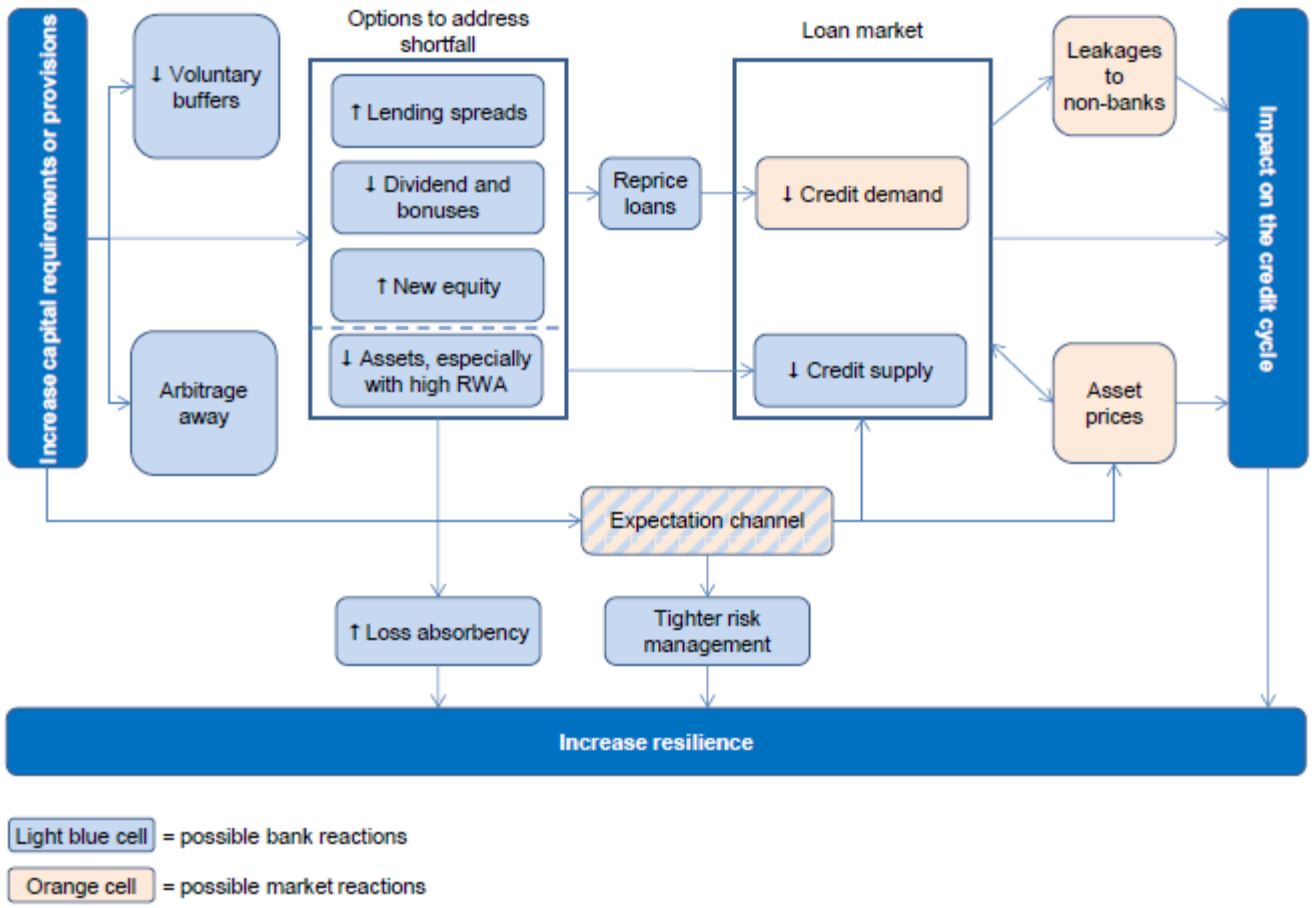
Frequency of use of measures pertaining to intermediate objectives

(Data labels show number of measures)



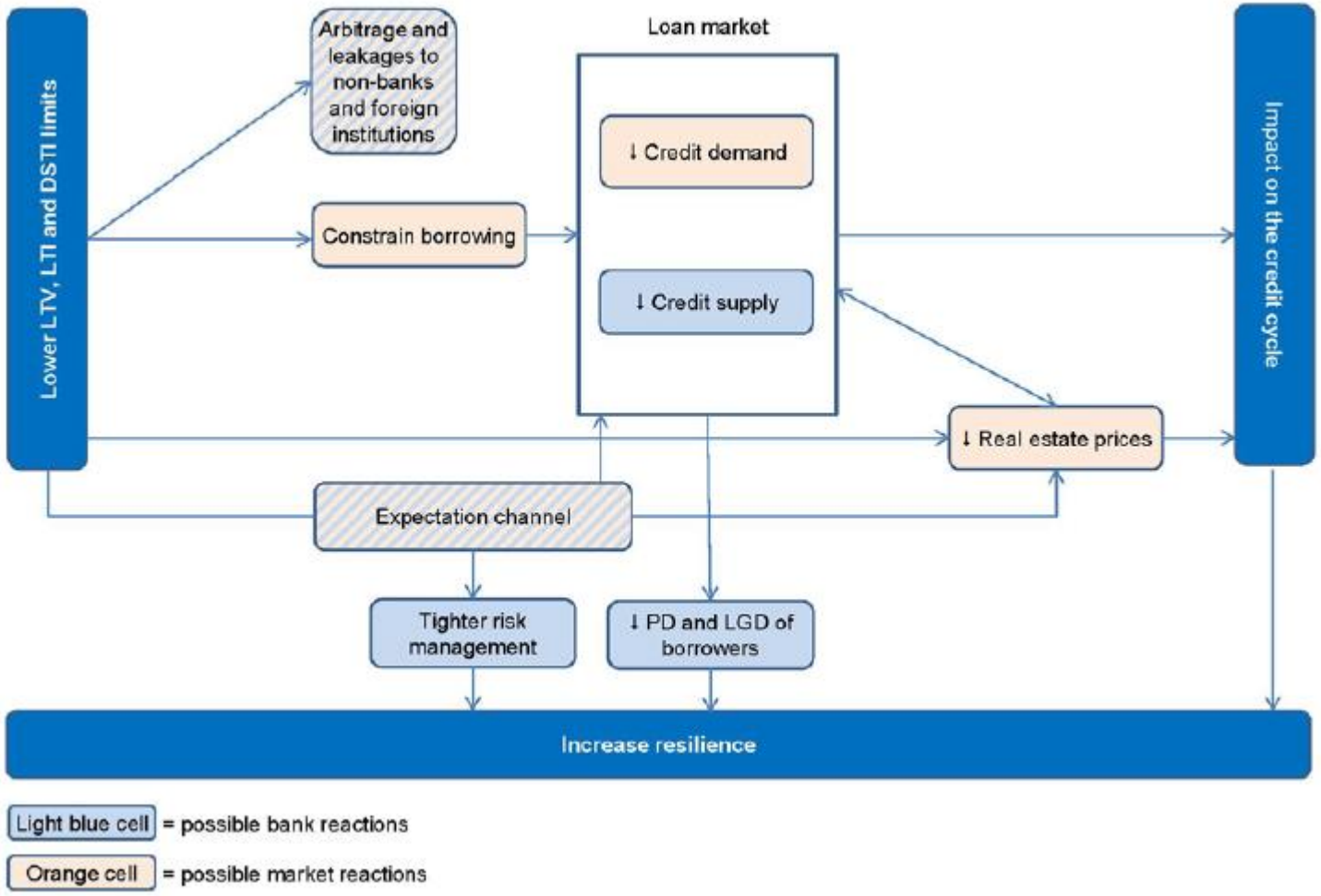
Source: ESRB 2017.

Transmission channels for capital-based macroprudential policy instruments



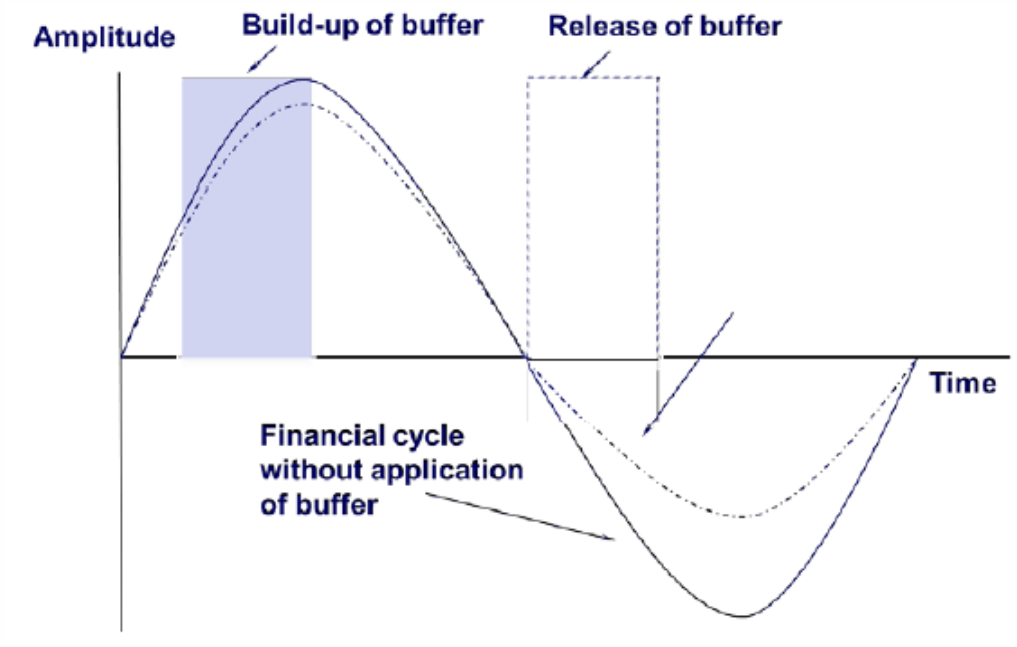
Source: adopted from CGFS 2012.

Transmission channels for borrower-based macroprudential policy instruments



Source: adopted from CGFS 2012.

Effect of counter-cyclical buffers over the cycle



- Assess whether use of a measure implies cost or benefit in short term, depending on stage in business cycle

- Assess whether long-run net benefit is positive/negative