Bank Regulation: Capital and Liquidity Requirements

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[1]Views and opinions expressed reflect those of the author and do not necessarily reflect those of the KC Fed or Federal Reserve System.

Introduction

- Dodd-Frank Act (DFA) reformed U.S. bank regulations
  (1) Capital requirements
    - Hold sufficient equity to fund assets
    - Intent: limit **insolvency default** risk

  (2) Liquidity requirements
    - Hold sufficient liquid assets relative to runnable debt
    - Intent: limit **liquidity default** risk and asset firesales

Introduction

- Pre-DFA
  - Capital requirements at **4%** (**leverage** and **risk-weighted**)
  - No liquidity requirements
- Post-DFA
  - Capital requirements raised to **6%**
  - New liquidity requirement:

$$\frac{\text{Liquid Assets}}{\text{Runnable Debt}} \geq \mathbf{100\%}$$

- Ongoing debate over policy efficacy
  - Too stringent, too lax?

Research Question

- **Question**: What was the impact of DFA bank regulation?
  - How do the requirements **interact**?
- Approach
  (1) Model: dynamic GE with heterogeneous banks
    - Policy role: addresses moral hazard and firesale risk
  (2) Baseline economy, calibrated to pre-DFA
    - U.S. Call Reports
  (3) Evaluate DFA
    - Decompose effects of capital and liquidity requirements
  (4) Other: optimal policy and aggregate shocks

Related Literature

Bank Capital Requirements

- Van den Heuvel [2008], Corbae and D'Erasmo [2010], Nguyen [2015], Davydiuk [2018], Begenau and Landvoigt [2018], Begenau [2019], Pancost and Robatto [2019]

Bank Capital + Liquidity Requirements

- Covas and Driscoll [2014], De Nicolo et al. [2014], **Corbae and D'Erasmo** [2021], Van den Heuvel [2019]

Firesale and Liquidity Risk

- Schleifer and Vishny [1992], Lorenzoni [2008], **Bianchi and Bigio** [2018]

Contribution: more comprehensive treatment of

(1) regulatory framework
(2) bank portfolio problem
(3) default risk (insolvency + liquidity)
(4) cross-sectional moments (capital, liquidity ratios)

Summary of Main Results

Dodd-Frank Act

- Threefold reduction in banking sector default risk
- Welfare **improving**
  - Mostly attributed to capital requirements
- Liquidity requirements alone **increase** total default risk

Policy Interactions

- Capital requirement: **complementary** effect on bank liquidity
- Liquidity requirement: **adverse** effect on bank equity

Optimal Policy

- Joint optimal policy
  - Capital requirement: **6.75%**
  - Liquidity requirement: **95%**

Model

Model Agents

1. Banks
   - intermediate between HH and loan projects
   - hold portfolio of assets + liabilities
   - subject to liquidity + insolvency default
2. Money market lenders
   - provide wholesale funding to banks
   - wholesale funds subject to early withdrawal shocks
3. Outside investors
   - buy firesold assets on secondary, spot market
4. Government
   - provides deposit insurance
5. Households
   - pay lump sum tax
   - equity owners of bank, money market sectors

Illustration

Key Friction

- Banks can default
  1. (1) insolvency default
  2. (2) liquidity default
- Banks don't internalize the **costs of default**
  - Due to deposit insurance, limited liability
- Implication: unregulated banks are **excessively risky**
- Capital and Liquidity requirements reduce default risk

Banks

What is a Bank?

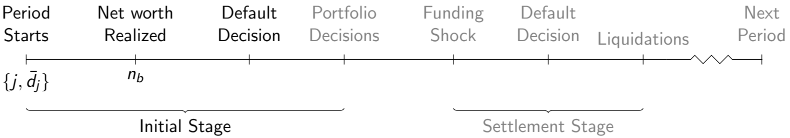
- A bank is a chartered firm with intermediation technology
- Bank charter includes
  - deposit insurance
  - regulatory requirements
- Intermediation technology affects cost of
  - lending
  - debt funding

Decisions: Two Stages

(1) Initial stage
  - insolvency default decision
  - portfolio decisions

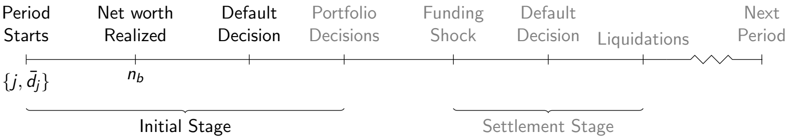
(2) Settlement stage: given funding shock,
  - liquidity default decision
  - asset liquidations

Initial Stage



- j: fixed type $j = 1, 2, ..., J$
  - affects cost of lending, deposit-taking
  - probability mass p_j
- $\bar{d}_j$: deposit borrowing constraint
  - fixed and stochastic component
- n_b: initial net worth

Initial Stage



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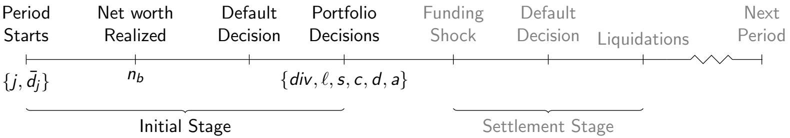
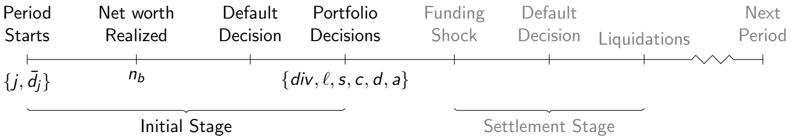
limited availability of deposit funding

Initial Stage



Assets	Liabilities
loans ℓ	deposits d
gov't sec. s	wholesale a
cash c	equity

Initial Stage



origination cost $g(\ell_j; \theta_j)$;
idiosyncratic risk

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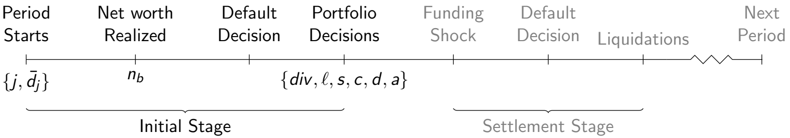
Initial Stage



risk-free gov.'t bond

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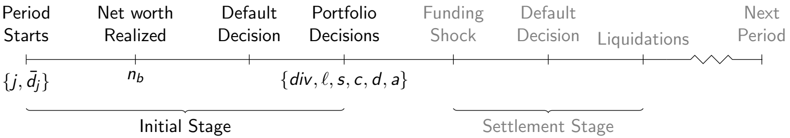
Initial Stage



Assets	Liabilities
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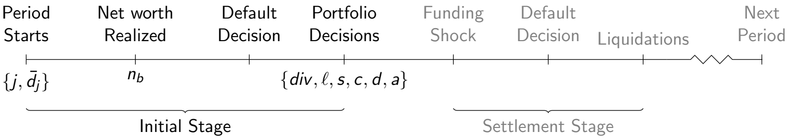
no interest revenue;
settlement properties

Initial Stage



Assets	Liabilities
loans ℓ	deposits d
gov't sec. s	wholesale a
cash c	equity

insured, stable

uninsured, runnable

Initial Stage Dynamic Program

- Define choice set as $\mathbf{y} = \big(div, \ell, s, c, d, a\big)$
- Given no default, the bank solves

$$V^b(n_b; j, \bar{d}_j) = \max_{\mathbf{y}} \quad div + E_{\delta'}\Bigg[\underbrace{max\Big\{0, \overbrace{\tilde{V}^b(\mathbf{y}; j, \bar{d}_j, \delta')}^{\text{Value if operate}}\Big\}}_{\text{liquidity default}}\Bigg]$$

$s.t.$ market constraints

regulatory constraints

non-negativity constraints

Market Constraints

- budget constraint

$$div + \underbrace{s + c + \ell}_{\text{Assets}} + g(\ell; \boldsymbol{\theta_j}) = n_b + \underbrace{a + d}_{\text{Debt}}$$

- collateral constraint

$$(1 + h)s \geq a$$

given haircut h

- deposit constraint

$$d \leq \bar{d}_j$$

- financial friction

$$div \geq 0$$

Regulatory Constraints

- <u>leverage requirement $\left(\frac{\text{Equity}}{\text{Assets}}\right)$</u>

$$\frac{\ell + s + c - [a + d]}{\ell + s + c} \geq \phi^{lev}$$

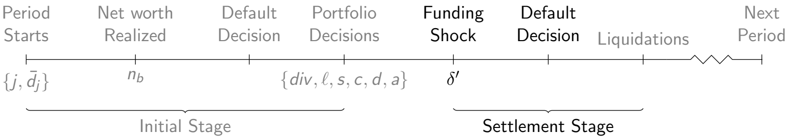
- <u>risk-weighted capital requirement $\left(\frac{\text{Equity}}{\text{Loans}}\right)$</u>

$$\frac{\ell + s + c - [a + d]}{\ell} \geq \phi^{cr}$$

- <u>liquidity requirement $\left(\frac{\text{Liquid Assets}}{\text{Runnable Debt}}\right)$</u>

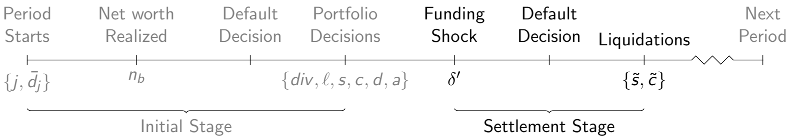
$$\frac{c + (1 - h^s)s}{a} \geq \phi^{lr}$$

Settlement Stage



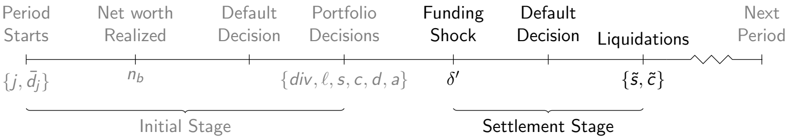
- δ': wholesale funding shock
  - fraction $\delta' \in [0, 1]$ of funds withdrawn
  - idiosyncratic risk

Settlement Stage



- $\tilde{s}$: securities liquidation
  - liquidation price p^*
- $\tilde{c}$: cash settlement

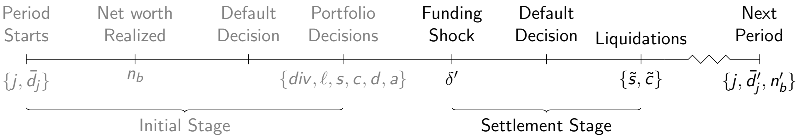
Settlement Stage



- $\tilde{s}$: securities liquidation
  - liquidation price p^*
- $\tilde{c}$: cash settlement

sold on spot market
to outside investors

Settlement Stage



- n'_b : after-tax net worth

$$n'_b = \tau \max\left\{0, \underbrace{i'_\ell \ell + i_s(s - \tilde{s}) - r^d d - r^a(1-\delta')a}_{\text{earnings before taxes}}\right\} + \\ + \ell + s - \tilde{s} + c - \tilde{c} - d - (1-\delta')a$$

Settlement Stage Dynamic Program

$$\tilde{V}^b(\mathbf{y}; j, \bar{d}_j, \delta') = \max_{\tilde{s},\tilde{c}} \quad \gamma\beta E_{i'_\ell,\bar{d}'}\left[\underbrace{max\{0, \overbrace{V^b(n'_b; j, \bar{d}'_j)}^{\text{Value if operate}}\}}_{\text{insolvency default}}\right]$$

$$s.t. \quad \delta' a = p^* \tilde{s} + \tilde{c}$$

$$s.t. \quad \tilde{c} \in [0, c] \quad \text{and} \quad \tilde{s} \in [0, s]$$

$$s.t. \quad n'_b \text{ law of motion}$$

where $\boldsymbol{\gamma}\beta \leq \beta$ (i.e. banks less patient than households)

Settlement Stage Dynamic Program

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settlement decisions constrained by
Initial Stage portfolio decisions

Settlement Stage Dynamic Program

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lower γ banks discount the *cost* of default
(i.e. foregone dividends)

Other Financial Intermediaries

1. Money market lenders
2. Securities spot market

Money Market and Securities Spot Market

Money Market Lenders

- Provide wholesale funding a_m and issue dividends div_m
- Not covered by deposit insurance
- Equity shares held by households

Securities Spot Market

- Downward-sloping demand for liquidated bank securities
- External investors with limited demand
  - e.g. segmented markets

Money Market Lender Problem | Outside Investor Problem

Residual Claimants

1. Government
2. Households

Government and Households

Government

- Sets lump sum tax to balance budget
- Deposit insurance: fraction ξ of bank assets lost in default

Households

- CRRA utility and discount with β
- Choices over consumption, deposit savings and equity shares
  - Equity in money market and banking sectors

Deposit Insurance Formula Household Problem

Equilibrium

1. Concept
2. Characterization

Equilibrium Concept

- Stationary recursive competitive equilibrium
- Invariant bank distribution $\lambda^j(n_b, \bar{d}_j)$
- Market clearing
  1. equity markets (banking, money market) at price (p_b, p_m)
  2. deposits at rate R^d
  3. wholesale funding at rate R^a
  4. liquidated securities at price p^*

Equilibrium Definition

Bank Portfolio Decisions

- Debt funding pecking order
  - Deposits preferred to wholesale funds ($d \succ a$)
- Interior asset portfolio
  - Risk-return tradeoff for securities & loans
  - Cash as precautionary buffer

Cost of Funds

Proposition

In the Settlement Stage, banks always settle with available cash before liquidating securities.

Wholesale Size Correlations

The Impact of Bank Regulations

- Capital requirements target equity ratios — Illustration
  - Reduce insolvency default risk
- Liquidity requirements target liquidity ratios — Illustration
  - Reduce liquidity default risk
- Policy Interactions
  (i) Capital requirements **improve** bank liquidity — Mechanism
  - higher cap req $\rightarrow$ lower liquidity default

  (ii) Liquidity requirements **deteriorate** bank equity — Mechanism
  - higher liq req $\rightarrow$ higher insolvency default

The Impact of Bank Regulations

- Capital requirements target equity ratios (Illustration)
  - Reduce insolvency default risk
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Main Idea: capital requirements reduce both types of default

Quantitative Results

1. Calibration
2. DFA Analysis
3. Aggregate Shocks
4. Optimal Policy

External Calibration

- Use Call Reports to externally calibrate bank j technology
  (1) loan origination $\boldsymbol{\theta_j} \frac{\ell^2}{2}$

  (2) deposit borrowing constraint process

$$\bar{d}_j' = \boldsymbol{\bar{\mu}_{d,j}} + \boldsymbol{\rho_j} \bar{d}_j + \epsilon'$$

  where $\epsilon' \sim N(0, \boldsymbol{\sigma_j^\epsilon})$

- Choose $J = 3$ bank types
  - Partition panel data by size (total assets)
    - j=1: \$1-\$10 billion
    - j=2: \$10-\$50 billion
    - j=3: >\$50 billion

Call Report Data | Cost Function Estimation | Deposit Process $\bar{d}$

Key Externally Calibrated Parameters

Parameter	Label	Value	Source/Target
β	HH Discount Factor	0.99	$R^d = 1.01$
ξ	Default Recovery	0.65	FDIC
ϕ^{lev}	Leverage Requirement	0.04	Pre-DFA
ϕ^{cr}	Capital Requirement	0.04	Pre-DFA
ϕ^{lr}	Liquidity Requirement	0	Pre-DFA
μ	Mean Loan Return	1.04	Call Reports
τ	Corporate Tax Rate	0.32	Call Reports

Funding Shock δ'

Internally Calibrated Parameters

Parameter	Value	Label	Target	Model (%)	Data (%)
γ	0.961	Bank Discount	Default Rate	0.79	1.04
$i_s - r^d$	0.56	Risk-free Spread	Loan-Security ratio	3.7	3.4
$\tilde{\alpha}$	-0.02	Firesale Elasticity	Deposit-Wholesale Ratio	3.4	3.2
σ	0.04	Volatility Loan Return	Risk-weighted Eq Ratio	5.2	9.6
$\bar{\mu}_{d,1}$	0.012	Capacity Constraint	Deposit Share	71.7	73.3
$\bar{\mu}_{d,2}$	0.034	Capacity Constraint	Deposit Share	84.3	58.2
$\bar{\mu}_{d,3}$	0.011	Capacity Constraint	Deposit Share	44.8	45.3

Cross-Section Correlations

Non-Targeted Moments

- Model captures cross-sectional size correlations with equity and liquidity ratios

Label	Model (%)	Data (%)
$Corr$(Size,RWE)	-0.29	-0.22
$Corr$(Size,Liq)	0.21	0.21
Liquidity Ratio	73.3	53.1
Return on Equity	7.2	11.0
Leverage Ratio	5.2	7.3

Dodd-Frank Analysis (Levels)

Label	**Pre-Reform**	**Reform**	**Partial I** (6% CR,0% LR)	**Partial II** (4% CR,100% LR)
RW Equity Ratio	5.2	6.4	6.3	5.2
Leverage Ratio	4.1	6.0	6.0	4.0
Liquidity Ratio	73.3	100.1	72.4	102.7
Insolvency Default	0.79	0.23	0.22	0.96
Liquidity Default	0.14	0	0.09	0
Total Default	0.93	0.23	0.31	0.96

Wholesale Funding Use

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DFA significantly reduced default risk: 0.93% to 0.23% (annualized)

Wholesale Funding Use

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capital requirements alone reduce liquidity default risk

Wholesale Funding Use

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liquidity requirements increase insolvency default risk

Wholesale Funding Use

Dodd-Frank Analysis (% Change)

Label	Pre-Reform	Reform	Partial I (6% CR,0% LR)	Partial II (4% CR,100% LR)
Aggregate Lending	–	-2.0	-1.8	-10.0
Aggregate Balance Sheet	–	-15.7	-18.9	-9.2
Aggregate Wholesale Funding	–	-86.0	-88.6	-32.7
Household Consumption	–	0.74	0.70	-1.97

Bank Growth/Level Data

Dodd-Frank Analysis (% Change)

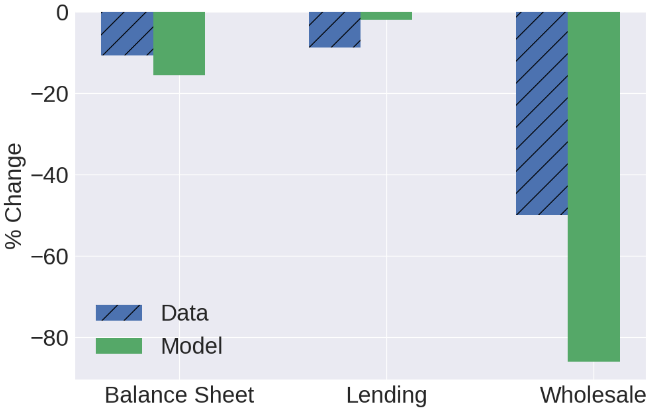
Label	Pre-DFA	DFA	Partial DFA I (6% CR,0% LR)	Partial DFA II (4% CR,100% LR)
Aggregate Lending	–	-2.0	-1.8	-10.0
Aggregate Balance Sheet	–	-15.7	-18.9	-9.2
Aggregate Wholesale Funding	–	-86.0	-88.6	-32.7
Household Consumption	–	**0.74**	**0.70**	-1.97

welfare gains driven almost entirely
by capital regulation

Bank Growth/Level Data

Impact of Dodd-Frank Act

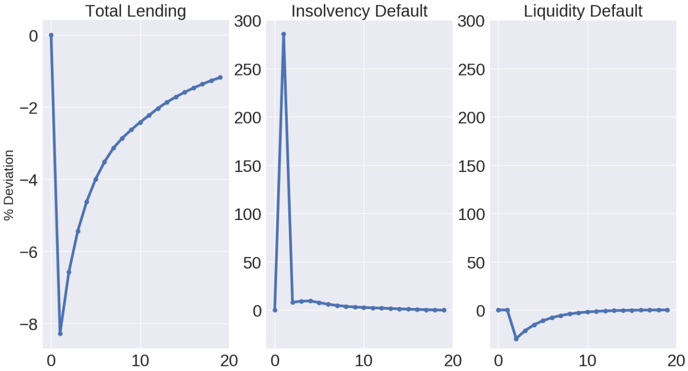
- Look at post-DFA aggregate data, relative to trend



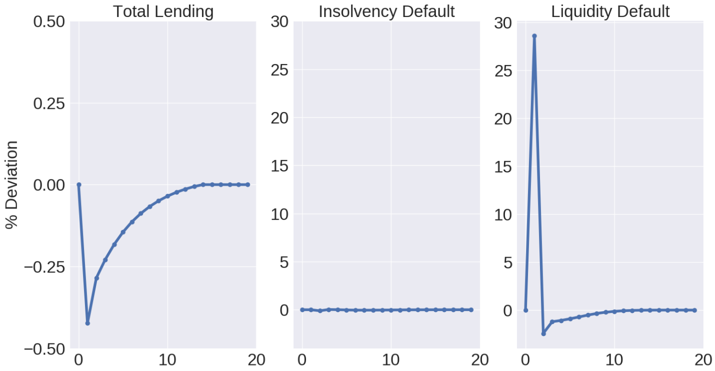
Aggregate Shocks

- Consider two types of unanticipated aggregate shocks
  1. Loan returns
  2. Wholesale funding withdrawal
- Objects of interest:
  - Total lending
  - Insolvency default
  - Liquidity default
- Today: pre-DFA economy
  - Future: compare pre- and post-DFA economies

-1% Shock to Loan Returns



-10% Wholesale Funding Withdrawal

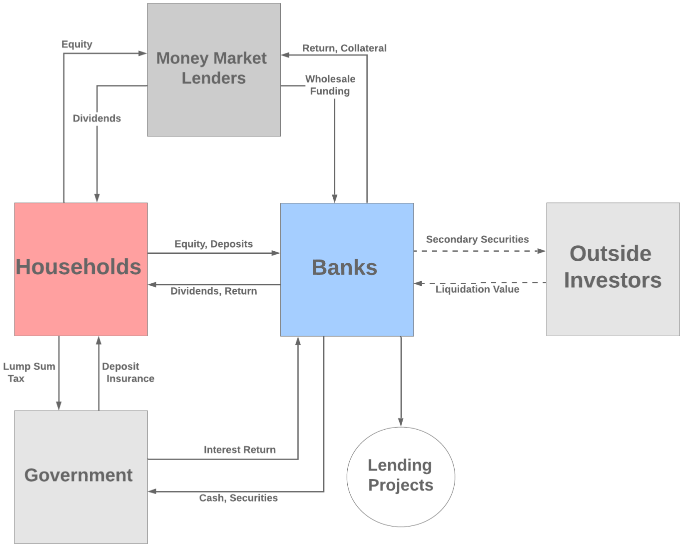


Optimal Policy

- Welfare criterion: HH lifetime consumption
- Joint optimal policy
  - Capital requirement: **6.75%**
  - Liquidity requirement: **95%**
- Higher CRs reduce wholesale funding usage
  - Socially *easier* to require banks to hold more liquid assets
- Other aggregate changes
  - Lending: **-3.4%**
  - Total balance sheet: **-20.5%**

Thank You!

Economy Illustration



Return

Money Market Lenders Problem

- For each unit of lending a_m, lender receives fractions
  1. α^c : payoffs from collateral seizures
  2. α^w : payoffs from early withdrawals
  3. $1 - \alpha^c - \alpha^w$: payoffs from repayment at maturity
- (α^c, α^w) are equilibrium objects
- Money market lenders solve

$$V^m(n_m) = \max_{a_m, div_m} \quad div_m + \beta V^m(n_m')$$

$$s.t. \quad div_m + a_m = n_m$$

$$s.t. \quad n_m' = a_m \left[\alpha^c(1+h) + \alpha^w + (1 - \alpha^c - \alpha^w) R^a \right]$$

Return

Outside Securities Investor Problem

- Investors purchase securities in the Settlement Stage on a spot market
- Investors solve the static problem

$$\max_{s_o} \quad (s_o)^{\alpha} - p^* s_o$$

Return

Deposit Insurance

- In default, fraction ξ of assets are lost
- For a bank in liquidity default, deposit insurance covers

$$R^d d - \xi\left[(1+i'_\ell)\ell + (1+i_s)s + c - (1+h)a\right]$$

- For a bank in insolvency default, deposit insurance covers

$$R^d d - \xi\left[(1+i'_\ell)\ell + (1+i_s)(s-\tilde{s}) + (c-\tilde{c}) + \delta' a - (1-\delta')(1+h)a\right]$$

- In each case, wholesale funding lenders seize collateral first
- Aggregate deposit insurance is summed using the invariant bank distribution $\lambda(n_b, j, \bar{d})$

Return

Households

Each period, given networth n_h, solve

$$
\begin{aligned}
V^h(n_h) = \max_{c_h, d_h, \{e_i\}} \quad & u(c_h) + \beta V^h(n_h') \\
s.t. \quad & c_h + d_h + \sum_{i \in \{b,m\}} e_i p_i = n_h \\
s.t. \quad & n_h' = (1 + r^d) d_h + \sum_{i \in \{b,m\}} e_i (p_i + Div_i) + T + \omega
\end{aligned}
$$

where p_i is share price and Div_i is dividend for share $i \in \{b, m\}$

Return

Equilibrium

Given the idiosyncratic exogenous processes $\left\{i_l, \delta, \{\bar{d}_j\}_{j=1}^J\right\}$, a stationary recursive competitive equilibrium is defined as a set of prices $\{R^d, R^a, p_b, p_m, p^*\}$, initial stage bank policy functions
$\mathbf{g_b}(n_b, j, \bar{d}_j) = \{\ell(n_b, j, \bar{d}_j), s(n_b, j, \bar{d}_j), c(n_b, j, \bar{d}_j), d(n_b, j, \bar{d}_j), a(n_b, j, \bar{d}_j), div(n_b, j, \bar{d}_j)\}$, settlement stage bank policy functions $\tilde{\mathbf{g_b}}(\mathbf{y}, \delta', j, \bar{d}_j) = \left\{\tilde{c}(\mathbf{y}, \delta', j, \bar{d}_j), \tilde{s}(\mathbf{y}, \delta', j, \bar{d}_j)\right\}$, household policy functions $\mathbf{g_h}(n_h) = \left\{c_h(n_h), d_h(n_h), s_b(n_h), s_m(n_h)\right\}$, aggregate wholesale lending a_m, aggregate security liquidations s_o and marginal bank distributions $\{\lambda^j(n_b, \bar{d}_j)\}_{j=1}^J$ such that

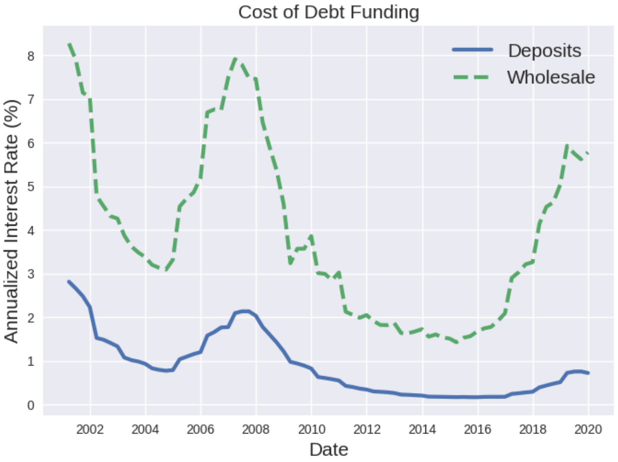
1. $V^h(n_h)$ and $\mathbf{g_h}(n_h)$ solve the household problem,
2. $V^b(n_b, j, \bar{d}_j)$, $\tilde{V}^b(\mathbf{y}, \delta', j, \bar{d}_j)$, $\mathbf{g_b}(n_b, j, \bar{d}_j)$ and $\tilde{\mathbf{g_b}}(\mathbf{y}, \delta', j, \bar{d}_j)$ solve the bank problem,
3. Money market lenders solve their problem
4. Outside securities investors solve their problem
5. The marginal distribution of banks follows law of motion

$$\lambda^j = \Gamma^j(\lambda^j) \qquad \forall j = 1, 2, ..., J$$

   for transition function Γ^j and is consistent with firm/household maximization
6. Market clearing
   - 6.1 $e_b = e_m = 1$ (Equity Shares)
   - 6.2 $\int_{N_b} \sum_j \sum_{\bar{d}_j} d(n_b, j, \bar{d}_j) d\lambda^j(n_b, j, \bar{d}_j) = d_h(n_h)$ (Deposits)
   - 6.3 $\int_{N_b} \sum_j \sum_{\bar{d}_j} a(n_b, j, \bar{d}_j) d\lambda^j(n_b, j, \bar{d}_j) = a_m$ (Wholesale Funds)
   - 6.4 $\int_{N_b} \sum_j \sum_{\bar{d}_j} \left[\sum_{\delta'} \pi_{\delta'} \tilde{s}(\mathbf{y}, \delta', j, \bar{d}_j)\right] d\lambda^j(n_b, j, \bar{d}_j) = s_o$ (Secondary Securities)

Return

Bank Debt Funding Costs



Wholesale Funding Size Correlations

Empirical method:

(1) Regress wholesale funding shares on bank size

(2) Control for fixed effects and other lines of business
  - use ratio of non-interest to interest income

(3) Look at full sample and sub-samples
  - Pre-DFA: 2001 Q1 - 2010 Q1
  - Post-DFA: 2010 Q2 - Present

Wholesale Funding Size Correlations

Wholesale Funding Shares Regression

	(Pre-DFA) wholesale share	(Post-DFA) wholesale share	(Full Sample) wholesale share
Intercept	1,670***	675***	1,071***
	(11.4)	(4.37)	(5.07)
Size	**19.1*****	**-0.23**	**3.51*****
	(1.37)	(0.34)	(0.44)
Income Ratio	-26.5***	-1.25***	-2.02***
	(3.29)	(0.30)	(0.43)
Time FE	✓	✓	✓
Time Periods	37	39	76
Entities	842	1061	1407
R^2	0.017	0.001	0.002

$^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$

Return

Interaction: Capital Requirements Improve Liquidity

(I) Higher liquidity requirements reduce bank balance sheets
- Response to less profitability

(II) Liability side: substitution from wholesale to deposits ($\downarrow \boldsymbol{a}$)
- debt funding preference for deposits

(III) Asset side: stable liquid asset share ($\leftrightarrow \boldsymbol{c} + \boldsymbol{s}$)

(IV) Net effect:
- increase in bank liquidity ($\uparrow \frac{\boldsymbol{c}+\boldsymbol{s}}{\boldsymbol{a}}$)
- reduction in liquidity default

Return

Interaction: Liquidity Requirements Deteriorate Equity

(I) Higher capital requirements reduce bank balance sheets

(II) Asset side: large substitution into loans ($\uparrow \ell$)

- higher marginal benefit from DRS + balance sheet shrink

(III) Liability side: stable equity share ($\leftrightarrow$ ***equity***)

(IV) Net effect:

- decrease in risk-weighted equity ratios ($\downarrow \frac{\textbf{\textit{equity}}}{\ell}$)
- increase in insolvency default

Return

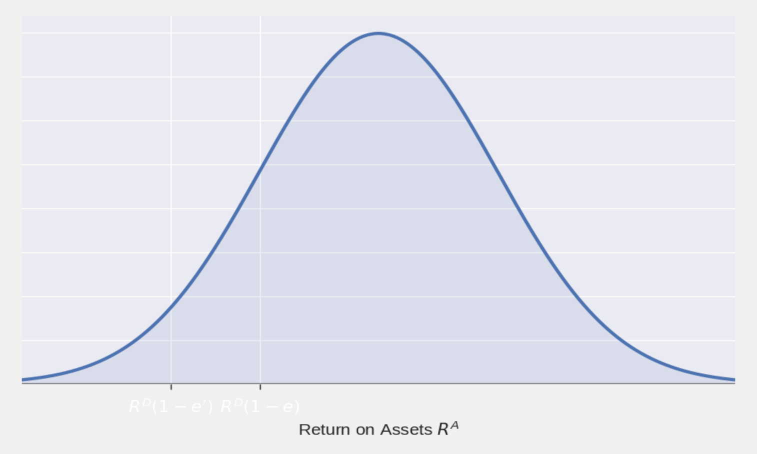
Call Report Data

- Source: U.S. Reports of Condition and Income (Call reports)
  - panel data
  - bank (charter)- level balance sheet data
- Frequency: quarterly
- Range: 2000-2018
- Restrictions: Nominal assets >$1 billion

Return

Capital Requirements Reduce Insolvency Default

$$Prob(\text{Insolvency Default}) = Prob(n_b \leq 0)$$

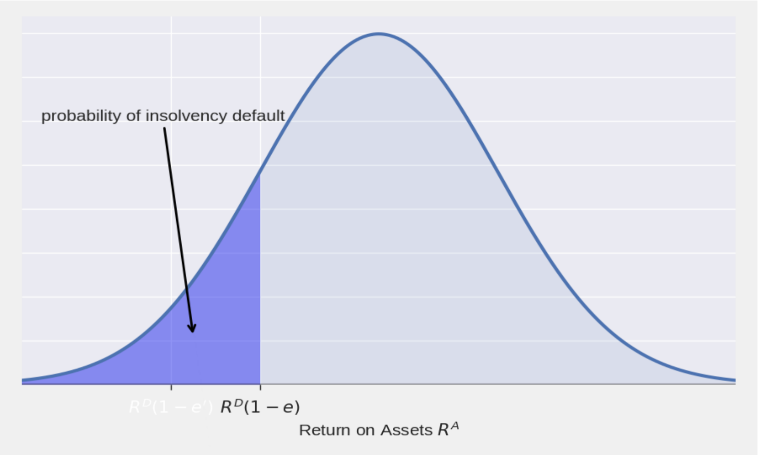


Capital Requirements Reduce Insolvency Default

$$Prob(\text{Insolvency Default}) = Prob(R^A \times Assets \leq R^D \times Debt)$$

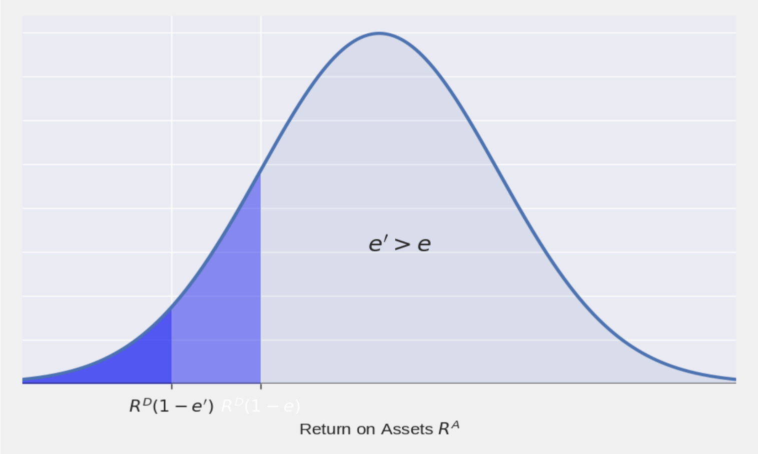
Capital Requirements Reduce Insolvency Default

$$Prob(\text{Insolvency Default}) = Prob(R^A \leq R^D(1-e))$$



Capital Requirements Reduce Insolvency Default

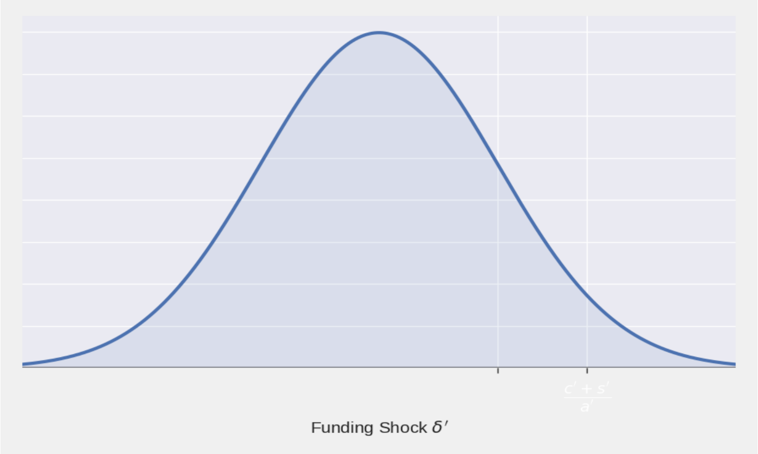
$$Prob(\text{Insolvency Default}) = Prob(R^A \leq R^D(1-e'))$$



Return

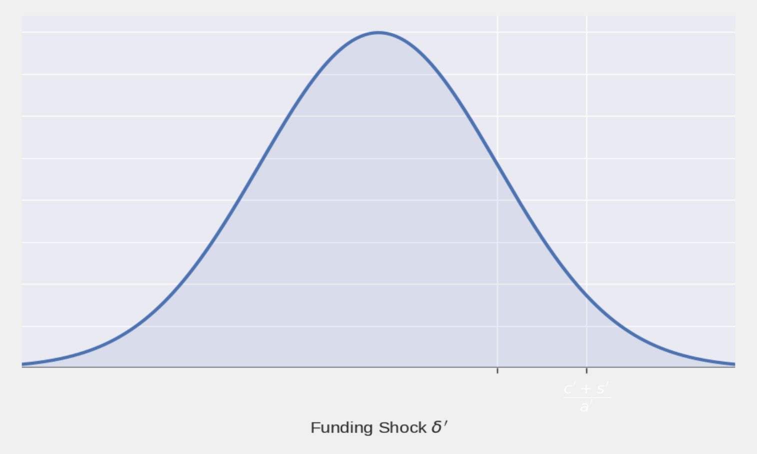
Liquidity Requirements Reduce Liquidity Default

$$Prob(\text{Liquidity Default}) = Prob(\text{liq assets} < \text{funding withdrawal})$$



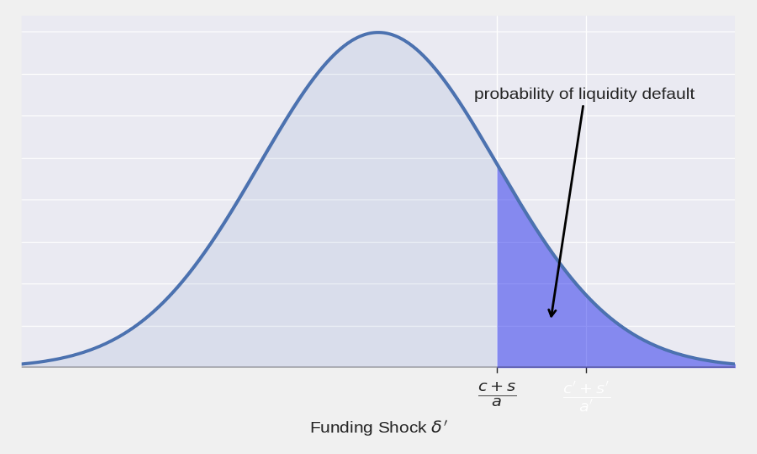
Liquidity Requirements Reduce Liquidity Default

$$Prob(\text{Liquidity Default}) = Prob(c + s < \delta' a)$$



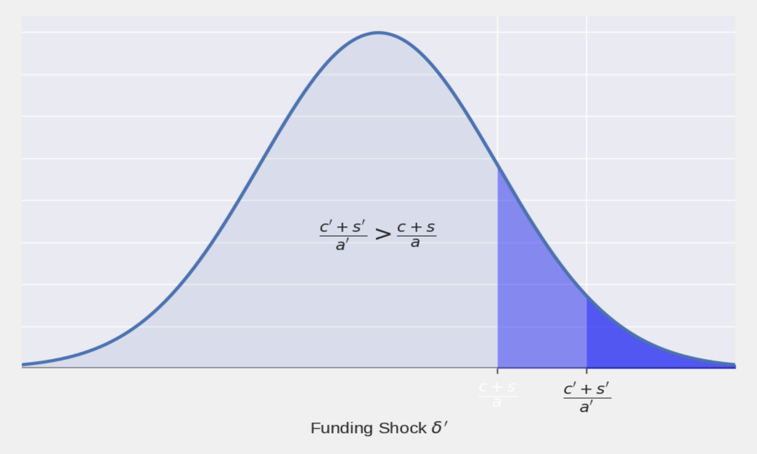
Liquidity Requirements Reduce Liquidity Default

$$Prob(\text{Liquidity Default}) = Prob(\delta' > \frac{c+s}{a})$$



Liquidity Requirements Reduce Liquidity Default

$$Prob(\text{Liquidity Default}) = Prob(\delta' > \frac{c' + s'}{a'})$$



Return

Cost Function Estimation

- Use Call Report panel data (FFIEC Form 041, 051) to infer bank θ's with empirical cost functions
- Construct data analogue to $\theta\frac{\ell^2}{2}$:
  - net non-interest expenditures
- Steps
  1. Filter data
  2. Create bank quantile groups (by size)
  3. Estimate quantile bank cost function
  4. Recover $\hat{\theta}$s by equating model/empirical marginal costs

Cost Function Estimation

1. Filter data
   - Drop banks with assets $< \$1B$
   - Drop observations with negative (i) lending, (ii) labor expense, (iii) fixed input and (iv) borrowings
2. Create quantile groups
   - Quantile thresholds: $\{0.8, 0.95\}$
   - Corresponds to \$10 billion, \$50 billion
3. Estimate quantile bank cost function:

$$Cost_{it}^{q} = \beta_0^q + \alpha_t^q + \beta_1^q \ell_{it}^q + \beta_2^q \ell_{it}^{q\,2} + \underbrace{\sum_k \beta_k^q \ell_{it}^q x_{k,(i,t)}^q}_{\text{interactions}} + \sum_j \beta_j^q x_{j,(i,t)}^q$$

for each quantile group q

Cost Function Estimation

4. Recover $\hat{\theta}$s
   - Model marginal cost: $\theta_j \ell$
   - Empirical marginal cost:

$$MC^j(\ell, \mathbf{x}) = \hat{\beta}_1^j + \left[2\hat{\beta}_2^j + \sum_k \hat{\beta}_k x_k\right]\ell$$

LOAN COST FUNCTION ESTIMATES

Bank Group	**1**	**2**	**3**
Probability Mass	0.85	0.1	0.05
$\hat{\boldsymbol{\theta}}_j$	0.033	0.024	0.021

Return

Funding Shock Process δ'

- Model: Intra-period, fraction δ' of wholesale funds withdrawn
  - δ' is a discrete, iid process: $\left\{ \left(\delta_1, \delta_2, ..., \delta_J\right), \left(p_1^\delta, p_2^\delta, ..., p_J^\delta\right) \right\}$
- Empirical Method:
  (i) create wholesale funds data analogue a_{it}
  - repo + fed funds + large time deposits (<1yr maturity) + trading liabilities + other borrowed money (<1yr maturity)

  (ii) Compute wholesale *run-off* rates $r_{it} = \frac{a_{i,t-1} - a_{i,t}}{a_{i,t-1}}$

  (iii) For specific t, generate cross-section distribution

  (iv) Pick percentiles $\{\bar{p}_1, \bar{p}_2, ..., \bar{p}_{J-1}\} \rightarrow \{\bar{r}_1, \bar{r}_2, ..., \bar{r}_{J-1}\}$

Funding Shock Process δ'

(v) for each $j = 1, 2, ..., J$

- if $j = 1$, then $\begin{cases} \delta_1 = \frac{\bar{r}_{min} + \bar{r}_1}{2} \\ p_1^{\delta} = \bar{p}_1 \end{cases}$
- if $j = 2, ..., J-1$, then $\begin{cases} \delta_j = \frac{\bar{r}_{j-1} + \bar{r}_j}{2} \\ p_j^{\delta} = \bar{p}_j - \bar{p}_{j-1} \end{cases}$
- if $j = J$, then $\begin{cases} \delta_J = \frac{\bar{r}_J + \bar{r}_{max}}{2} \\ p_J^{\delta} = 1 - \bar{p}_J \end{cases}$

Return

Deposit Capacity Constraint Process $\bar{d}$

- Model: banks choose deposits d
  - Choice bounded above by $\bar{d}$ (i.e. $d \leq \bar{d}$)
  - $\bar{d}$ is individual, exogenous first-order process $(\bar{D}, P_d)$
- Intuition: banks prefer deposits to wholesale funds (it's cheaper) but...
  - face uninsurable deposit inflow/outflow
  - rely on wholesale funding to optimally finance assets.
  - i.e. $a > 0 \Rightarrow d = \bar{d}$
- Empirical Method: estimate AR(1) process at the bank-level for deposits
  - Discretize with Tauchen method

Deposit Capacity Constraint Process $\bar{d}$

(1) Create bank groups 1,2 and 3 (as in loan cost estimation)

(2) Deflate series

(3) For each bank
   (a) normalize deposits with average
   (b) de-trend with hp filter
   (c) estimate AR(1) process

(4) For each bank group
   (i) Take average of estimates $\left(\hat{\rho}, \hat{\sigma}_\epsilon\right)$
   (ii) Discretize with Tauchen

Deposit Capacity Constraint Process $\bar{d}$

Bank Group	**Bank Size (\$ Billion)**	$\hat{\rho}$	$\hat{\sigma}_\epsilon$	$\hat{\sigma}_d$
		persistence	error vol	deposit vol
1	≤ 10	0.62	0.18	0.23
2	$(10, 50)$	0.67	0.15	0.21
3	≥ 50	0.60	0.09	0.11

Table: Deposit Process Estimation

Return

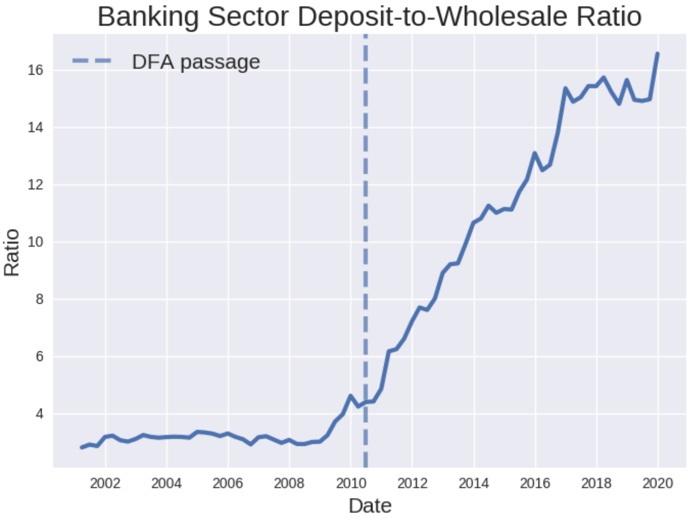
Cross-Section Correlations

TABLE 10
BANK CROSS-SECTION CORRELATION MATRIX

	Size	RWE	Lev	Liq	Ins Def	Liq Def	ROE
Size	1	–	–	–	–	–	–
RWE	**-0.29**	1	–	–	–	–	–
Lev	0.21	-0.09	1	–	–	–	–
Liq	**0.21**	-0.05	-0.05	1	–	–	–
Ins Def	**-0.26**	-0.08	-0.15	-0.08	1	–	–
Liq Def	**0.27**	-0.07	0.01	-0.06	**-0.12**	1	–
ROE	-0.01	**-0.57**	-0.19	-0.03	**0.69**	**-0.21**	1

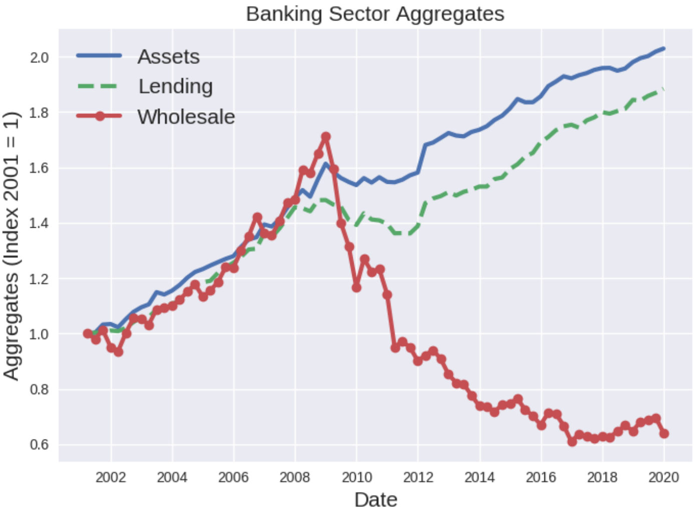
Return

Wholesale Funding Use Declined

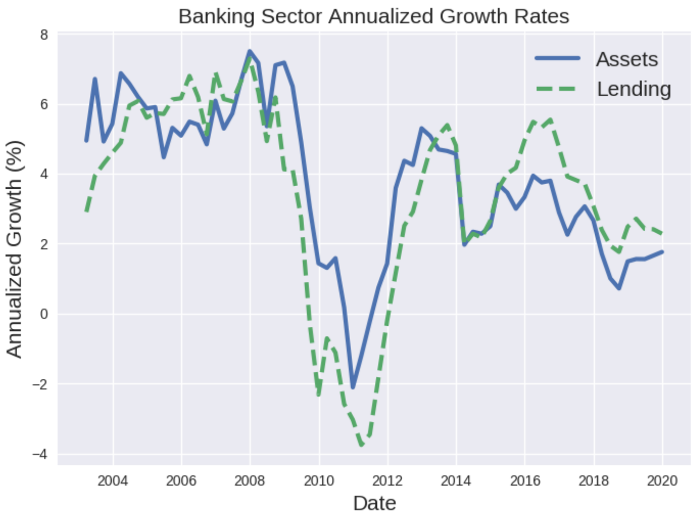


Return

Banking Sector Aggregates



Balance Sheet Growth



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