European Central Bank logo — EUROSYSTEM

A dynamic model of bank behaviour under multiple regulatory constraints*

Markus Behn
European Central Bank

Joint work with:

Claudio Daminato
ETH Zurich

Carmelo Salleo
European Central Bank

European Central Bank,

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Motivation

- Post-crisis regulatory framework is characterized by a large number of rules that impose constraints on banks' asset and liability structures

- Banks have taken (and are still taking) action to adjust to new framework

- Banking sector sitting at the core of the economy; key questions:

  – How do banks adjust their balance sheets to adapt to the new framework?

  – What do these adjustments mean for the supply of loans and the broad economy?

  – How do different types of regulations interact with each other?

What the paper does

- Develop a structural model of bank behavior under economic uncertainty and regulatory constraints on (risk-weighted) capital and liquidity ratios

- Provide economic rationale for voluntary capital and liquidity buffers

- Derive granular adjustment functions to study impact of regulatory change:

  – Intensity of reaction dependent on initial bindingness of regulatory constraints

  – Different modes of adjustment with different macroeconomic implications (e.g., capital ratios can be improved by raising fresh equity or by reducing the amount of loans)

  – Relevance of alternative modes may depend on initial balance sheet structure of the bank or on overall economic and financial conditions

  – Possible non-linearities in adjustment function and interactions between requirements

The model in a nutshell

- Stylized balance sheet with six different asset and liability classes

- Infinite horizon model with balance sheet adjustments in each period

- Banks maximize stream of expected future dividends, but want to avoid breaching regulatory requirements or having to raise fresh equity

- Uncertainty and regulatory constraints on solvency and liquidity positions

- Trade-offs on multiple dimensions: higher expected returns vs. higher risk of breaching regulatory requirements / having to raise external funds

- Study evolution of precautionary capital and / or liquidity buffers

Main results

- Regulatory requirements as key determinants of observed capital and liquidity structures; voluntary buffers based on precautionary motives

- Material impact of changes in regulatory capital requirements:

  – Banks fully replenish voluntary buffers following changes in requirements

  – Initial reduction in loans, but recovery as banks accumulate additional equity

  – More constrained banks react more strongly, usually involving a higher reduction in loans

- Also changes in liquidity requirements can have sizeable real effects:

  – Banks' privately preferred action: increase liquid asset holdings

  – May imply reduction in loans if banks become capital-constrained

Modelling assumptions – what the paper does <u>not</u>

- Social costs and benefits are out of scope for the paper:
    - No cost-benefit analysis of higher requirements, no 'optimal' capital / liquidity structure
    - Private considerations of a value-maximizing bank under regulation and uncertainty
    - A positive model of bank behavior (with obvious implications for the real economy)

- Partial equilibrium perspective, resting on a number of assumptions:
    - Banks as price takers: decisions do not have any impact on asset returns or funding cost
    - No relation between asset risk / leverage and the price of a funding instrument
    - Fluctuations in deposits entirely exogenous: no interbank competition for deposits

Overview

Model setup

- **Aim:** model of bank behavior under uncertainty and multiple constraints

- Discrete time, infinite horizon setting with risk-neutral managers

- Asset side: loans, liquid assets

- Liability side: equity, deposits, long-term debt, short-term debt

- Requirements on risk-weighted capital ratio and LCR-type liquidity ratio

- Shocks on assets returns, cost of funding, and volume of deposits

Balance sheet structure and adjustment

Assets	Liabilities
$L_{j,t}$, **Loans**	$E_{j,t}$, **Capital**
$-\ r^L_{j,t}$, return on loans	$-\ \Pi_{j,t}$, profits
$-\ m^L$, loan maturity	$-\ div_{j,t}$, dividends
$-\ g^L_{j,t}$, new loan issuance	
	$D_{j,t}$, **Deposits**
$F_{j,t}$, **Liquid assets**	$-\ i^D_{j,t}$, interest rate on deposits
$-\ r^F_{j,t}$, return on liquid assets	
$-\ lnP^F_{j,t}$, liquid asset prices	$LT_{j,t}$, **Long-term debt**
$-\ g^F_{j,t}$, liquid asset adjustment	$-\ i^{LT}_{j,t}$, interest rate on long-term debt
	$-\ m^{LT}$, long-term debt maturity
	$-\ g^{LT}_{j,t}$, new long-term debt issuance
	$ST_{j,t}$, **Short-term debt**
	$-\ i^{ST}_{j,t}$, interest rate on short-term debt
	$-\ g^{ST}_{j,t}$, short-term debt adjustment

Banks' adjustment decisions

- Banks take decisions to maximize the following expression:

$$\mathbb{E}_t\left[\sum_{s=t}^{T}\beta^{s-t}\left(\underbrace{div_{j,t+s}}_{\text{future dividends}} - \underbrace{\Omega \times \mathbb{1}(CR_{j,t+s} < \theta_{CR})}_{\text{cost of breaching capital requirements}} \right.\right.$$

$$\left.\left. - \underbrace{\Psi \times \mathbb{1}(LR_{j,t+s} < \theta_{LR})}_{\text{cost of breaching liquidity requirements}} - \underbrace{\Phi_1(-div_{j,t+s})^{\Phi_2} \times \mathbb{1}(div_{j,t+s} < 0)}_{\text{cost of raising fresh equity}}\right)\right]$$

- β: discount factor ($\beta < 1$); Ω, Ψ: cost of breaching regulatory capital or liquidity requirements; ϕ_1, ϕ_2: cost of having to raise fresh equity

Banks' adjustment decisions

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- Cost of breaching regulatory capital and / or liquidity requirements:

  - Reflecting negative consequences for shareholders in case of breach

  - Examples: bail-in, restrictions on distributions, other supervisory measures

  - Reminiscent of bankruptcy costs in classical trade-off models of capital structure

Banks' adjustment decisions

- Banks take decisions to maximize the following expression:

$$\mathbb{E}_t \left[\sum_{s=t}^{T} \beta^{s-t} \left(\underbrace{div_{j,t+s}}_{\text{future dividends}} - \underbrace{\Omega \times \mathbb{1}(CR_{j,t+s} < \theta_{CR})}_{\text{cost of breaching capital requirements}} \right.\right.$$
$$\left.\left. - \underbrace{\Psi \times \mathbb{1}(LR_{j,t+s} < \theta_{LR})}_{\text{cost of breaching liquidity requirements}} - \underbrace{\Phi_1(-div_{j,t+s})^{\Phi_2} \times \mathbb{1}(div_{j,t+s} < 0)}_{\text{cost of raising fresh equity}} \right) \right]$$

- Cost of raising external equity

  – Reflecting direct transactional costs and indirect costs of raising external equity

  – Indirect costs may relate to debt overhang (Myers 1977, Admati et al. 2012) or signaling issues (Myers & Majluf 1984)

  – Costs do not apply if banks retain earnings (in line with pecking order theories)

Banks' adjustment decisions

- Banks take decisions to maximize the following expression:

$$
\mathbb{E}_t\left[\sum_{s=t}^{T}\beta^{s-t}\left(\underbrace{div_{j,t+s}}_{\text{future dividends}} - \underbrace{\Omega\times\mathbb{1}(CR_{j,t+s}<\theta_{CR})}_{\text{cost of breaching capital requirements}} \right.\right.
$$

$$
\left.\left. - \underbrace{\Psi\times\mathbb{1}(LR_{j,t+s}<\theta_{LR})}_{\text{cost of breaching liquidity requirements}} - \underbrace{\Phi_1(-div_{j,t+s})^{\Phi_2}\times\mathbb{1}(div_{j,t+s}<0)}_{\text{cost of raising fresh equity}}\right)\right]
$$

- Structural parameters β, Ω, Ψ, ϕ_1, ϕ_2 are key and need to be estimated

Asset structure and adjustment

- Loans and liquid assets evolve according to the following equations:

$$L_{j,t+1} = L_{j,t}\left(1 - \frac{1}{m^L} + g_{j,t}^L\right) \qquad \text{with} \quad g_{j,t}^L \in [0, \overline{g_t^L}]$$

$$F_{j,t+1} = F_{j,t}(1 + g_{j,t}^F) \qquad \text{with} \quad g_{j,t}^F \in [\underline{g_t^F}, \overline{g_t^F}]$$

- Stochastic returns on loans and liquid assets are defined as follows:

$$r_{j,t}^L = r_t^{CB} + \mu - \zeta + \eta_{j,t}^{rL} \qquad \text{with} \quad \eta_{j,t}^{rL} \sim \mathcal{N}(0, \sigma_{rL}^2)$$

$$r_{j,t}^F = r_t^{CB} + \psi + \eta_{j,t}^{rF} \qquad \text{with} \quad \eta_{j,t}^{rF} \sim \mathcal{N}(0, \sigma_{rF}^2)$$

- Loans have higher returns ($\mu - \zeta > \psi$), but are more risky ($\sigma_{rL}^2 > \sigma_{rF}^2$)

- Loans require higher amount of equity financing (higher risk weight) and are more difficult to fund with short-term debt (liquidity rules)

Debt structure and adjustment

- Interest rates on long-term debt and short-term debt are given by:

$$i_{j,t}^{LT} = r_t^{CB} + \xi + \eta_{j,t}^{iL} \qquad \text{with} \quad \eta_{j,t}^{iL} \sim \mathcal{N}(0, \sigma_{iL}^2)$$

$$i_{j,t}^{ST} = r_t^{CB} + \gamma + \eta_{j,t}^{iS} \qquad \text{with} \quad \eta_{j,t}^{iS} \sim \mathcal{N}(0, \sigma_{iS}^2)$$

- Evolution of long-term debt and short-term debt is determined by:

$$LT_{j,t+1} = LT_{j,t}\left(1 - \frac{1}{m^{LT}} + g_{j,t}^{LT}\right) \qquad \text{with} \quad g_{j,t}^{LT} \in [0, \overline{g_t^{LT}}]$$

$$ST_{j,t+1} = ST_{j,t}(1 + g_{j,t}^{ST}) \qquad \text{with} \quad g_{j,t}^{ST} \in [\underline{g_t^{ST}}, \overline{g_t^{ST}}]$$

- Long-term debt more costly ($\xi > \psi$), but insurance against shocks

- Deposits exogenously determined, possible volume shocks each period:

$$D_{j,t+1} = D_{j,t} + \eta_{j,t}^{D} \qquad \text{with} \quad \eta_{j,t}^{D} \sim \mathcal{N}(0, \sigma_D^2)$$

Quarterly profits and evolution of equity

- Given choices and realization of the shocks on asset returns, cost of funding, and volume of deposits, banks obtain quarterly profits Π

- Profits are retained or distributed, equity evolves according to:

$$E_{j,t+1} = E_{j,t} + \Pi_{j,t+1} - div_{j,t}$$

Possible ways to adjust capital / liquidity ratios

$$CR_{j,t+1} = \frac{E_{j,t+1}}{RW_{j,t+1}A_{j,t+1}} \qquad\qquad LR_{j,t+1} = \frac{F_{j,t+1}}{w_{ST} \times ST_{j,t+1} + w_D \times D_{j,t+1}}$$

Ways to improve the capital ratio:

1. Retain earnings / raise equity to buy back debt   (E ↑, A →)

2. Retain earnings / raise equity to fund asset growth   (E ↑ = A ↑)

3. Sell / reduce assets to buy back debt   (E →, A ↓)

4. Reshuffle assets to less risky activities   (RW ↓, E →, A →)

Ways to improve the liquidity ratio:

1. Increase liquid asset holdings   (F ↑, ST →)

2. Decrease the amount of short-term debt   (F →, ST ↓)

Solution of the model

- Banks take decisions in each period to maximize their value function

- Model is solved via backward induction, assuming liquidation in period T

- Value function iteration approach with discretized choice/state variables, taking expectations with respect to the realization of the shocks

- Optimal choices (adjustment of loans, liquid assets, long- and short-term debt and payout ratio) for each possible balance sheet structure

Overview

Estimation strategy

1. Parameters characterizing profit function and shock variances assumed to be exogenous financial factors; obtained from supervisory data

2. Remaining structural parameters (β, Ω, Ψ, ϕ_1, ϕ_2, ζ) estimated by making use of the economic model to match key moments in the supervisory data:

   i.   Given parameters obtained in 1, fix a set of structural parameters

   ii. Given these parameters, derive optimal decisions for each point of the state space

   iii. Use the obtained policy functions to simulate the dynamic behavior of 2000 banks

   iv. Compare moments in simulated data with those observed in actual data

   v.   Select structural parameters to minimize distance between simulated / empirical moments

Exogenous parameters

- Parameters characterizing exogenous processes estimated from quarterly supervisory data (COREP/FINREP, 116 banks, 2014Q3 to 2016Q3):

r^{CB}, central bank rate	0.0000
μ, spread on loans	0.0069
ψ, spread on liquid assets	0.0038
ϕ, mark-up on deposits	0.0014
ξ, mark-up on long-term debt	0.0039
γ, mark-up on short-term debt	0.0022
ι_1, where $\log(\text{operating costs}) = \iota_1 + \iota_2 \times \log(\text{assets})$	-4.902
ι_2, where $\log(\text{operating costs}) = \iota_1 + \iota_2 \times \log(\text{assets})$	0.968
m^L, maturity of loans (in quarters)	40
m^{LT}, maturity of long-term debt (in quarters)	32

Shock variances

- Shock variances estimated via two-step procedure:

1. Regress log differences of the variables of interest on observable characteristics to separate endogenous from exogenous variation

2. Estimate variances of obtained residuals by using a GMM strategy

St. dev. of shocks to return on loans	0.250
St. dev. of shocks to return on liquid assets	0.234
St. dev. of shocks to liquid asset prices	0.000
St. dev. of shocks to interest rates on short-term debt	0.283
St. dev. of shocks to interest rates on long-term debt	0.188
St. dev. of shocks to volume of deposits	0.031

Regulatory requirements

- Parametrization of regulatory requirements obtained from supervisory data, Basel III regulations, and ECB internal data base on capital requirements:

w^L, risk weight on loans	0.555
w^F, risk weight on liquid assets	0.125
w^O, risk weight from operational risk	0.04
w^{ST}, liquidity weight on short-term debt	1
w^D, liquidity weight on deposits	0.05
θ_{RW}, capital requirement	0.12
θ_{LR}, liquidity requirement	0.9

Estimation results for structural parameters

β, discount factor	0.986
Ω, cost of breaching capital requirements (in % of capital)	0.46
Ψ, cost of breaching liquidity requirements (in % of capital)	0.28
Φ_1, parameter in cost function for raising equity	1.09
Φ_2, parameter in cost function for raising equity	1.04
ζ, expected default rate on loans	0.0011

- Discount factor corresponds to an annual cost of equity of 6 percent

- Breaching capital more costly than breaching liquidity requirements

- Raising fresh equity in the market relatively costly ('last resort')

- Expected impairment rate on loans in line with observed rate

Overview

Increase in capital requirements ($\theta_{CR}\uparrow$, +1PP)

Risk-Weighted Capital Ratio
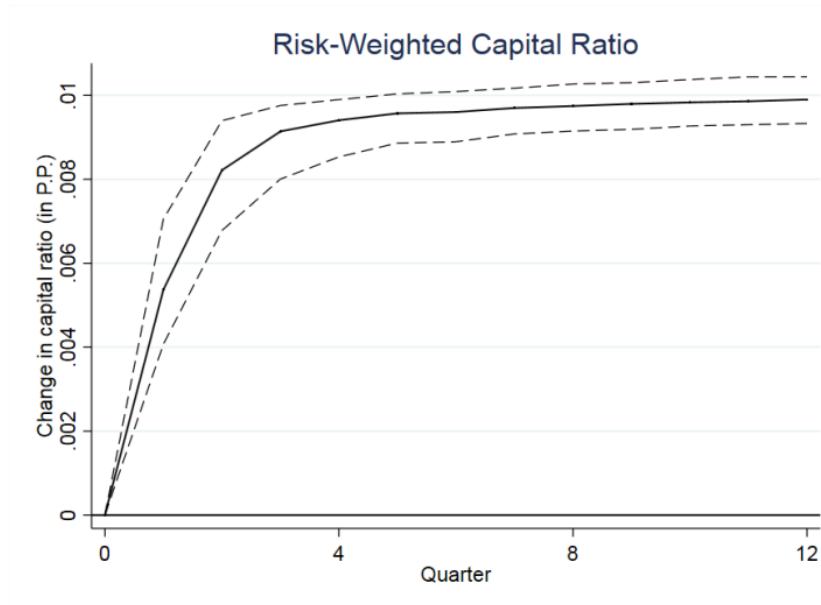
- Banks replenish voluntary buffers following the increase (but go no further)

- Little variation with respect to the magnitude of the change in capital ratios

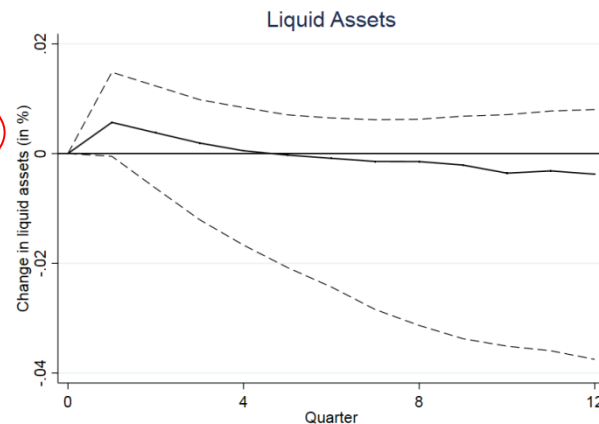- BUT: important heterogeneity with respect to the mode of adjustment

Different modes of adjustment ($\theta_{CR} \uparrow$, +1PP)

Ways to improve the capital ratio:

1. Retain earnings / raise equity to buy back debt

2. Retain earnings / raise equity to fund asset growth

3. Sell/reduce assets to buy back debt

4. Reshuffle assets to less risky activities

Different modes of adjustment ($\theta_{CR}\uparrow$, +1PP)

Dividends over Assets

Assets

Loans

Liquid Assets

Ways to improve the capital ratio:

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Different modes of adjustment ($\theta_{CR}\uparrow$, +1PP)

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Different modes of adjustment ($\theta_{CR} \uparrow$, +1PP)

Ways to improve the capital ratio:

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Heterogeneity in responses ($\theta_{CR}\uparrow$, +1PP)

Dividends over Assets

Loans
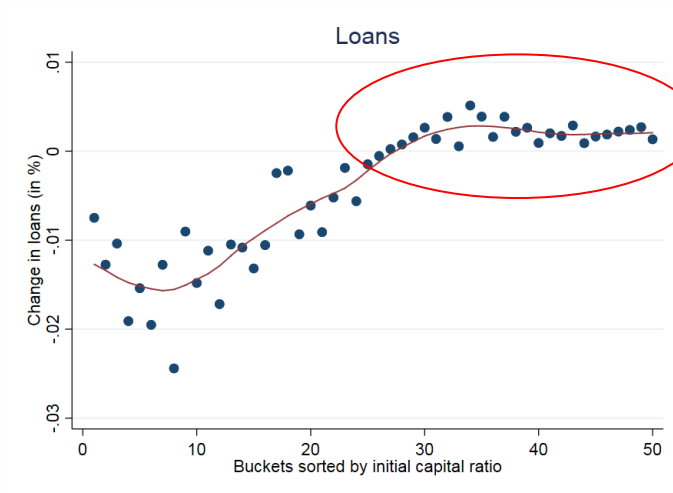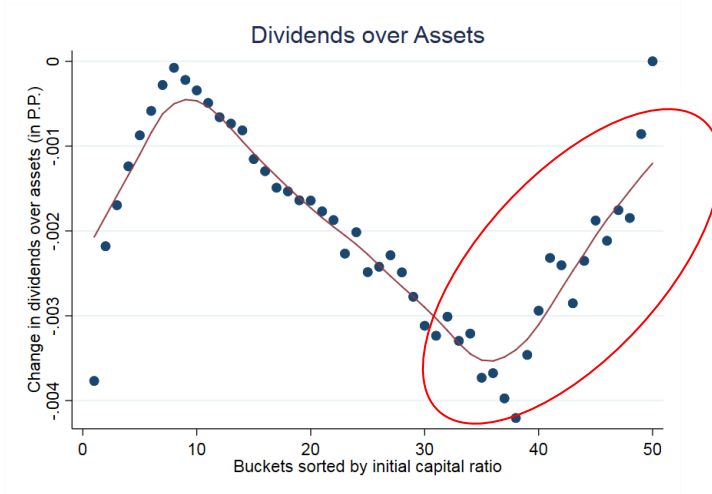
UNCONSTRAINED:

Reduce dividends relative to baseline, keep lending relative constant (moderate pressure to adjust)

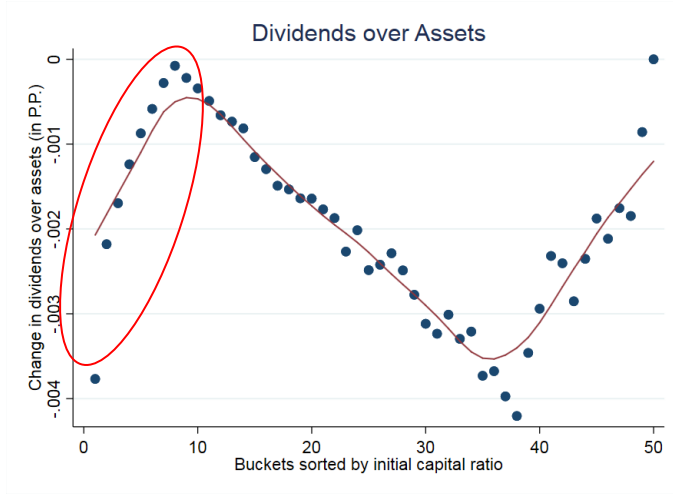# Heterogeneity in responses ($\theta_{CR}\uparrow$, +1PP)

Dividends over Assets
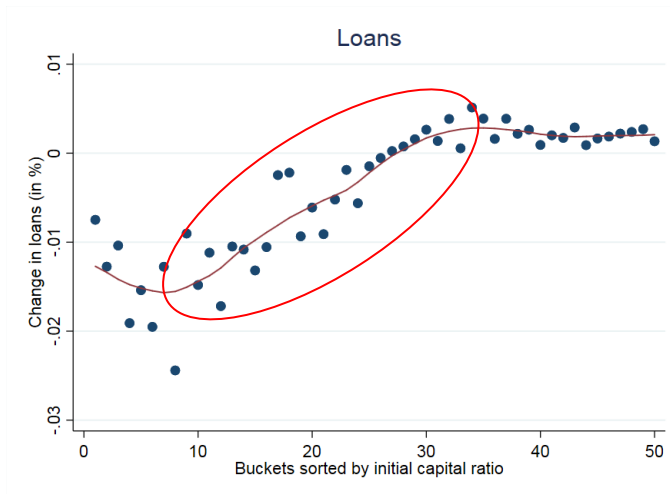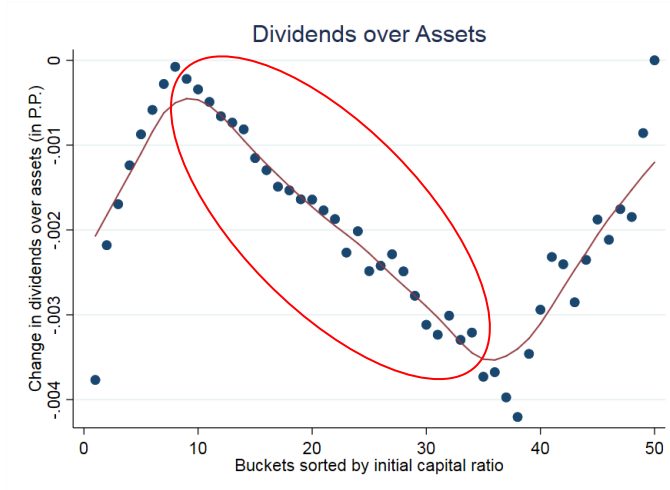
Loans

MODERATELY
CONSTRAINED:

Cut dividends to 0;
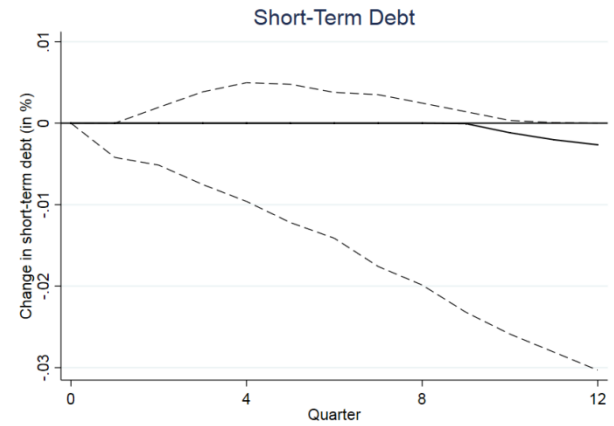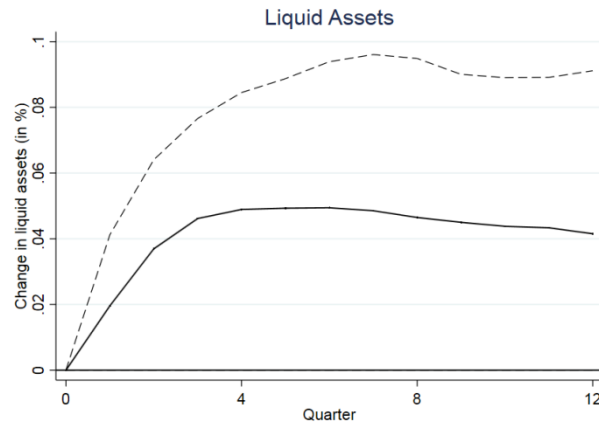but further need to
adjust leads to a
reduction in loans

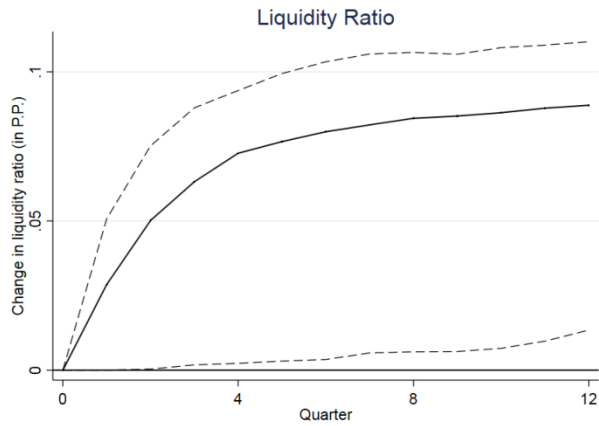# Heterogeneity in responses ($\theta_{CR}\uparrow$, +1PP)
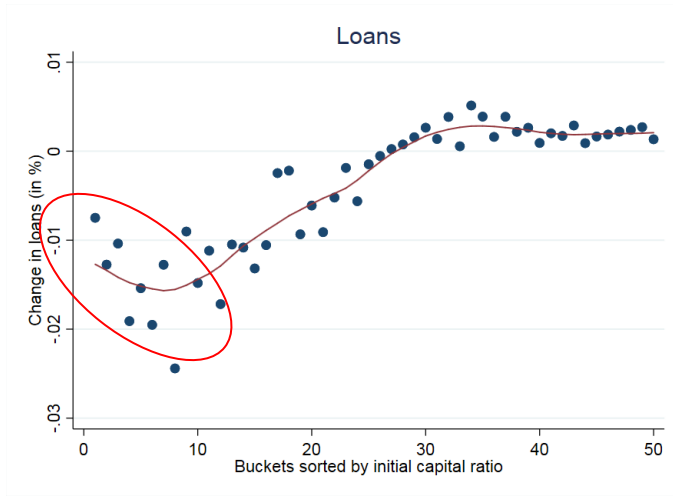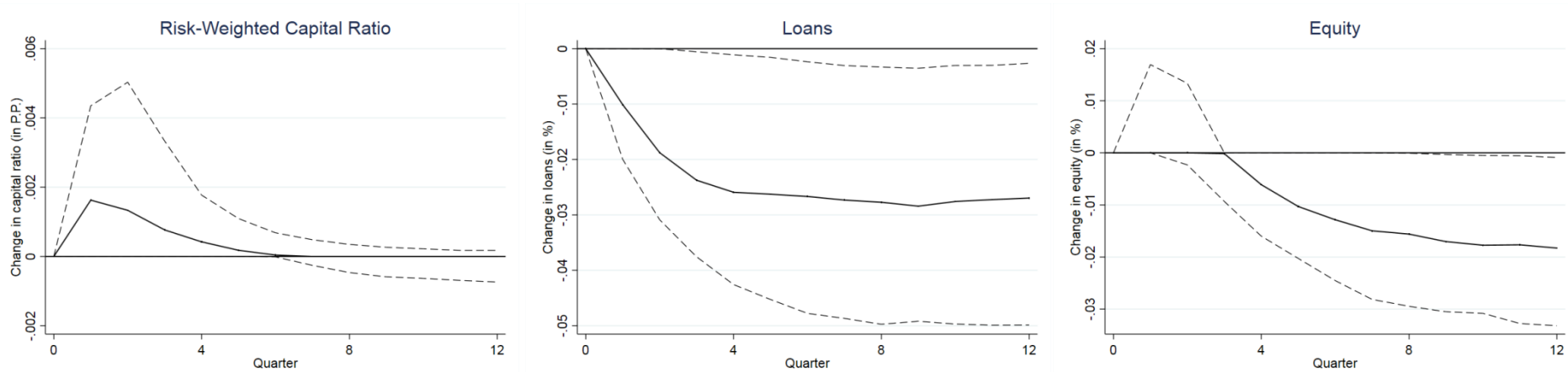

SEVERELY
CONSTRAINED:

High pressure to
adjust forces to raise
external equity; new
equity allows to
support lending

Increase in liquidity requirements ($\theta_{LR}\uparrow$, +10PP)

- Almost complete replenishment of voluntary buffers following policy change

- Banks increase liquid assets and decrease the amount of short-term debt

Increase in liquidity requirements ($\theta_{LR}\uparrow$, +10PP)

- Target capital ratios unaffected , but liquid assets have positive risk weights

- Further adjustments necessary to keep capital ratios in line with target

→ Real effects of changes in liquidity requirements likely to depend on the extent by which increasing liquid assets makes banks capital constrained

Overview

Conclusion and next steps

- Structural model provides micro foundation for observed adjustments

- Changes in capital and liquidity requirements can have sizable real effects, dependent on banks' initial balance sheet structure

- Important non-linearities in adjustment functions, usually neglected in models on the relationship between bank capital and lending

- Possible interactions between capital and liquidity requirements

Conclusion and next steps

Possible applications:

- Use model to gauge impact of future policy measures/regulatory changes

- Combine with macro model on the relation between lending and output

Possible extensions:

- Relation between asset risk / leverage and the cost of funding

- Possible frictions related to cutting back dividends

- Relation between choice and return variables (general equilibrium)