Views are the authors' and do not represent those of the Bank of Canada

A Q-Theory of Banks

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Motivation

- **Post Financial Crisis Banking Theory**
  - Many macro-finance models with different frictions
    - Effects of regulatory policies / welfare
    - Bank net-worth key state variable
    - Net-worth $\approx$ bank leverage (scaled bank equity)
  - What frictions & constraints determine bank leverage dynamics?
  - How to measure bank leverage?
    - Important difference between theory and data: accounting values
    - Not just measurement issue: reg. constraints in accounting values
    - Lowers incentives to report losses (Caballero et al, 2008; Milbradt, 2012; Blattner et al, forthcoming)

This paper

- **Five stylized facts**
  - Informative about what frictions and constraints matter
  - Many potential micro-foundations
- **Dynamic bank optimization model**
  - Built to quantitatively match stylized facts pre- and post-(fin)-crisis
    - Endogenous leverage target (trade-off)
    - Balance sheet stickiness
    - Accounting rules & regulatory constraints
  - Use model to conduct counterfactual exercise
    - What are the effects of new accounting towards early recognition of losses?
    - How does regulatory forbearance affect banks in this model?

Five Stylized facts

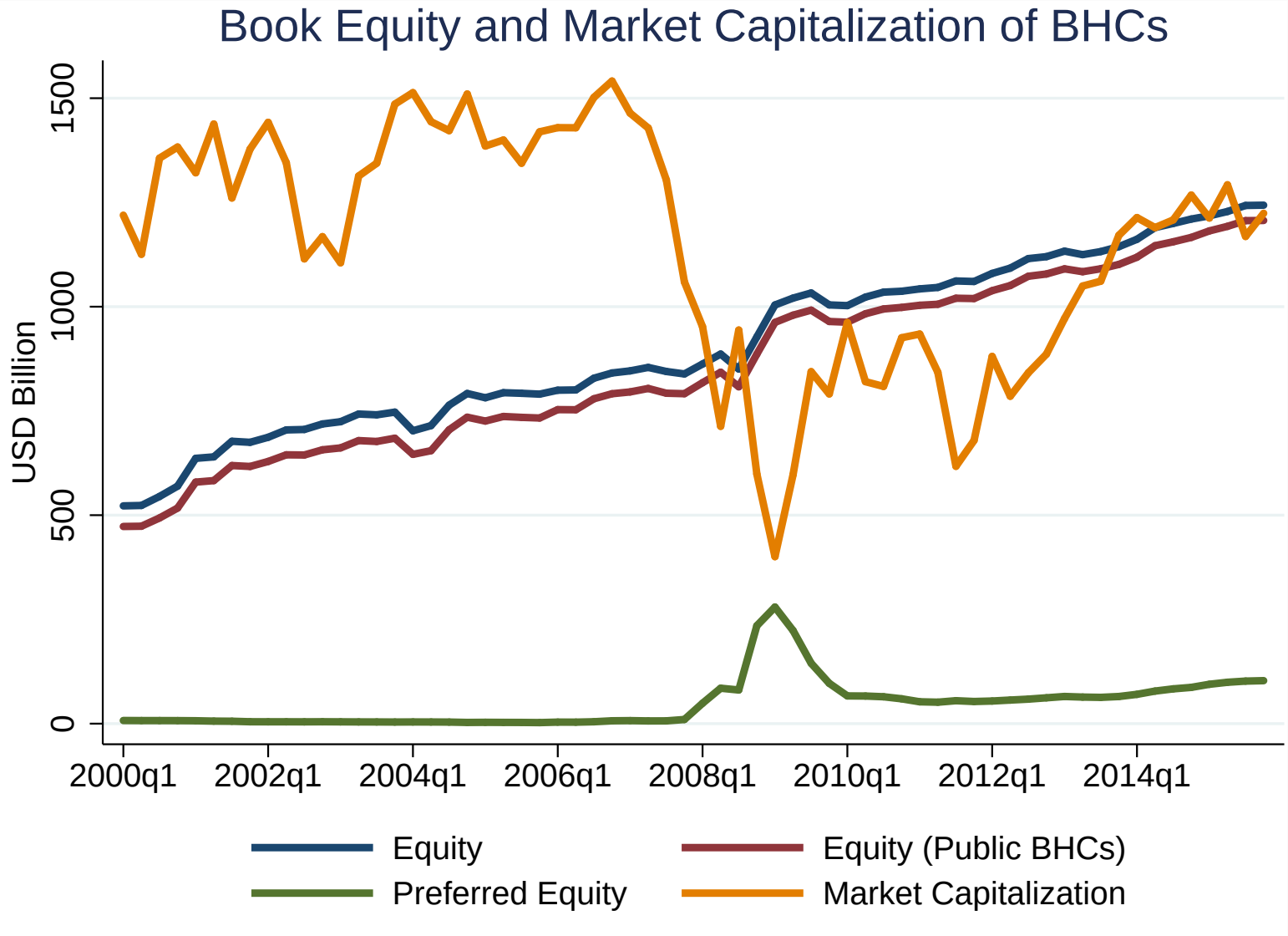
- Data: FR-Y-9C (BHC quarterly filings) matched to CRSP (2000-2018)

1. TS: Market & book equity values diverge - esp. during crises
2. XS: Books are slow to recognize losses
3. XS: Book equity buffer, leeway on market leverage
4. XS: Leverage dynamics consistent with target leverage ratio:
   - Negative net-worth shock increases market leverage (IRFs)
   - Slow reversion back to target
5. How do banks delever after negative net-worth shock?
   - Pre-crisis: adj. primarily by reducing assets
   - Post-crisis: faster adj. compared to before / also increasing equity

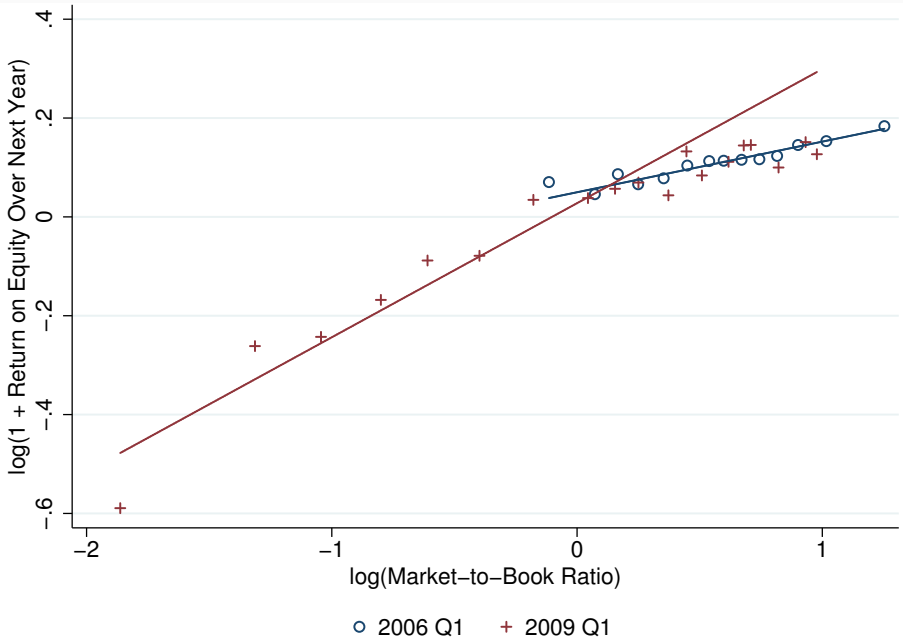
Bank Data

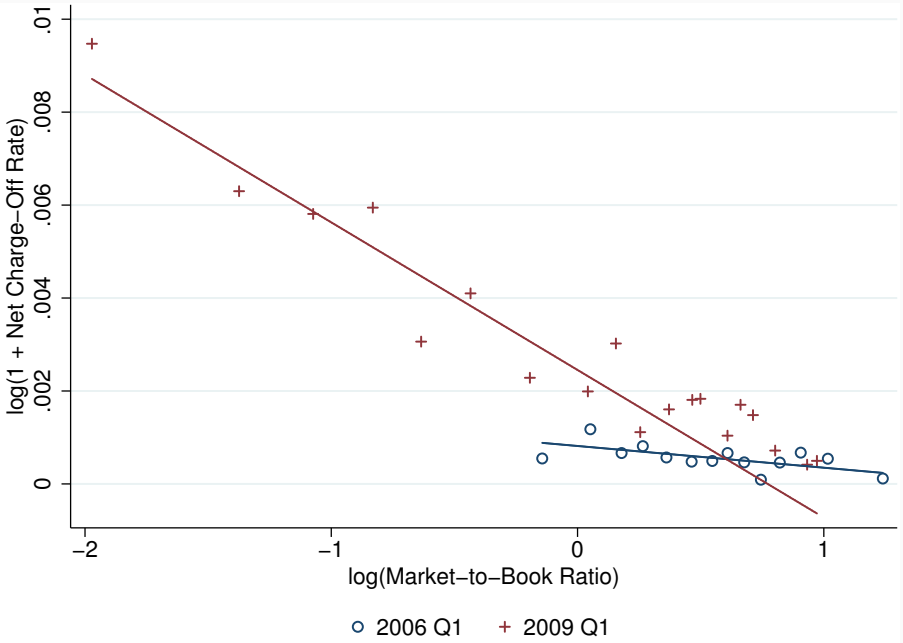
- FR Y-9C quarterly filings for bank holding companies (BHC)
  - BHC consolidates banks' position across different subdivisions
  - Exclude new entrants (e.g. GS, MS, ...)
  - Merge with CRSP data

Fact 1:

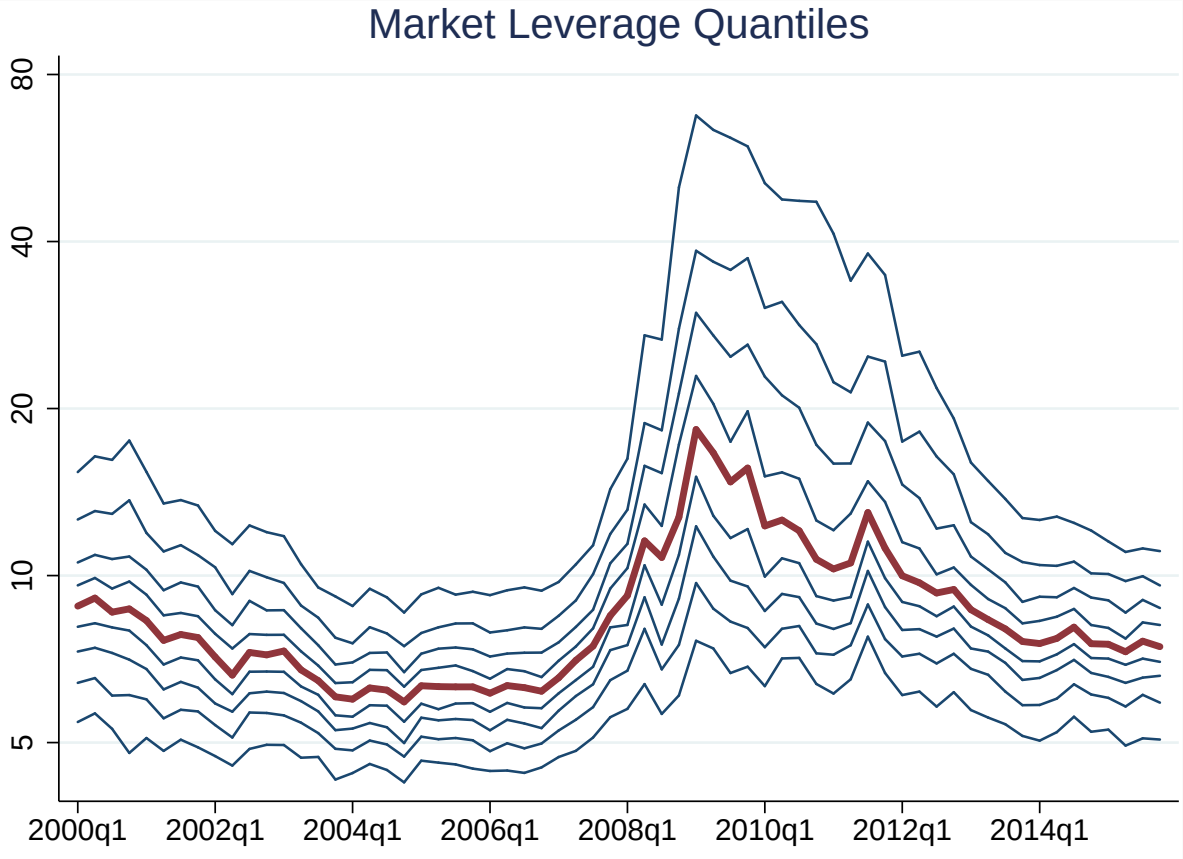

Book Equity and Market Capitalization of BHCs
USD Billion
0
500
1000
1500
2000q1
2002q1
2004q1
2006q1
2008q1
2010q1
2012q1
2014q1
Equity
Equity (Public BHCs)
Preferred Equity
Market Capitalization

Fact 2: Market Information



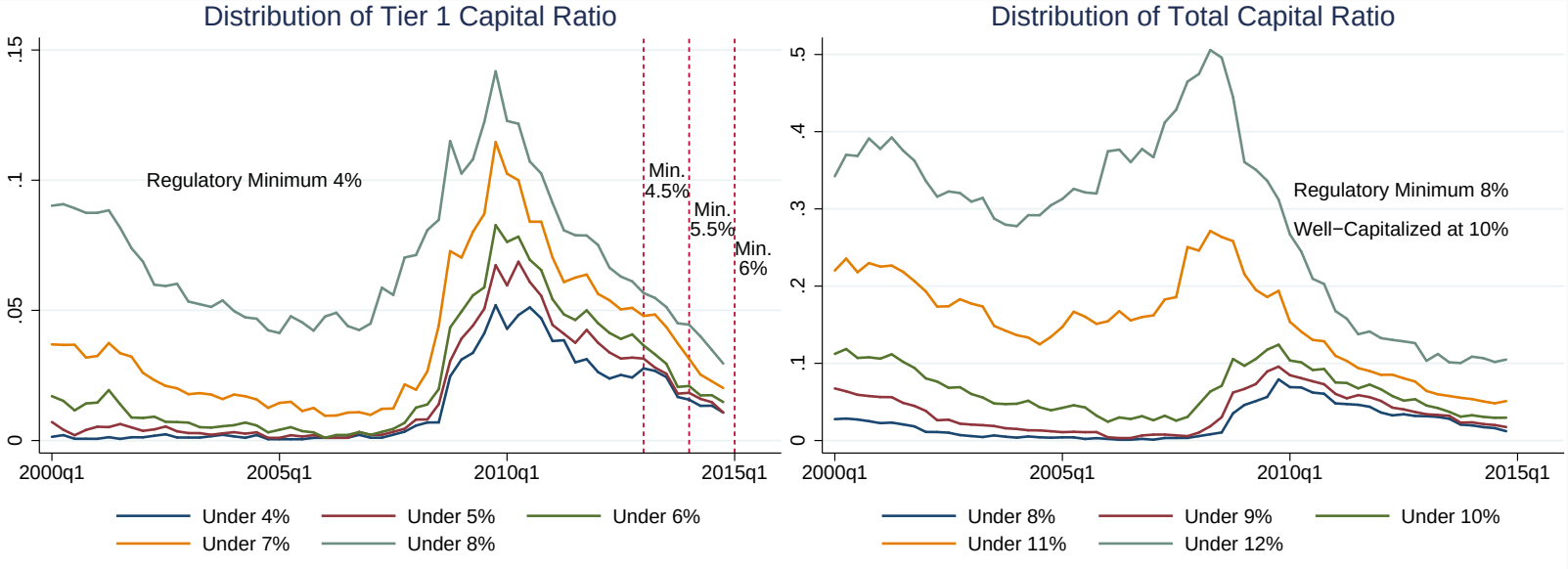


Fact 3: ↑Market-leverage dispersion [1/2]



- note: log scale
- binding market based constraints: opposite prediction

Fact 3: Book-Leverage buffer [2/2]



- minor fraction of banks below capital ratio
- much more compressed distribution than market values

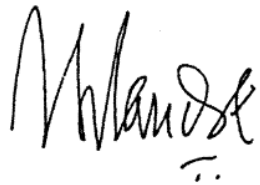
Taking Stock: Book/Market Value Differences?

- Historical cost accounting
  - banks must acknowledge asset impairments:
    - after "estimable and probable" (will change in 2020)
  - Other securities are held at "fair value"
    - fair values based on similar assets (Level 2), or model (Level 3)
- Off-balance sheet items
- Evergreening

Discussion: Book/Market Differences?

- Citibank Annual Report to Shareholders 2008

By using our databases and customer insight, we have been able to identify customers at risk of delinquency and reach out to them to restructure their loans *before* they slip into default. Our Citi Homeownership Assistance Program (CHAP) is a proactive program that helps avoid the loss of homes and protects credit scores and future borrowing potential. Through new assistance programs, we have helped about 440,000 homeowners weather the downturn. We are also pleased to support the Administration's approach to mortgage loan modifications.



Vikram Pandit
Chief Executive Officer, Citigroup Inc.

Fact 4: response to "wealth" shocks

- How banks respond to equity losses:

$$\Delta \log(y_{i,t}) = \alpha_t + \sum_{h=0}^{20} (\gamma_h \cdot \varepsilon_{i,t-h} + \gamma_h \cdot Post_t \ \varepsilon_{i,t-h}) + \epsilon_{i,t}$$

  - $y_{i,t}$: dividends, liability growth, leverage, market leverage
  - $\varepsilon_{i,t-h}$: equity loss h periods ago
  - i is bank, t is a quarter

- Panel: 1990.Q3 2006Q4 (pre) - 2010Q4 to 2016.Q4 (post)

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- Challenge: $\varepsilon_{i,t-h}$ not registered in books

Fact 4: response to equity losses

- Approach: estimate $\hat{\varepsilon}_{i,t}$ using

$$\underbrace{r_{it}}_{\text{Raw Return}} - \underbrace{r_t^f}_{\text{Risk-Free Rate}} = \alpha_i + \underbrace{X_t}_{\text{factors}} \underbrace{\beta_i}_{\text{loadings}} + \underbrace{\varepsilon_{it}}_{\text{Idiosyncratic Component}}$$

  - $r_{i,t}$: stock return
  - $\hat{\varepsilon}_{it}$: "idiosyncratic wealth shocks"

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  - $r_{i,t}$: stock return
  - $\hat{\varepsilon}_{it}$: "idiosyncratic wealth shocks"

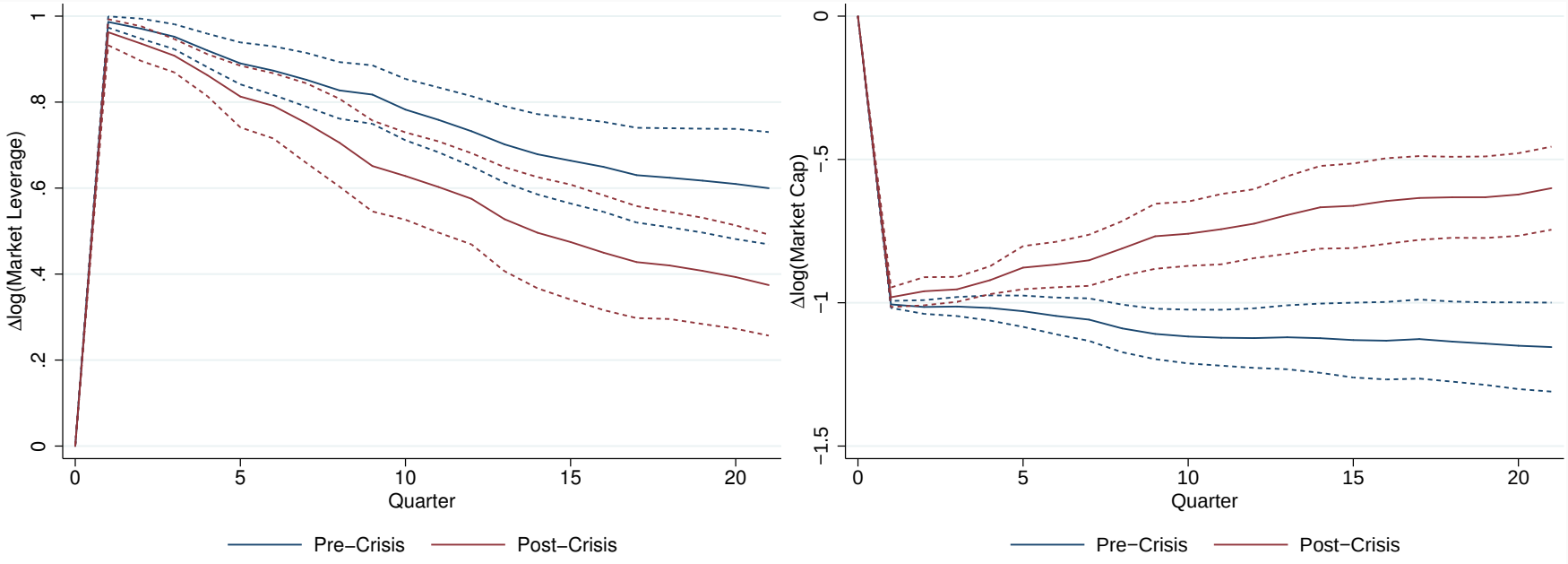
- Identification:
  - controls for aggregate risk premia (market, interest rates, credit factors)
  - assumption: shocks *unpredictable,* first observable to markets, not in books

    $\Rightarrow$cross-sectional return $\approx$ idiosyncratic shock to wealth

$\Rightarrow$ corrobarate $\hat{\varepsilon}_{it}$ with narrative (newspaper article approach)

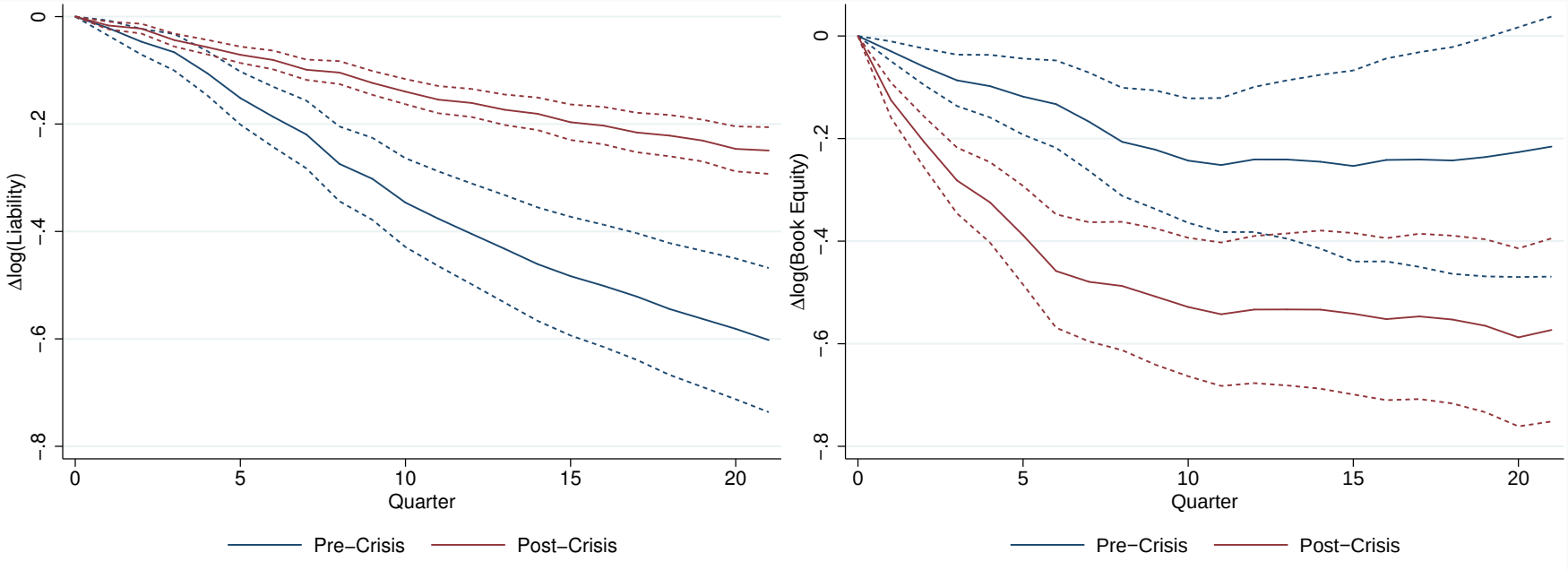
$\Rightarrow$alternatives: stress-testing, size, investment opportunities

Fact 4: banks target market leverage



- No restrictions on $\sum \gamma_h = 0$

Fact 5: how did they return to target?



- reflects maturity or asset sales

Discussion: leverage target?

- Wells Fargo - 2019Q3 Basel III Pillar 3 Regulatory Capital Disclosures:

  "Wells Fargo's objective in managing its capital is to maintain capital at an amount commensurate with our risk profile and risk tolerance objectives, and to meet both regulatory and market expectations. We primarily fund our regulatory capital needs through the retention of earnings net of both dividends and share repurchases, as well as through the issuance of preferred stock, long-term debt and other qualifying instruments. We manage capital to meet internal capital targets with the goal of ensuring that sufficient capital reserves remain in excess of regulatory requirements and applicable internal buffers."

Robustness Checks

- Asymmetries
- Big vs. Small Banks
- Stress Tests
- Placebo
- Flight-to-Quality + Bank profitability?

Dynamic bank optimization model

Model set up

- Cross-section of dynamic bank optimization problems
- Balance sheet
  - Long term loans
  - Funded with equity and deposits
  - Balance sheet stickiness via convex loan funding costs
- Endogenous capital structure
  - Cannot issue equity only retained earnings / dividend smoothing motive
  - Liquidation costs
- Three equity value concepts:
  - Fair value / fundamental value
  - Accounting value
  - Market value
- Regulatory constraints & fair value leverage cap w/ costly liquidation

Assets

- Balance sheet

$$\text{Loans} = \text{Deposits} + \text{Equity}$$

- Loans long term: δL mature and deliver exogenous return r^L
- New loan issuance I requires issuing deposits:

$$\Phi(I, L) = I + \frac{\gamma}{2}\left(\frac{I}{L} - \delta\right)^2 L$$

Asset risk & Acccounting

- Poisson process N_t governs loan default events
  - w/ prob σ idiosyncratic share ε of loans defaults
- Distinction b/w book value $\bar{L}$ and fair value L loans

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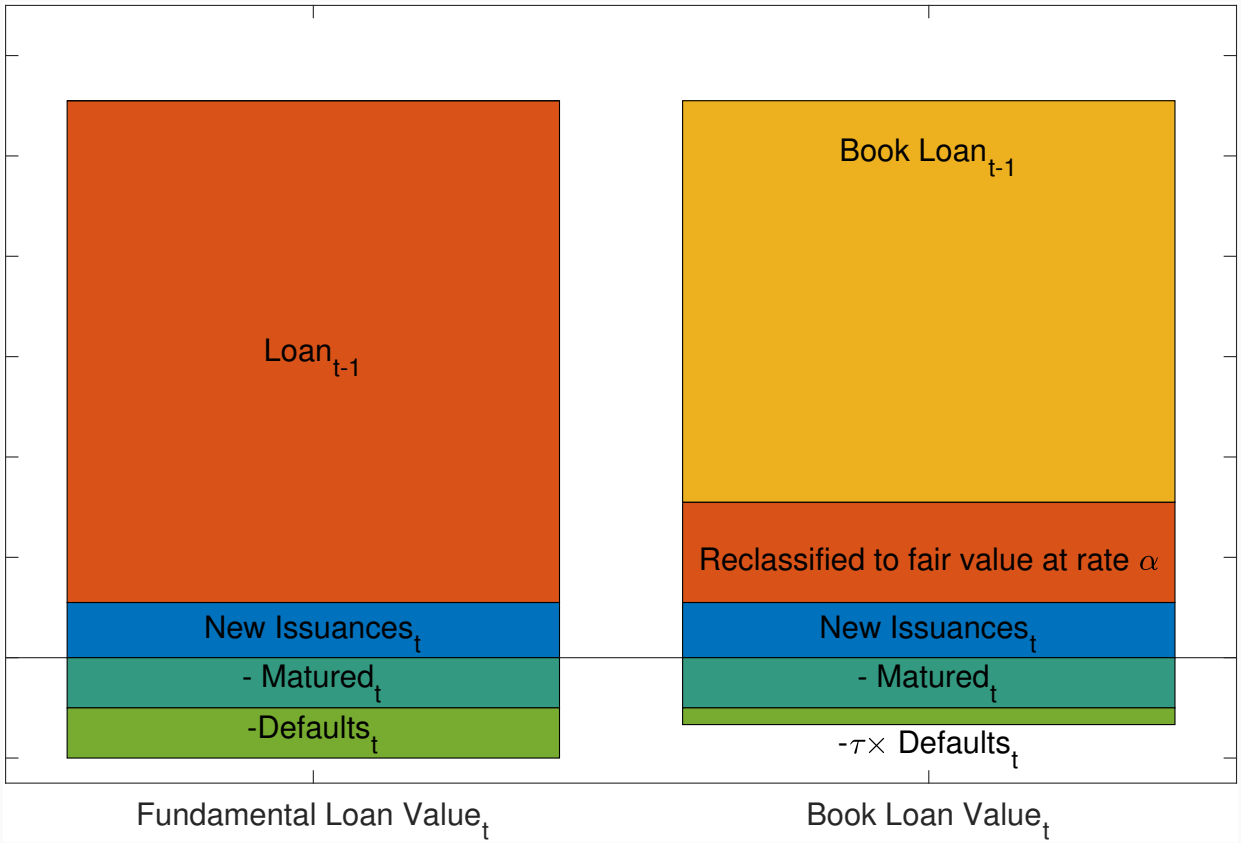


In equations

- Fair value:

$$dL_t = \left(\underbrace{-\delta L_t}_{\text{matured principal}} + \underbrace{I_t}_{\text{new loan issuance}} \right) dt - \underbrace{\varepsilon L_t dN_t}_{\text{actual losses}}$$

- Accounting value:

$$d\bar{L}_t = \left(\underbrace{-\delta L_t}_{\text{matured principal}} + \underbrace{I_t}_{\text{new loan issuance}} \right) dt - \underbrace{\alpha \left(\bar{L}_t - L_t \right) dt}_{\text{delayed accounting}} - \underbrace{\tau \varepsilon L_t dN}_{\text{recognized losses}}$$

- Fair value / accounting value ratio:

$$q_t \equiv \frac{L_t}{\bar{L}_t}$$

Deposits

- Perfectly elastic supply of deposits at exogenous rate r^D
- Law of motion for deposits D_t

$$dD_t = \Big[\underbrace{r^D D_t}_{\text{repay deposits}} - \underbrace{\left(r^L + \delta\right) L_t}_{\text{interest \& principal on loans}} + \underbrace{\Phi\left(I_t, L_t\right)}_{\text{loan funding costs}} + \underbrace{C}_{\text{dividends}} \Big] dt$$

Equity

- Define leverage $\lambda_t \equiv D_t/W_t$ and equity $W_t = L_t - D_t$
- Law of motion for equity

$$\frac{dW}{W} = \underbrace{\left[\underbrace{r^L(\lambda+1) - r^D\lambda}_{\text{net interest income}} - \underbrace{\frac{\gamma}{2}(\iota-\delta)^2(\lambda+1)}_{\text{capital loss from adjustment}} - \underbrace{c}_{\text{dividend rate}}\right]}_{\equiv \mu^W} dt$$

$$\underbrace{\underbrace{(-\varepsilon(\lambda+1))}_{\text{loss after default}}}_{\equiv J^W} dN$$

Liquidation sets

- Banks are liquidated if they violate
  (i) reg. constraint, (ii) fair value constraint, or (iii) cannot repay deposits

- Liquidation is costly

Bank Problem

- **Bankers**: Recursive utility with Duffie-Epstein aggregator f

$$V_t = \mathbb{E}_t \left[\int_t^\infty f\left(C_s, V_s\right) ds \right],$$

with time discount factor ρ, RA $= 0$ and EIS $= 1/\theta$.

  - **Bank Problem:** max value $V(L, \bar{L}, D)$ subject to:

    - loan, book, and deposit laws of motion, liquidation sets

    - **Prop:** only depends on $\{\lambda, q\}$:
    - $V\left(L, \bar{L}, D\right) = v\left(\lambda, q\right) W$
    - $c \equiv C\left(\lambda, q\right) / W$
    - $\iota \equiv I\left(\lambda, q\right) / L$
    - $d\lambda = \left(\iota - \delta - \text{drift}_{\text{Equity}}\right)(\lambda + 1)\,\text{dt} + \frac{\varepsilon(\lambda+1)}{1-\varepsilon(\lambda+1)} \lambda dN$
    - $dq = (\iota - \delta + \alpha)(1 - q)\, q\text{dt} - \left(\frac{\varepsilon - \tau\varepsilon q}{1-\tau\varepsilon q}\right) q dN$

Frictionless solution

- No difference in market-to-book values: $\tau = 1$ ($\Rightarrow q = 1$).
- No balance sheet frictions: $\gamma = 0$.
- Leverage solves the static problem:

$$\max_{\lambda \in \left[0, \frac{\xi}{1-\xi}\right]} (1+v)\left(r^L - r^D\right)\lambda + \sigma \left\{ (1+v) \underbrace{\left(1 + J^W\right) \mathbb{I}\left[\lambda \leq \Lambda\right]}_{\text{wealth upon default shock}} + \underbrace{U(\eta)\, \mathbb{I}\left[\lambda > \Lambda\right]}_{\text{liquidation value}} \right\}$$

- Solution:
  - if bank not profitable (i.e. spread $\left(r^L - r^D\right)$ is too low) set $\lambda = 0$
  - if sufficiently profitable optimal leverage $\lambda > 0$
    - [interior] guarantees not to hit regulatory constraint: set at shadow liquidation boundary $\lambda^* = \Lambda$.
    - [corner] if $\varepsilon \to 0$
- Full model: slows down return to target over shocks

Frictionless model

- Difference in market-to-book values: $\tau < 1$ ($\Rightarrow q < 1$).
- No balance sheet frictions: $\gamma = 0$.

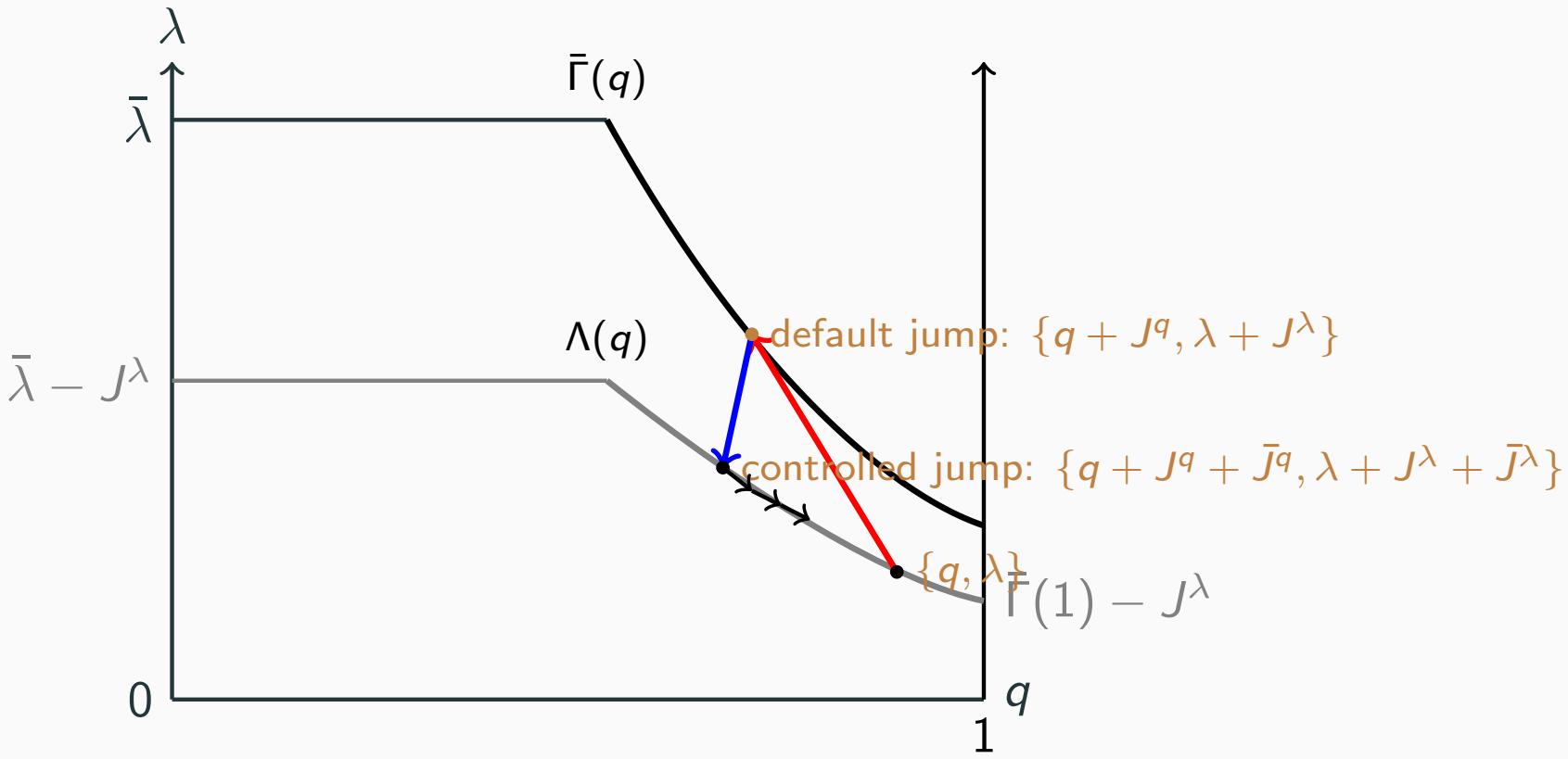


Figure 1: Illustration of $\{q, \lambda\}$ dynamics.

Parametrization

- Solve the model using finite differences (numerical method).
- Match to quarterly BHC data matched to market data from CRSP
- Parameter set 1: independently calibrated

Parameter	Description	Target
$r^L = 1.01\%$	Loan yield	BHC data: interest income / loans
$r^D = 0.51\%$	Bank debt yield	BHC data: interest expense / debt
$\delta = 7.69\%$	Loan maturity	FFIEC 031/041: avg mat of loans & sec
$\bar{\lambda} = 50$	Market leverage constraint	CRSP/BHC: xs 97.5% prct leverage
$\xi = 0.926$	Capital requirement	Capital req of 8% to be well-capitalized
$\rho = 0.25\%$	Banker's discount rate	CRSP: Mean dividend rate
$\varepsilon = 0.25\%$	Average default shocks	Accumulated bank losses
$\sigma = 0.4791$	Arrival rate of Poisson process	Match loan charge-off rate
$\alpha = 4\%$	Recognition rate of books	Peak of charge-off rate fin crisis

- Parameter set 2: jointly estimated/calibrated matching IRFs of the data

Investor valuation

- Construct outside investor (risk-neutral) valuation of bank
- Investors can buy bank shares but not directly emulate banking activities
  - Wealth inside a bank can grow at a higher rate than alternative implied by investors' discount rate
  - Market value of W can therefore be higher than W

Construct impulse response function from simulated data

- Excess return shocks in model:

$$\Delta R_{t,t'} = R_{t,t'} - E_t \left[R_{t,t'} \right]$$

where

$$R_{t,t'} = \frac{\int_t^{t'} c(\tau) W(\tau) d\tau + s(\lambda(t'), q(t')) W(t')}{s(\lambda(t), q(t)) W(t)}$$

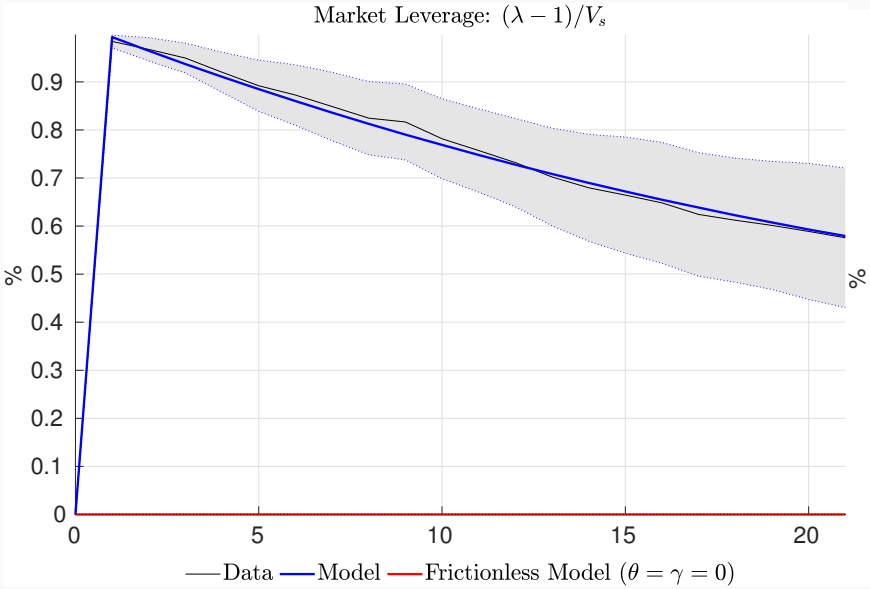
and $s(\lambda, q)$ is the valuation of 1 dollar of bank equity by a risk-neutral investor

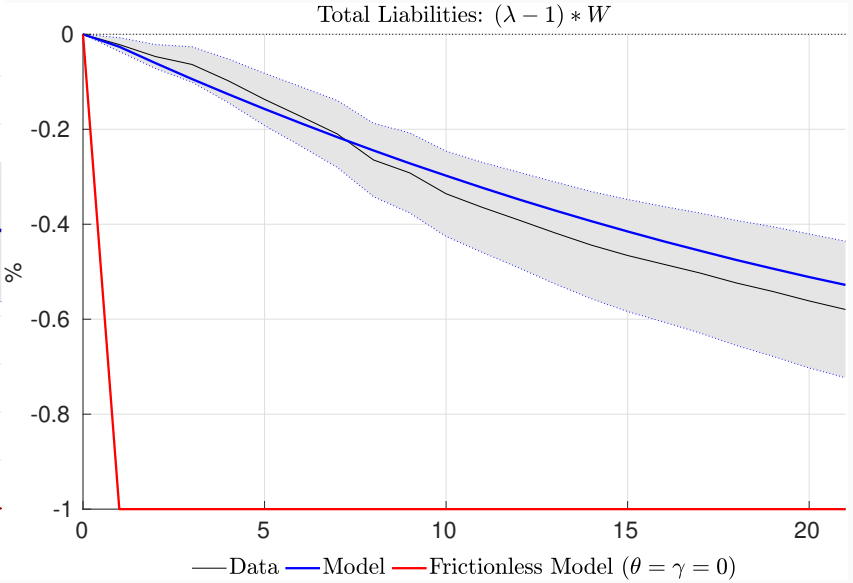
Estimation

- Balance sheet adjustment costs: $\Phi(\iota, 1) \equiv 1 + \frac{\gamma}{2}(\iota - \delta)^2$
- Estimate $\{\gamma, \theta\}$ to match market leverage and liabilities IRFs to net-worth shocks pre-crisis & post-crisis
- Estimate τ to match book leverage initial response pre-crisis

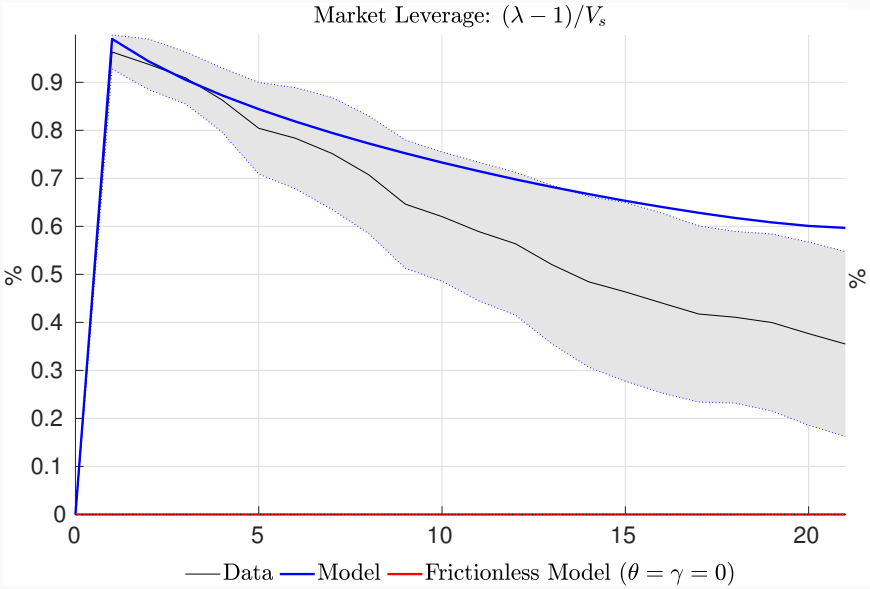
	Matching: IRFs	
Parameter	**Pre-Crisis**	**Post-Crisis**
γ	0.01	3.95
θ	2.31	2.00
τ	1%	-

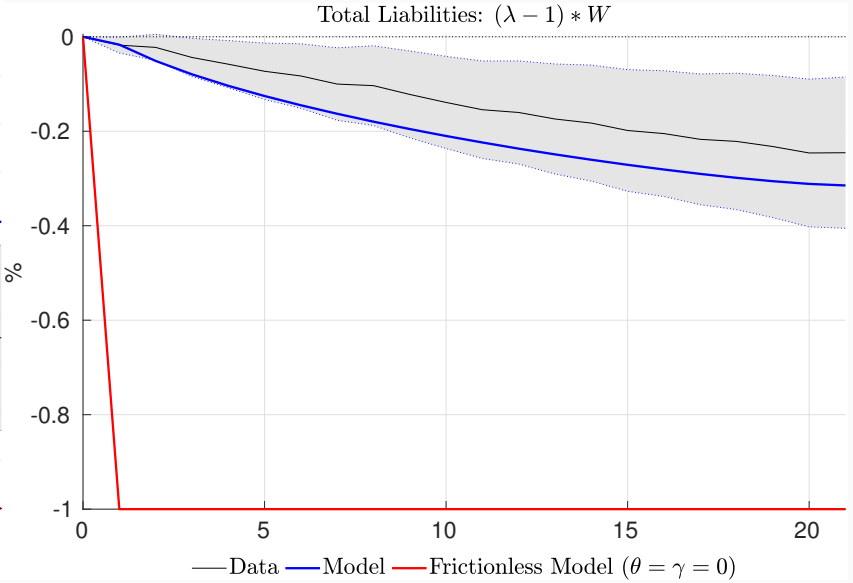
Pre-crisis Fit



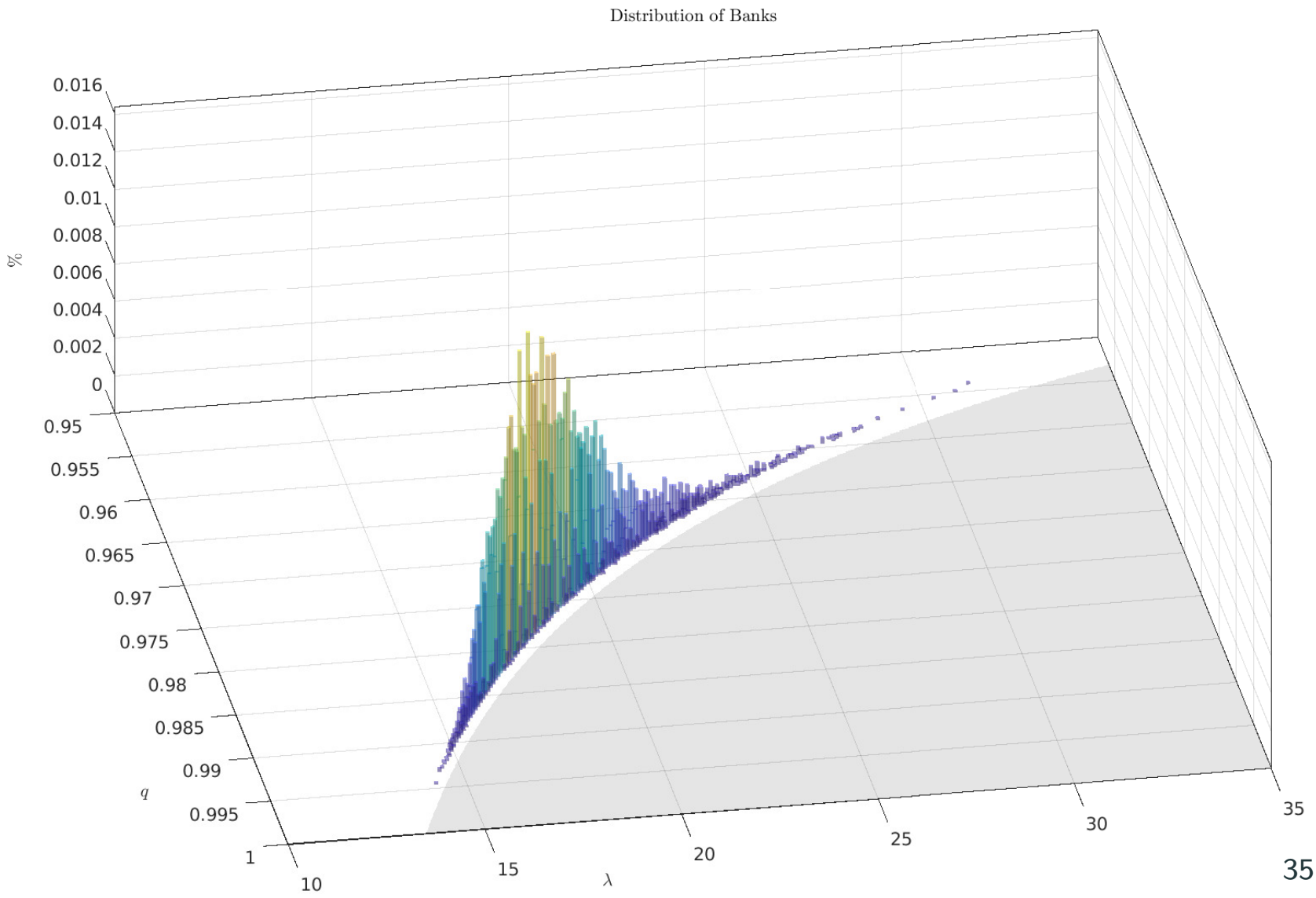


Post-crisis Fit





Distribution of banks



Impact of accounting rules

- Recall evolution of book value of loans

$$d\bar{L}_t = \left(\underbrace{-\delta L_t}_{\text{matured principal}} + \underbrace{I_t}_{\text{new loan issuance}} \right) dt - \underbrace{\alpha \left(\bar{L}_t - L_t \right) dt}_{\text{delayed accounting}} - \underbrace{\tau \varepsilon L_t dN}_{\text{recognized losses}}$$

  - What are the effects of changing the speed of recognition of losses?

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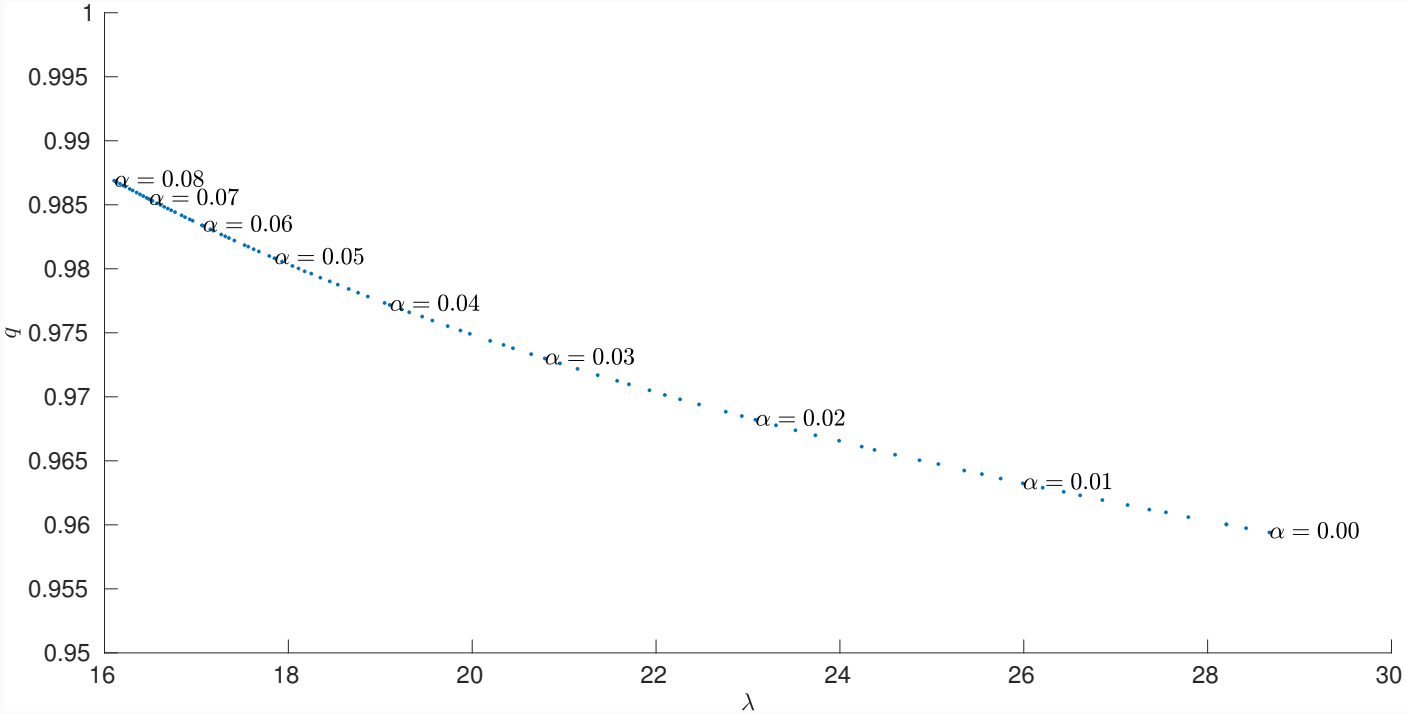
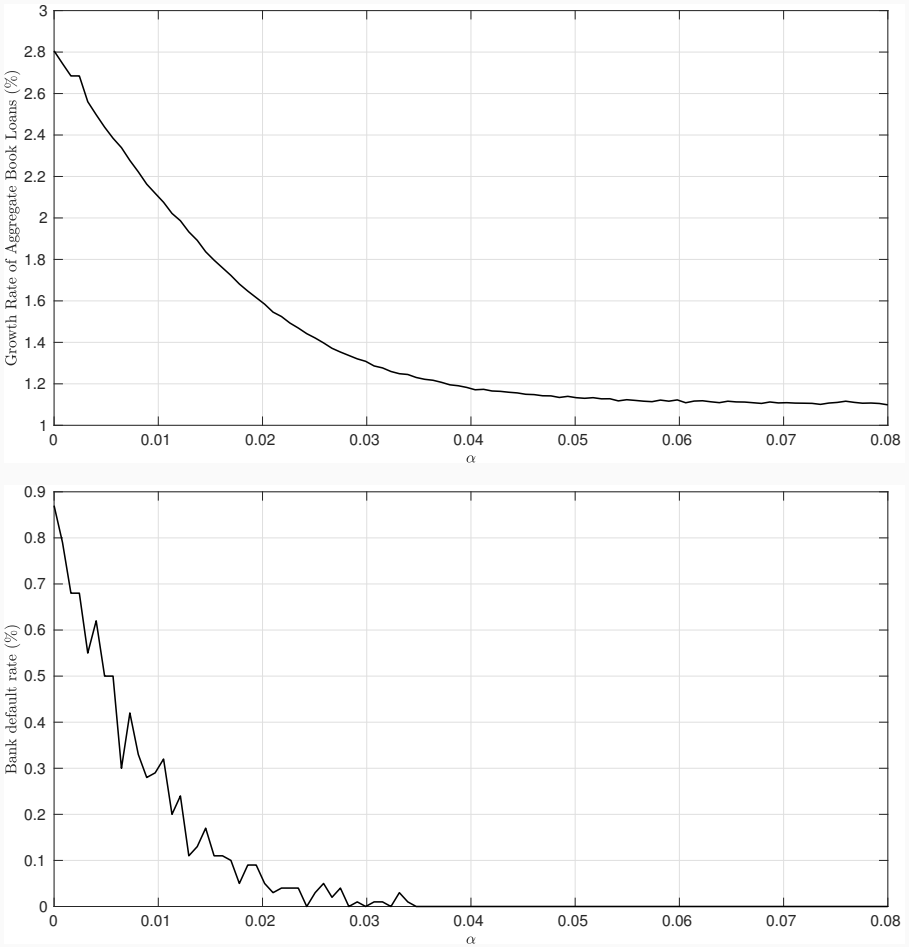


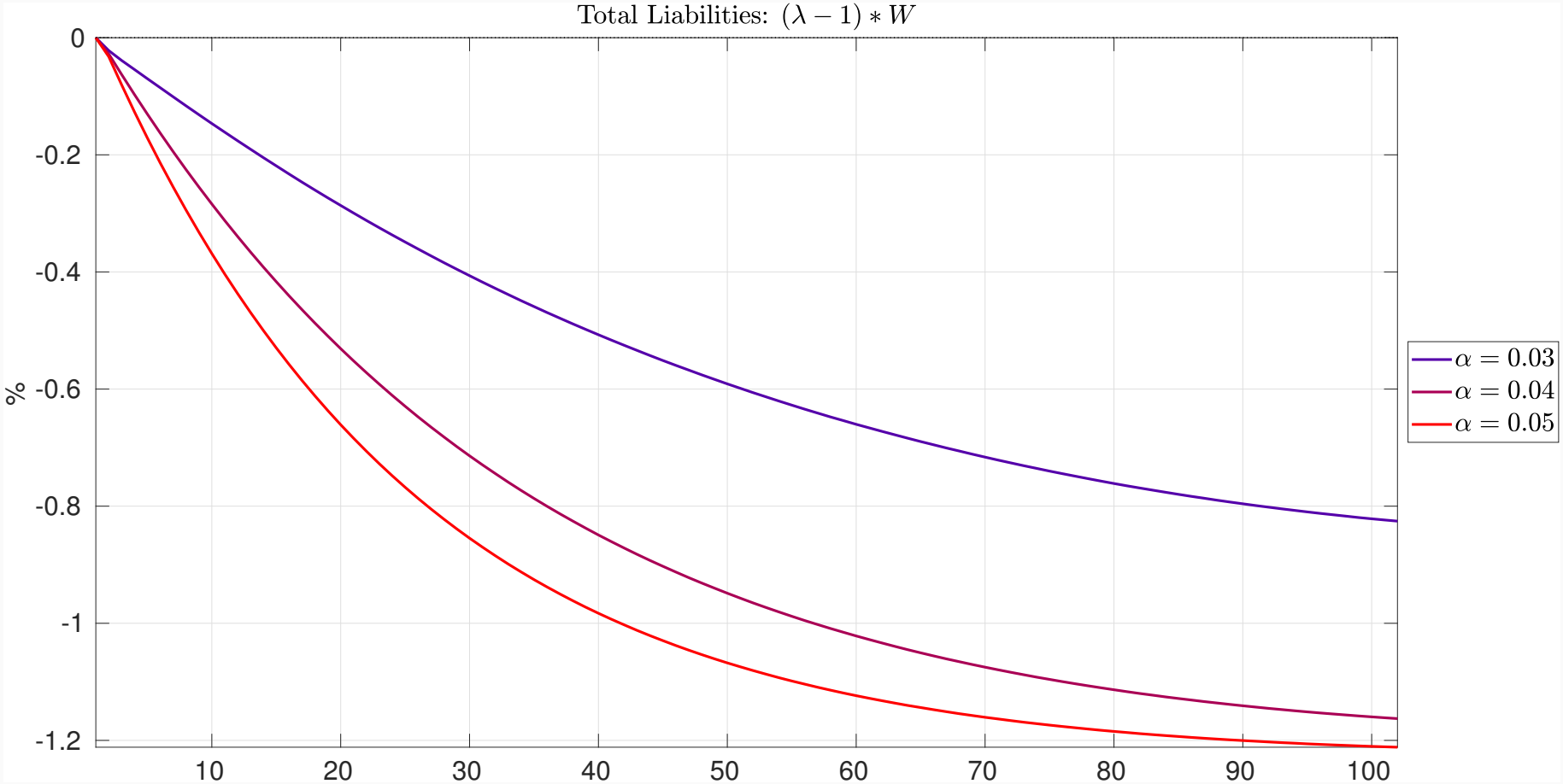
  - All steady states are observationally equivalent: **same** book leverage.

Trade-off for delayed recognition

Higher leverage $\rightarrow$ higher loan/equity growth & higher default rates.



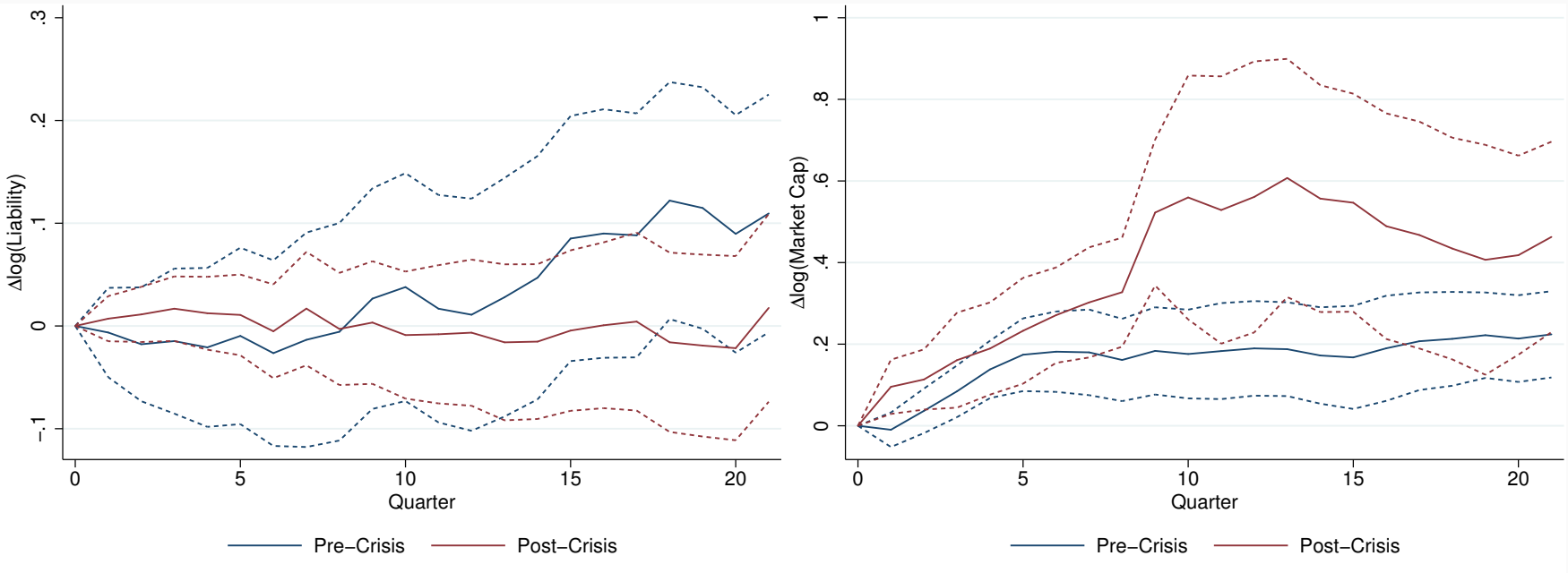
Delayed recognition $\rightarrow$ slower adjustment to default shock



Conclusion

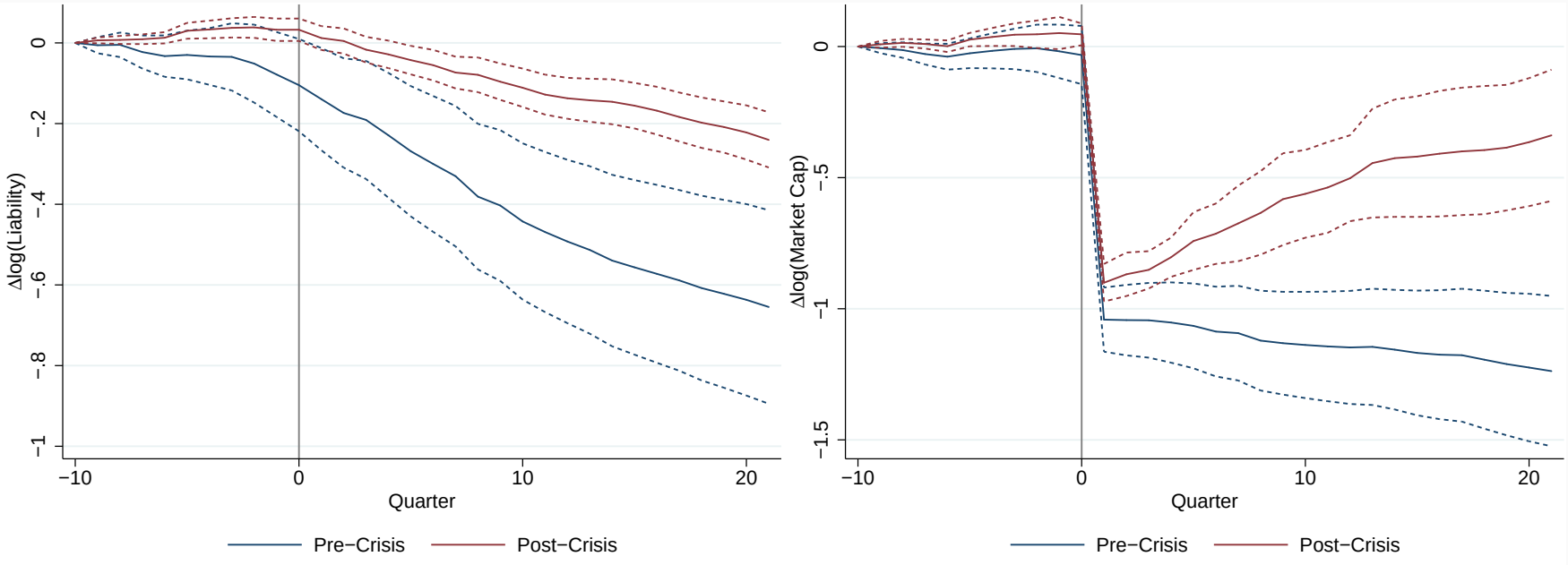
- Use five stylized facts to inform bank optimization model.
- Model w/ book vs. market distinction, equity financing frictions, adjustment costs, occasionally binding constraints.
- Match bank leverage dynamics quantitatively.
- Implication for policy:
  - Balance sheet frictions key to determine leverage dynamics.
  - Accounting rules matter:
    - for how accurate books reflect fundamental values
    - effective risk-taking by banks
    - for how close to the constraints banks effectively are.
  - Elements are key to think about effects of accounting changes and regulatory forbearance during crises.

Asymmetry



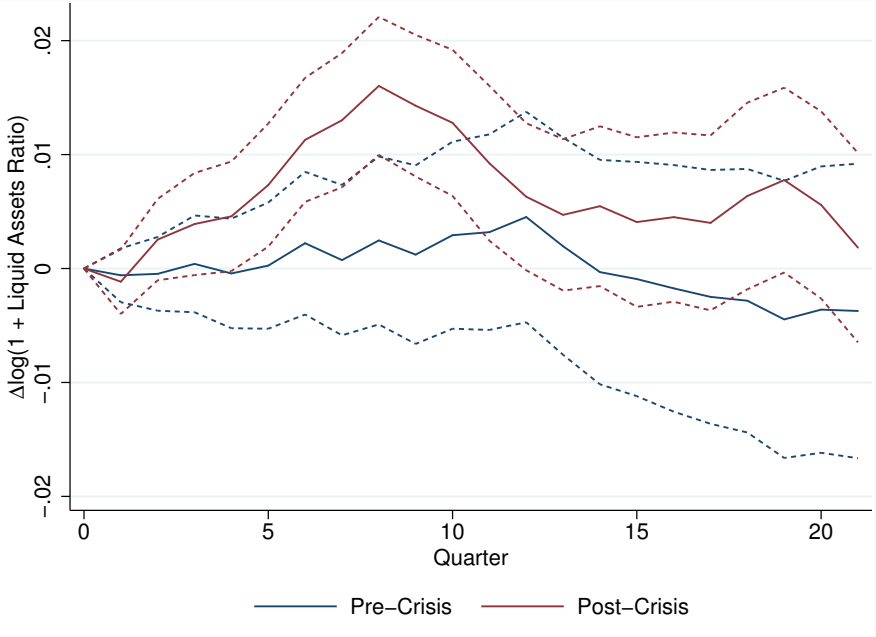
- IRF for positive and negative shock
  - negative shock minus the negative of positive shock
- There is evidence of some asymmetry, but not well-powered to detect nonlinearities

Placebo Tests



No evidence of a trend before the shock hits

No "Flight to Quality" After Shocks



Liquid Assets Ratio:= (Cash + T-Bills) / Total Assets

Average = 0.05

Size and Stress Tests

- Run regressions dropping banks subject to stress testing
- no difference