Aggregate Bank Capital and Credit Dynamics

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The views expressed in this paper are those of the authors and do not necessarily represent those of the IMF or IMF policy.

Motivation

- Financial regulators and central banks now control powerful macro-prudential tools for promoting systemic stability.
- Long-term impact on growth and financial stability?
- DSGE models cannot really help: they were designed to reproduce short-term reactions of prices and output to monetary policy decisions.
- To study the long-term impact of macro-prudential policies on growth and financial stability, one needs a different type of model.
- We provide an example of such a model.

Our contribution

- General equilibrium dynamic model with financial frictions, in the spirit of *Brunnermeier-Sannikov (2014)* and *He-Krishnamurthy (2013)*.
- Banks are explicitly modeled.
- Bank capital serves as a loss-absorbing buffer and determines the volume of lending.
- Model allows the analysis of the ***long-run*** effects of minimum capital requirements on lending and systemic stability.
- Main implications are in line with empirical evidence.

Related literature

1. **Macro-finance in continuous time**

   Brunnermeier-Sannikov (2014, 2015), He-Krishnamurthy (2012, 2013), Di Tella (2015), Phelan (2015).

2. **Welfare impact of capital requirements**
   - *Van den Heuvel (2008)*
   - *Martinez-Miera and Suarez (2014)*
   - *DeNicolò-Gamba-Lucchetta (2014)*
   - *Nguyen (2014)*
   - *Begenau (2015)*

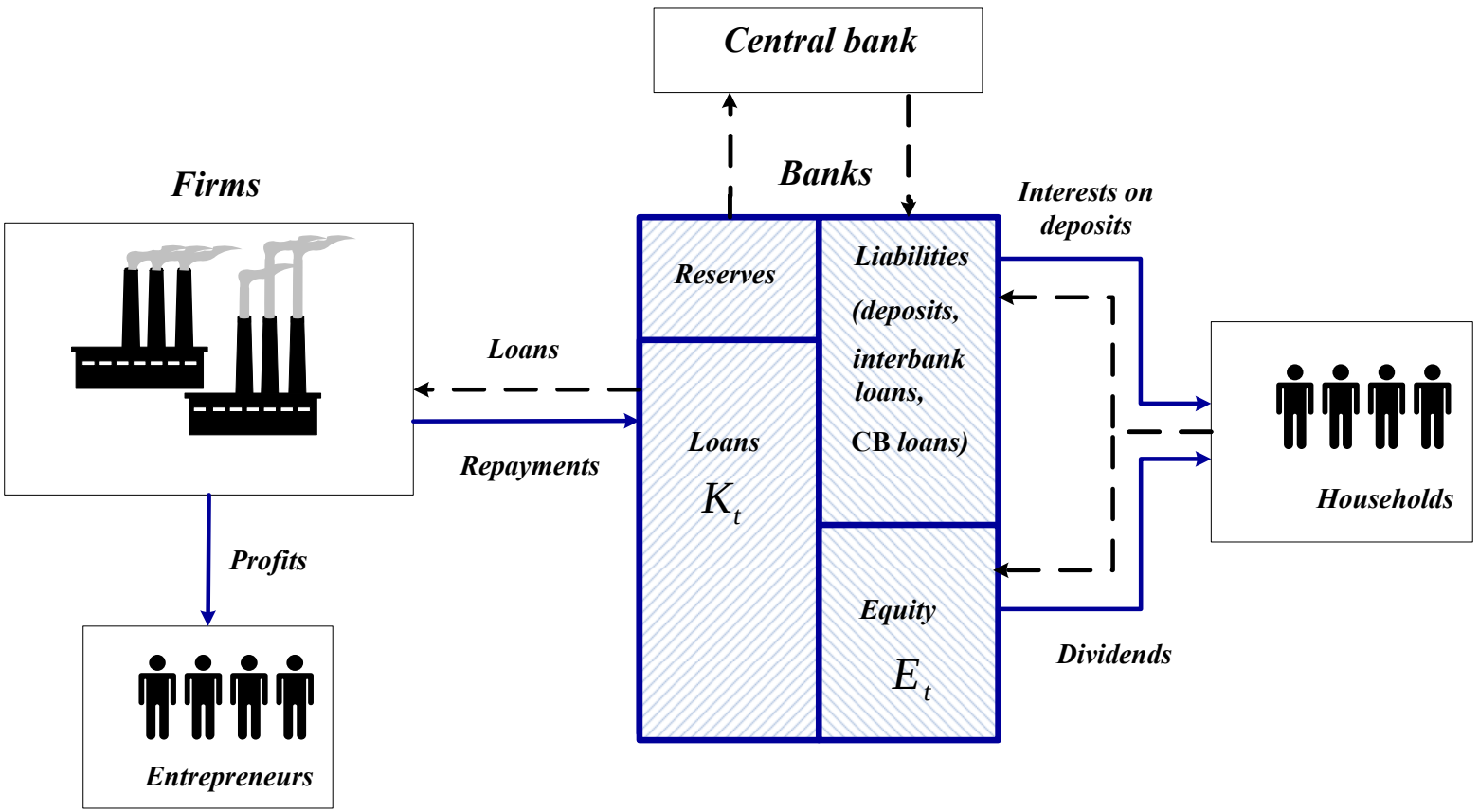
ROADMAP

1. Model
2. Competitive equilibrium
3. Long run dynamics
4. Credit market failure
5. Application to macro prudential policy analysis

Model

- General equilibrium model: real sector and banking sector.
- One physical good, can be consumed or invested.
- Households invest their savings in bank deposits and bank equity.
- Banks invest in (risky) loans to entrepreneurs and reserves (can be <0).
- **Equity** acts as a buffer to guarantee safety of deposits (no deposit insurance) and interbank borrowings.
- Entrepreneurs have no capital and must borrow from banks, who monitor them: no direct finance.

GLOBAL PICTURE



Model

- Households and entrepreneurs are risk neutral and discount future consumption at rate ρ.
- Interbank rate r is fixed and less than ρ.
- Households receive interest r_D on deposits. At equilibrium $r_D = r$.
- Households derive utility from holding riskless deposits (*transactional demand for safe assets* as in Stein (2012)).
- Supply of deposits is fixed and is a decreasing function of $(\rho - r)$.
- For simplicity, $r \equiv 0$ (all qualitative results hold when $r > 0$).

MODEL

Firms:

- can borrow 1 unit of productive capital from banks at time t, must repay $1 + R_t h$ at $t + h$
- if borrow, produce xh unit of good, where x is distributed over $[0, \overline{R}]$ with density $f(x)$
- borrow when $x > R_t$; **aggregate demand for loans** is a decreasing function of loan rate R

$$L(R) = \int_R^{\overline{R}} f(x)dx$$

- productive capital is destroyed (default) with probability

$$pdt + \sigma_0 dZ_t,$$

where $\{Z_t, t \geq 0\}$ is a standard Brownian motion (aggregate shocks)

Model

- Aggregate shocks in the real sector translate into banks' profits/losses
- Book equity of an individual bank evolves:

$$de_t = \underbrace{k_t[(R_t - p)dt - \sigma_0 dZ_t]}_{\text{return on a bank's loans}} - \underbrace{d\delta_t}_{\text{dividends}} + \underbrace{di_t}_{\text{recapitalizations}},$$

  where k_t is the volume of lending to firms at time t

- **Aggregate** bank equity evolves:

$$dE_t = \underbrace{K_t[(R_t - p)dt - \sigma_0 dZ_t]}_{\text{return on total loans}} - \underbrace{d\Delta_t}_{\text{dividends}} + \underbrace{dI_t}_{\text{recapitalizations}},$$

  where K_t is aggregate lending

- **Main friction:** issuing new equity entails proportional cost γ
- **Markovian competitive equilibrium:** $R_t = R(E_t)$ and $K(E_t) = L(R(E_t))$

AN INDIVIDUAL BANK'S PROBLEM

- An individual bank chooses lending, dividend and recapitalization policies to maximize shareholder value:

$$v(e_t, E_t) = \max_{k_s, d\delta_s, di_s} \mathbb{E}\Big[\int_t^{+\infty} e^{-\rho(s-t)}(d\delta_s - (1+\gamma)di_s)\Big]$$

- Shareholder value is linear in e:

$$v(e, E) \equiv eu(E),$$

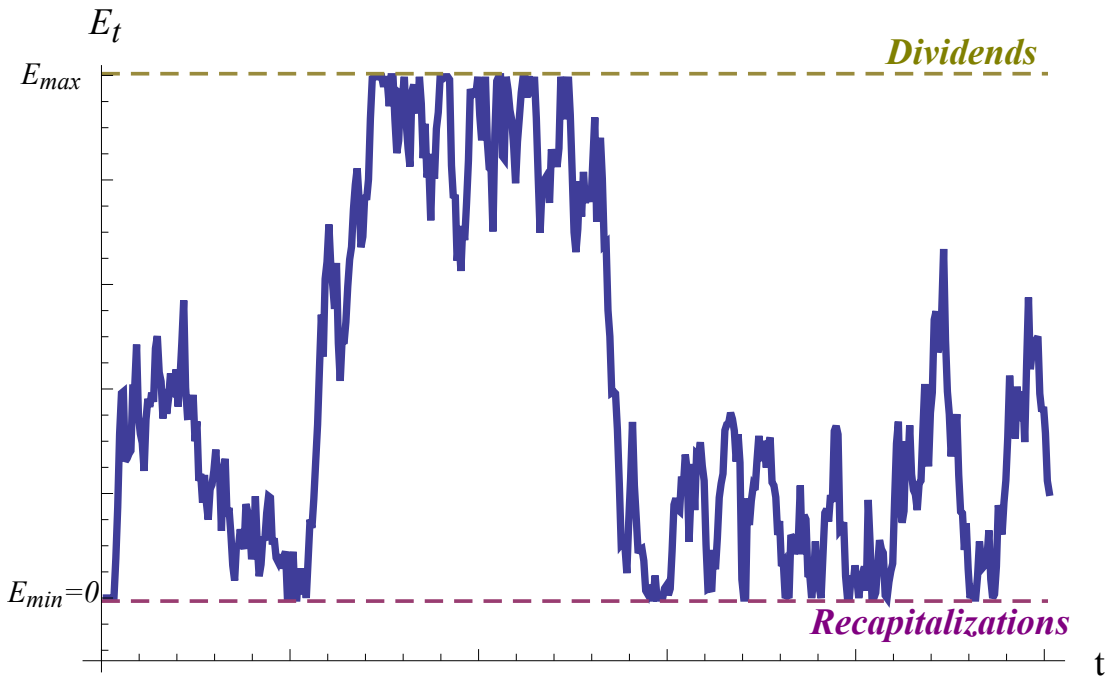
where $u(E)$ is the *Market-to-Book ratio*.

- Only aggregate capital E matters for banks' policies.

DIVIDEND AND RECAPITALIZATION POLICIES

Dividend/recapitalization policies of a "barrier" type:

- banks distribute dividends when $E_t = E_{max}$, such that $u(E_{max}) = 1$;
- banks recapitalize when $E_t = E_{min} = 0$



EQUILIBRIUM LOAN RATE

- Positive loan spread:

$$R(E) - p = \underbrace{\sigma_0^2 K(E)\Big[-\frac{u'(E)}{u(E)}\Big]}_{\text{"lending premium"}}, \qquad \text{where} \quad u'(E) < 0$$

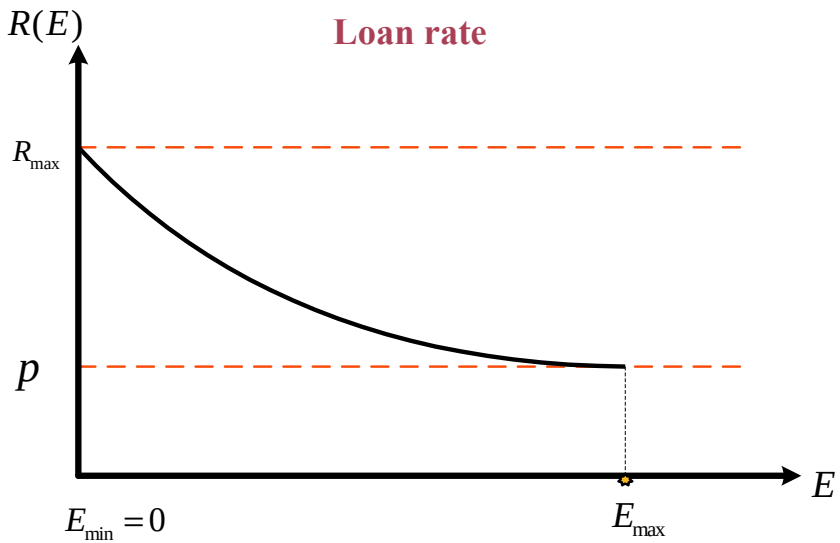
- **Source of lending premium:** *implied risk-aversion* of bankers with respect to variations in aggregate capital
- $u(.)$ is a discounted martingale:

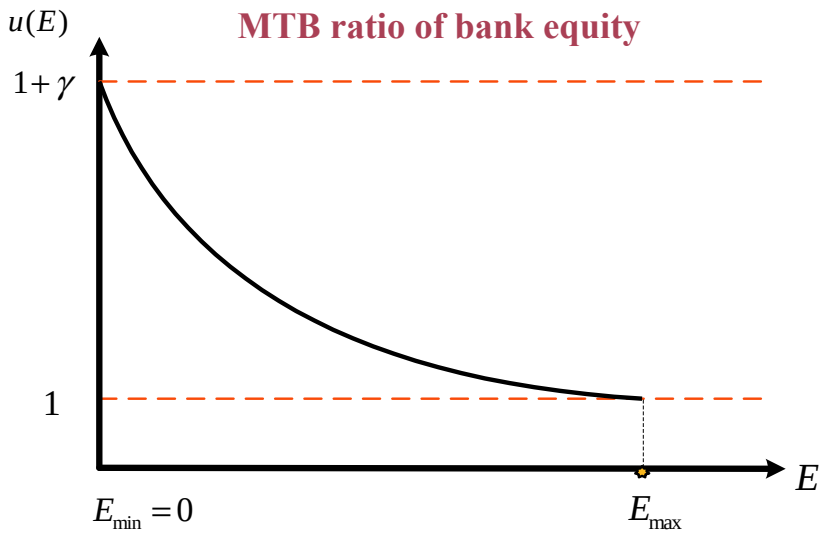
$$\rho u(E) = L(R)(R(E) - p)u'(E) + \frac{\sigma_0^2 L^2(R)}{2} u''(E)$$

- From these two equations we deduce

$$R'(E) = -\frac{1}{H[R(E)]}, \qquad \text{where } H(R) = \frac{\sigma_0^2[L(R) - (R-p)L'(R)]}{2\rho\sigma_0^2 + (R-p)^2}$$

EQUILIBRIUM LOAN RATE AND MTB RATIO





COMPETITIVE EQUILIBRIUM (CE)

- Aggregate bank capital evolves according to:

$$dE_t = L(R(E_t))\Big[(R(E_t) - p)dt - \sigma_0 dZ_t\Big]$$

- The loan rate function $R(E) : [0, E_{max}] \to [p, R_{max}]$ is implicitly given by

$$\boxed{E = \int_{R(E)}^{R_{max}} H(s)ds, \qquad \text{where} \qquad H(s) = \frac{\sigma_0^2[L(s) - (s-p)L'(s)]}{2\rho\sigma_0^2 + (s-p)^2}}$$

- R_{max} and E_{max} **increase with financing friction** γ
- **Testable predictions:** equilibrium loan rate and market-to-book ratio are decreasing functions of aggregate capital

Loan rate dynamics

- Loan rate $R_t = R(E_t)$ has **explicit** dynamics

$$dR_t = \boldsymbol{\mu}(\boldsymbol{R_t})dt + \boldsymbol{\sigma}(\boldsymbol{R_t})dZ_t, \qquad p \leq R_t \leq R_{max},$$

with

$$\boldsymbol{\sigma}(\boldsymbol{R}) = \frac{2\rho\sigma_0^2 + (R-p)^2}{\sigma_0\left(1 - (R-p)\frac{L'(R)}{L(R)}\right)} \quad \text{and} \quad \boldsymbol{\mu}(\boldsymbol{R}) = \sigma(R)h(R),$$

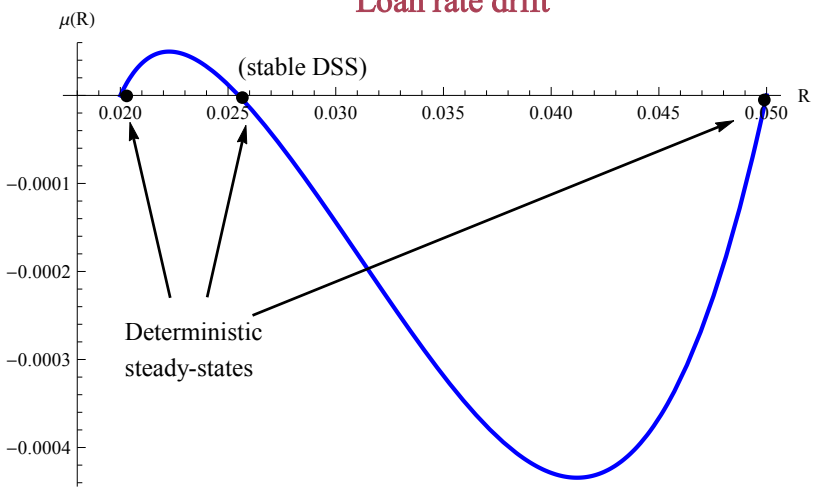
where $h(.)$ is explicit.

NUMERICAL EXAMPLE

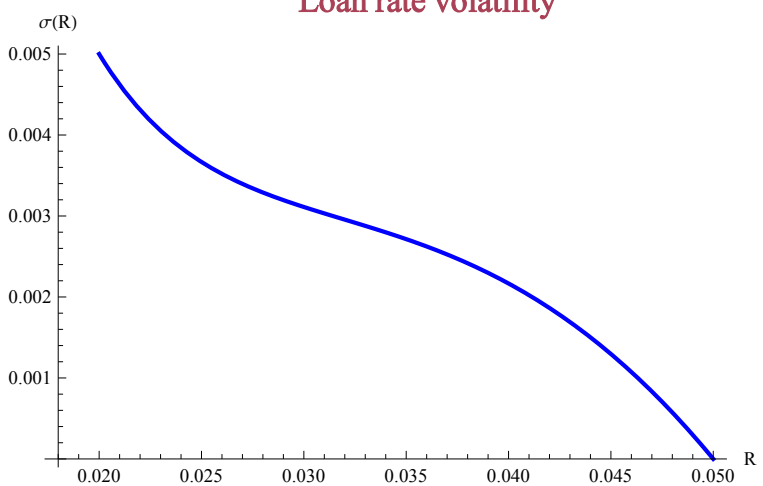
Particular specification of the demand for loans (max. lending $\equiv 1$):

$$L(R) = \left(\frac{\overline{R} - R}{\overline{R} - p}\right)^{\beta} \qquad \text{where} \qquad \beta > 0, \quad \overline{R} > p$$

Loan rate drift



Loan rate volatility

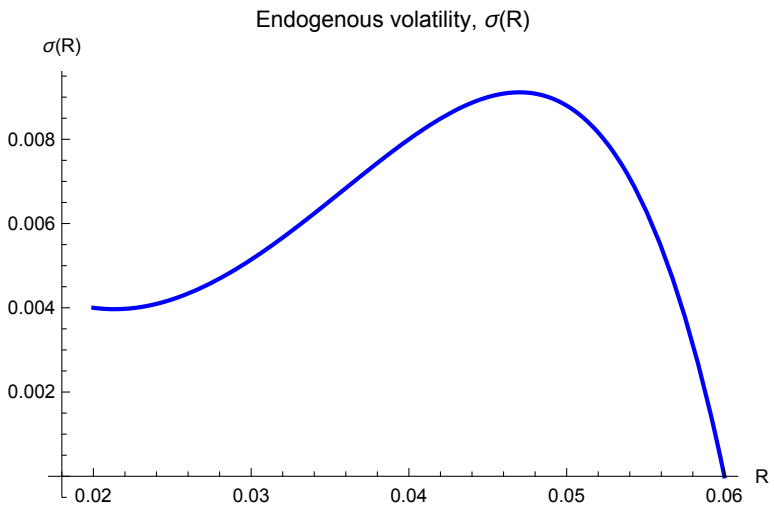


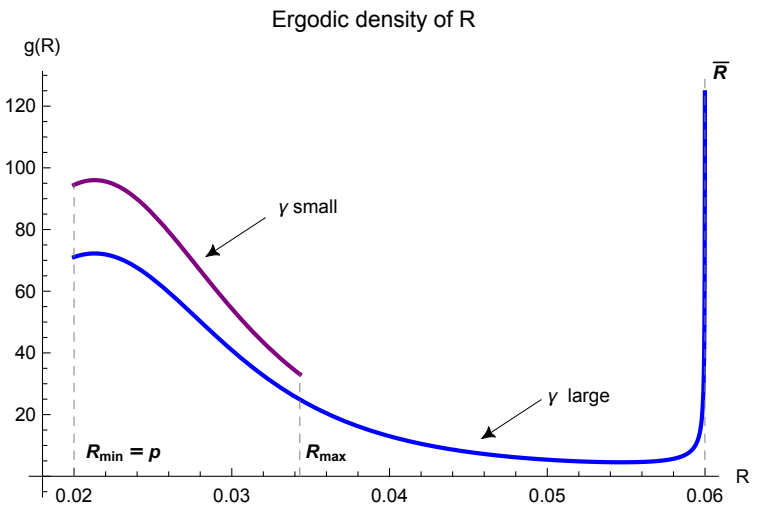
Remark: $\mu(R)$ is very small compared to $\sigma(R)$. Linearization around the (stable) DSS can be very misleading!

LONG RUN BEHAVIOR OF THE ECONOMY

- Full description of **long run behavior of the economy**: stochastic steady state.
- We can compute the **ergodic density** function of R (or E):

$$\boxed{\frac{g'(R)}{g(R)} = \frac{2\mu(R)}{\sigma^2(R)} - \frac{2\sigma'(R)}{\sigma(R)}, \quad \text{on} \quad [p, R_{max}]}$$

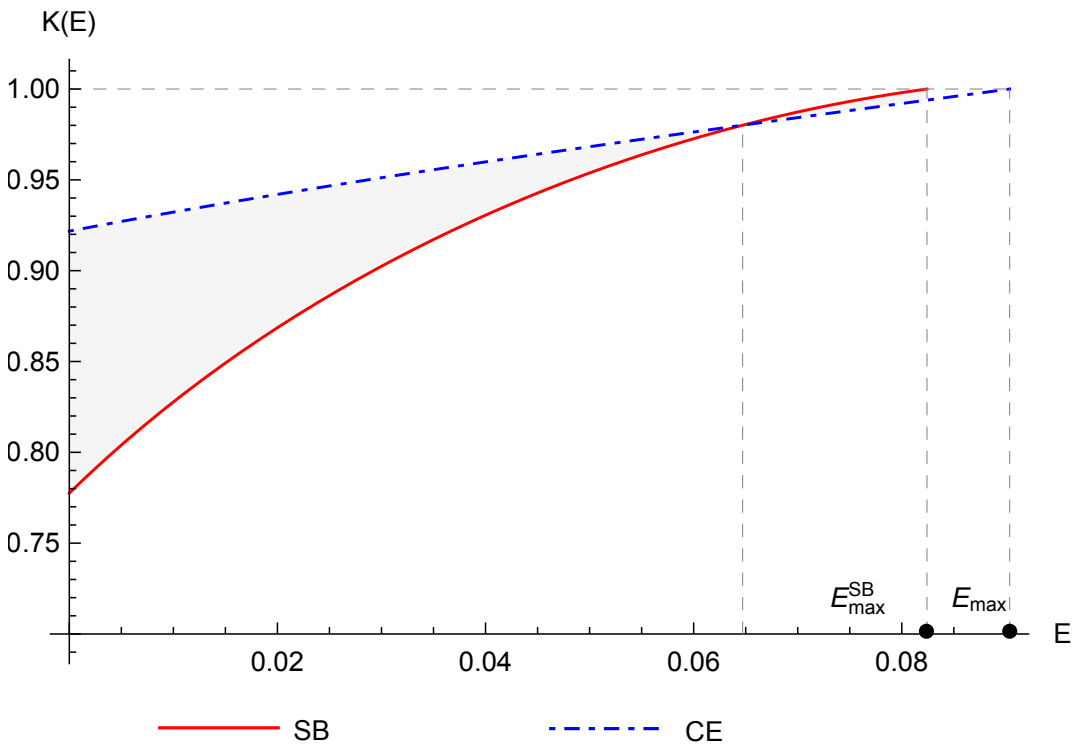




Remark: the long run behavior of the economy is driven by the endogenous volatility.

CE IS NOT CONSTRAINED EFFICIENT

- Banks do not internalize the impact of their lending decisions on the dynamics of E (i.e., endogenous volatility and expected profits).
- Compared to Second Best (SB), banks lend too much (overexposed to aggregate risk) when E is low and too little when E is high.



Application: Minimum Capital Ratio

- What happens if banks are subject to a minimal Capital Ratio (CR) Λ?

$$\boxed{e_t \geq \Lambda k_t}$$

- Maximization problem of an individual bank:

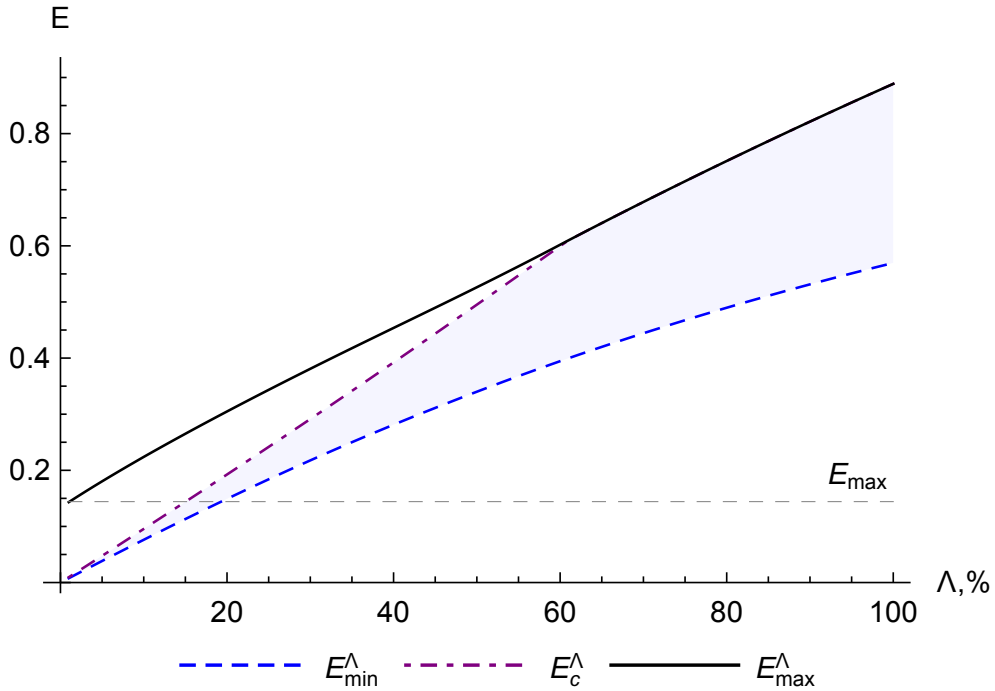
$$v_\Lambda(e, E) = \max_{k_t \leq \frac{e}{\Lambda}, d\delta_t, di_t} \mathbb{E}\left[\int_0^{+\infty} e^{-\rho t}\left(d\delta_t - (1+\gamma)di_t\right)\right]$$

- Homogeneity property is preserved:

$$v_\Lambda(e, E) \equiv e u_\Lambda(E)$$

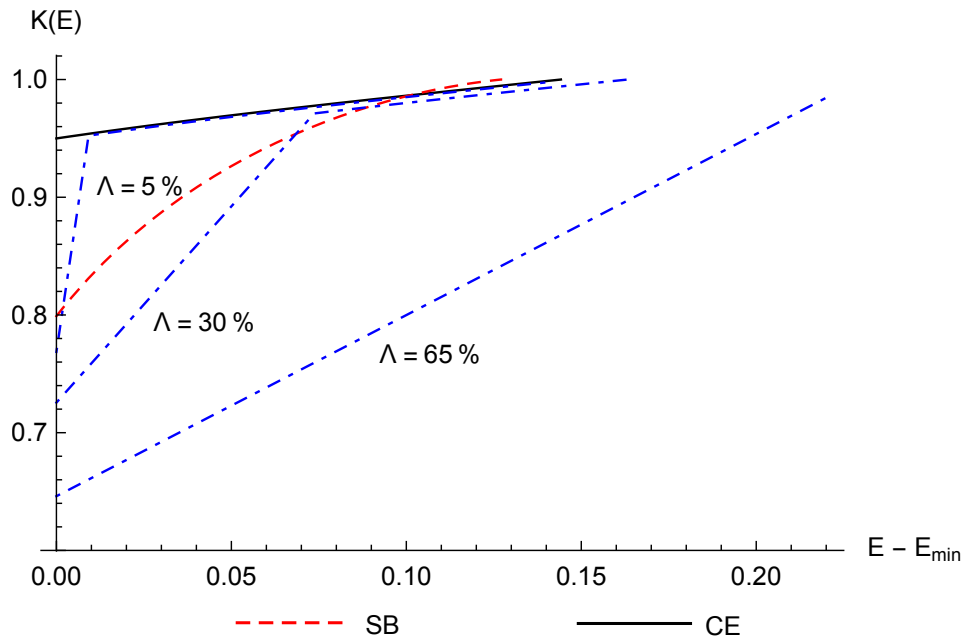
- We find that CR constraint binds for low E and is slack for high E.
- $u_\Lambda(.)$ and equilibrium loan rate $R_\Lambda(.)$ have different expressions in constrained $(\boldsymbol{E < E_c^\Lambda})$ and unconstrained $(\boldsymbol{E \geq E_c^\Lambda})$ regions.

CAPITAL RATIO AND BANK POLICIES



- Banks increase their target level of capital ($E^{\Lambda}_{max} > E_{max}$) and recapitalize earlier ($E^{\Lambda}_{min} > 0$).
- Small and moderate Λ: both the unconstrained and constrained regimes co-exist.
- Very high Λ: the unconstrained region disappears (no extra capital cushions).

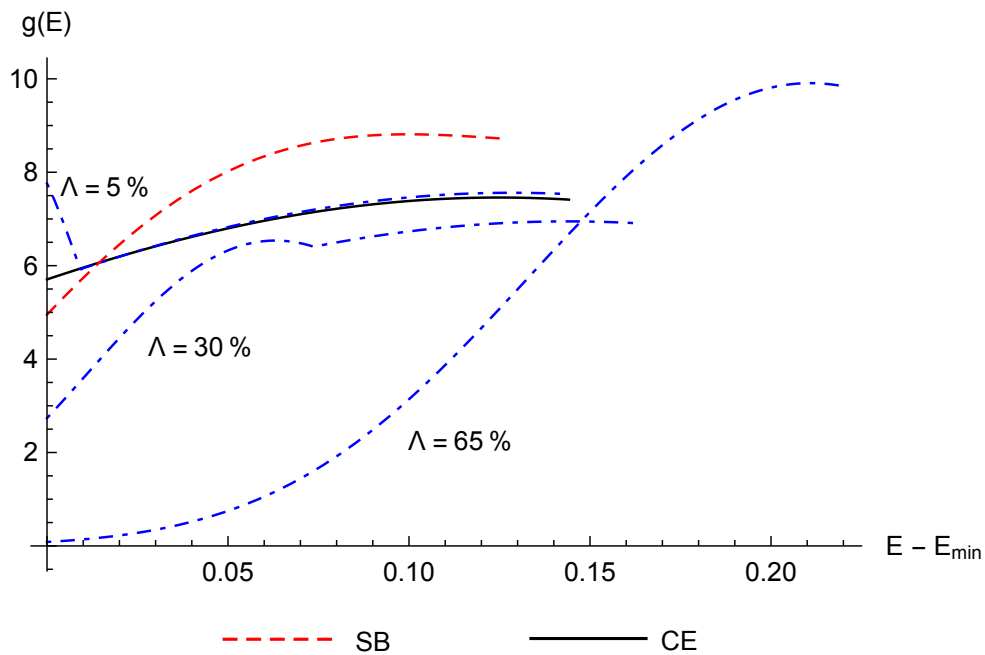
Capital ratio and lending



- Banks reduce lending not only in the constrained region, but also in the unconstrained one.
- Moderate capital requirements can bring lending closer to the SB level in the states with low capitalization.
- Very high capital requirements induce a severe reduction in lending in *all* states.

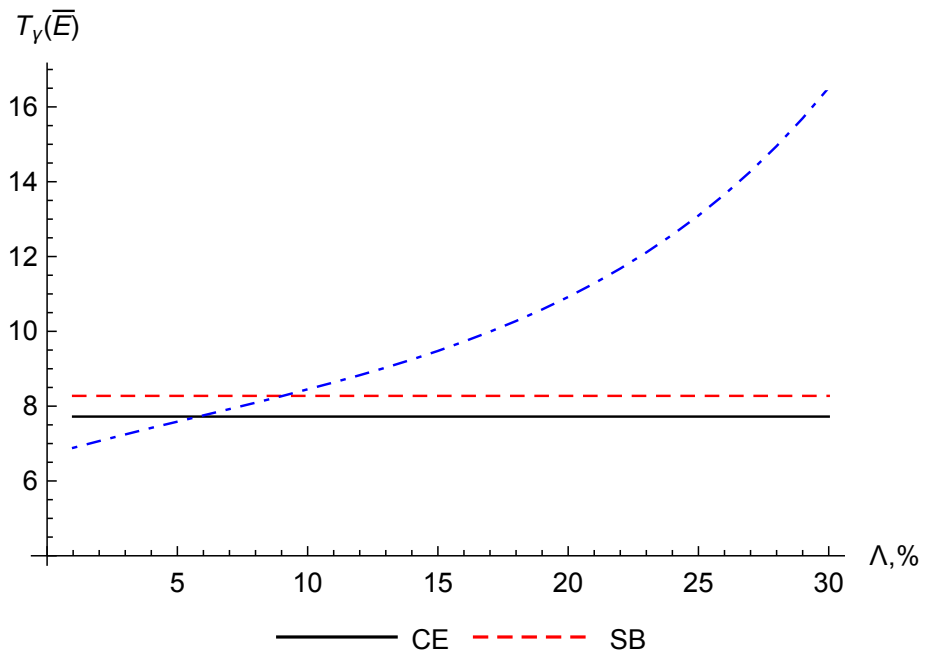
CAPITAL RATIO AND FINANCIAL (IN)STABILITY

- Capital requirements affect the probabilistic behavior of the system.
- Under low capital requirements, the ergodic density of E is concentrated in low capitalized states.



CAPITAL RATIO AND FINANCIAL (IN)STABILITY

- **Stability measure:** $T_\gamma(\overline{E})$ - the average time to recapitalization starting from the average level of aggregate capital $\overline{E}$.
- For low Λ, the system becomes even *less stable than in the absence of regulation*.
- For very high Λ, the system is more stable than in the Second Best.



Conclusion

- Tractable dynamic macro model where aggregate bank capital drives credit volume.
- Asymptotic behavior described by ergodic distribution (stochastic steady state).
- Model shows that pecuniary externalities in credit markets can arise even in the absence of fire-sales.
- Model permits simple analysis of macro-prudential policy.
- Further investigations:
  - interaction between macro-prudential and monetary policies
  - market financing complementary to bank financing

Thank you!

EMPIRICAL EVIDENCE: DATA DESCRIPTION

- Panel of publicly traded banks in 43 advanced and emerging market economies (1992-2012):
  - **U.S. banks**: 728 banks
  - **Japan**: 128 banks
  - **Banks in advanced economies**: 248 banks
  - **Banks in emerging market economies**: 183 banks

Identifier	***Variable***	***Measurement***
ret	*bank gross return on assets*	total interest income/earning assets
mtb	*market-to-book equity ratio*	market equity/book equity
logta	*Bank size*	Log Assets
loanasset	*% of loans to assets*	Total loans/total assets
bequity	*bank book equity*	bank book equity
npl	*non-performing loans*	non-performing loans
TBE	*total bank equity*	sum of bequity

EMPIRICAL EVIDENCE: CONDITIONAL CORRELATIONS

Predictions: Loan rate and MTB ratio are **decreasing** functions of aggregate bank capital

	US		Japan		Advanced (ex. US and Japan)		Emerging	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Explanatory variables	*ret*	*mtb*	*ret*	*mtb*	*ret*	*mtb*	*ret*	*mtb*
TBE	−0.00416***	−0.000139***	−0.0124***	−0.00466***	−0.0123***	−0.00374***	−0.00280***	−0.00215***
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]
bequity	0.00232**	−0.00945***	0.0254***	−0.00316*	0.0117***	−0.00113*	0.0167***	−0.00160*
	[0.01]	[0.00]	[0.00]	[0.07]	[0.00]	[0.08]	[0.00]	[0.10]
logta	−0.0454***	0.157***	0.0220	0.204***	−0.366***	−0.0164**	−0.370***	−0.00726
	[0.00]	[0.00]	[0.45]	[0.00]	[0.00]	[0.01]	[0.00]	[0.41]
loanasset	0.0228***	−0.000590	0.00561***	0.00388	−0.0282***	−0.00195***	−0.0357***	−0.000738
	[0.00]	[0.23]	[0.00]	[0.29]	[0.00]	[0.00]	[0.00]	[0.43]
npl	0.0274***	−0.0414***	0.0386***	0.0369***	0.0181*	−0.0110***	−0.0103	−0.00892***
	[0.00]	[0.00]	[0.00]	[0.00]	[0.09]	[0.00]	[0.16]	[0.00]
Constant	8.117***	−0.527***	6.897***	−1.002	16.88***	2.633***	24.22***	1.551***
	[0.00]	[0.00]	[0.00]	[0.11]	[0.00]	[0.00]	[0.00]	[0.00]
Number of banks	728	728	128	128	248	248	183	183
Bank/years	9,736	8,899	1,534	1,598	2,600	2,600	1,772	1,772
R-squared	0.794	0.429	0.803	0.385	0.700	0.506	0.737	0.392

Notes: robust p-values in brackets (*** - $p < 0.01$, ** - $p < 0.05$, * - $p < 0.1$).

$$Y_{it} = \alpha + \underbrace{\beta}_{<0} E_{t-1} + \gamma_1 bequity_{it-1} + ... + \gamma_5 Timedummy_{it} + \epsilon_{it}$$