EUROPEAN CENTRAL BANK
EUROSYSTEM

Illiquidity, Closure Policies and the Role of Lender of Last Resort

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ECB Workshop
Money Markets and Central Bank Balance Sheets
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Research agenda

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  - How does Central Bank (CB) collateral policy affect bank's investment and cash buffer decisions?

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  - What are the benefits and costs of CB collateral policy for equity and debt holders?

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  - What are the benefits and costs of CB collateral policy for equity and debt holders?
  - What are the trade-offs involved in equity issuance versus asset liquidation decisions in managing liquidity and default?

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2. Linking to empirical evidence on bank's borrowing capacity and the use of ECB's liquidity

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- **Cash buffers** $\rightarrow$ Banks hold lower cash buffers (relative to the counterfactual)
- **Loan portfolio**
  1. Higher loan portfolio investments in "bad states" (relative to the counterfactual)
     Mendicino, Jasova and Supera (2018) provide evidence for Portugal
  2. Reduces the expected costs of asset liquidations

Effects of CB on equity holders & debt holders

- **Equity holders**
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- **Debt holders** $\rightarrow$ decreases credit spreads of private debt of banks

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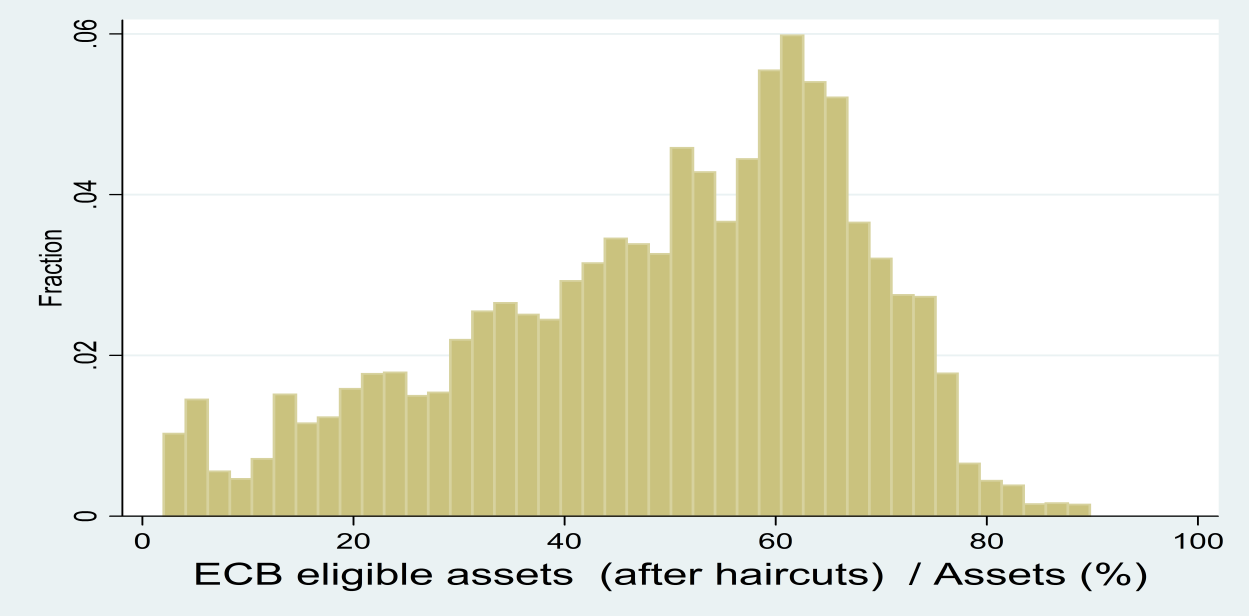
- **Our approach:**
  - **Debt securities**: security data holdings (SHS) and ECB eligibility list
  - **Loans**: ECB eligibility criteria

Links to empirical evidence (II)

- Significant cross-sectional variation of $1 - \Theta$ in the euro area banking sector



$$1 - \Theta = \frac{\text{Eligible assets (after haircuts)}}{\text{Assets}}$$

Links to empirical evidence (III)

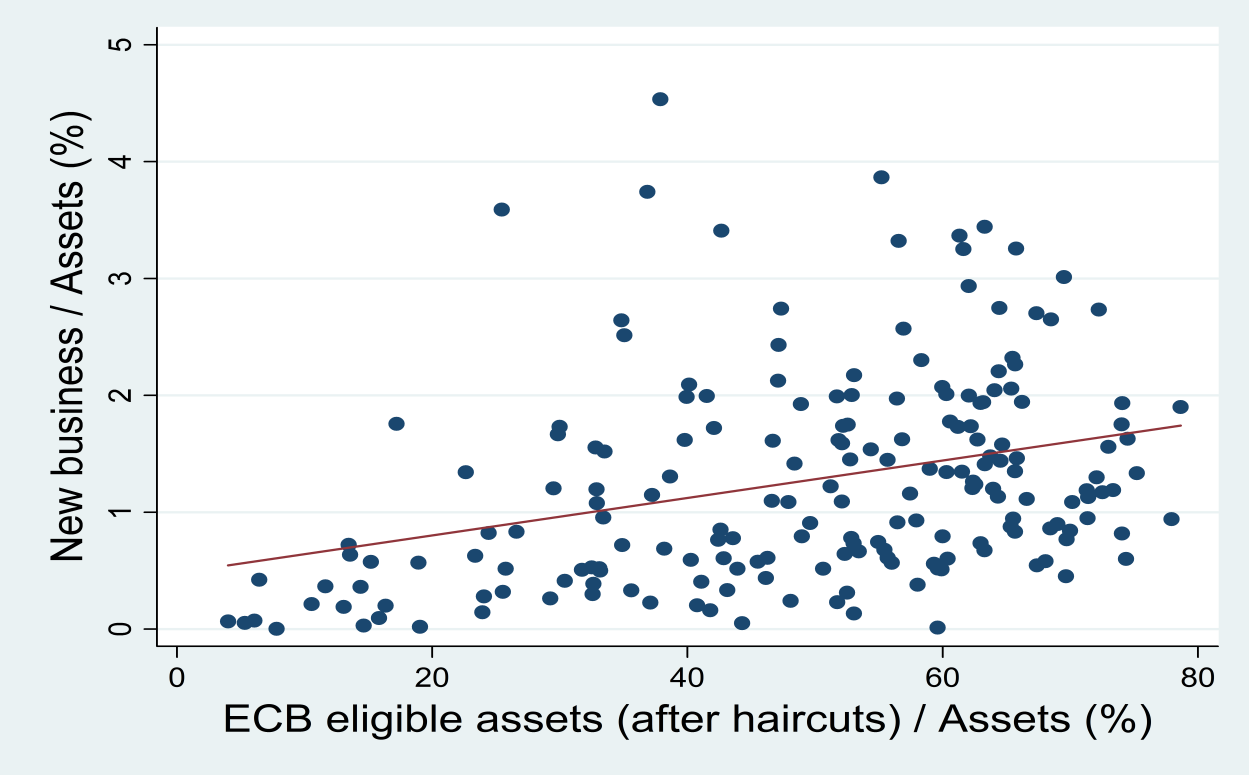


Figure: New loan business vs Borrowing Capacity with ECB

- Banks with a higher borrowing capacity who borrow from ECB invest more in new loans/investments

Related strands of literature

- **Role of Lender of Last Resort (LOLR)**
  Bagehot (1873), Bhattacharya and Gale (1987), Goodhart (1999,IF), Freixas, Parigi and Rochet (2000,JMCB), Rochet and Vives (2004,JEEA), Repullo (2005,IJCB), Bindseil (2014), Acharya and Tuckman (2014,IMFer), Nyborg (2016), Santos and Suarez (2016)
- **ECB collateral and liquidity policies**
  Brunetti, di Filippo and Harris (2011,RFS), Acharya and Steffen (2015,JFE), Drechsler, Drechsel, Marques-Ibanez and Schnabl (2016,JF), Garcia De Andoain, Heider, Hoerova and Manganelli (2016,JFI), Corradin and Rodriguez (2016), Carpinelli and Crosignani (2017), Crosignani, Faria-e-Castro and Fonseca (2017)
- **Capital structure and State-contingent liquidity**
  Leland (1994,JF), Asvanunt, Broadie and Sundaresan (2011,IJTAF), Bolton, Chen, Wang (2011,JF), De Nicolo, Gamba and Lucchetta (2014,RFS), Hugonnier and Morellec (2017,JFE).
- **Margins, Collateral and Liquidity**
  Bartolini, et.al (RFS, 2010), Garleanu and Pedersen (2009), Ashcraft, Garleanu, Pedersen (2010,NBER), Geanakoplos (2009, 2013), Risk Topography Systemic Risk and Macro Modeling (2014), Woodford (2015)

Model

Bank's balance sheet

- **Assets**
  - A - Assets' portfolio - loans and securities (hit by shocks)
  - $W > 0 \rightarrow$ Cash

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  - P - Risky short-term external debt (endogenous credit spreads) $\rightarrow$ rollover risk (subject to premature freezes)
  - $W < 0 \rightarrow$ CB liquidity (**illiquidity**)
  - E - Equity (or raise equity) (**illiquidity**)

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Bank does not hold cash and borrow from CB at the same time

Central Bank

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- $r + s^{CB}$ is borrowing rate against eligible collateral
- CB debt is senior to bank's existing debt

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We calibrate the model to the mean observed borrowing capacity $1 - \Theta$: $\approx 50\%$

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- **Closure:** $\frac{\text{Equity Book Value}}{\text{Assets}} < 5\%$
- Scenarios:
  1. **Counterfactual (No CB):** Costly issuance of equity ($W = 0$)
  2. **CB liquidity:** ($W < 0$) vs Costly issuance of equity

State variables

1. Assets' portfolio A

$$dA_t = (-\underbrace{\frac{1}{\delta}}_{\text{Assets' maturity}} A_t + \underbrace{I_t}_{\substack{\text{Investment} \\ \text{policy}}})dt$$

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2. Cash W

$$dW_t = \underbrace{dY_t}_{\substack{\text{Bank's} \\ \text{profits}}} + (r - \underbrace{\lambda}_{\text{Cost cash}})W_t - \underbrace{dU_t}_{\substack{\text{Dividends'} \\ \text{payment}}} \quad \text{if} \quad W_t > 0$$

$$dW_t = \underbrace{dY_t}_{\substack{\text{Bank's} \\ \text{profits}}} + (r + \underbrace{s^{CB}}_{\text{CB spread}})W_t + \underbrace{dH_t}_{\substack{\text{Equity} \\ \text{funding}}} \quad \text{if} \quad W_t \leq 0$$

Cash W

- Revenues' shock X

$$dX_t = \mu_X dt + \sigma_{X,1}\rho \underbrace{dZ_{1,t}}_{\text{Systematic}} + \sigma_{X,2}\sqrt{1-\rho^2} \underbrace{dZ_{2,t}}_{\text{Idiosyncratic}}$$

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- Bank's profits

$$dY_t = \underbrace{A_t dX_t}_{\text{Loss or gain}} + \underbrace{\frac{1}{\delta} A_t dt}_{\text{Loans matured}} - \underbrace{I_t^* dt}_{\text{Investment}} - \underbrace{g(I_t^*, \rho)}_{\text{Investment cost}} dt$$

$$- \underbrace{C_D}_{\text{Deposits}} dt - \underbrace{C}_{\text{Debt coupon}} dt + \underbrace{\frac{1}{m}(D(W, A, m; s) - P)}_{\text{Roll-over cost}} dt$$

where $D(W, A, m; s)$ market value of debt (m maturity)

Model's results

Parameters

Variable	**Symbol**	**Value**
Face value deposits	P_D	70
Face value external risky debt	P	30
Years of reimbursed loan	δ	10
Years to maturity debt	m	1
Mean loan-shock	μ_X	7.2%
Volatility of systematic loan shock	$\sigma_{X,1}$	7.5%
Volatility of idiosyncratic loan shock	$\sigma_{X,2}$	2.5%
Central bank haircut	θ	50%
Central Bank penalty rate	s^{CB}	0.50%
Liquidation value	l	70%
Marginal cost of equity issuance	γ	6%
Fixed cost of equity issuance	Φ	1%

Counterfactual

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- When the bank is solvent but runs of cash W
  1. **Liquidation:** the bank is liquidated
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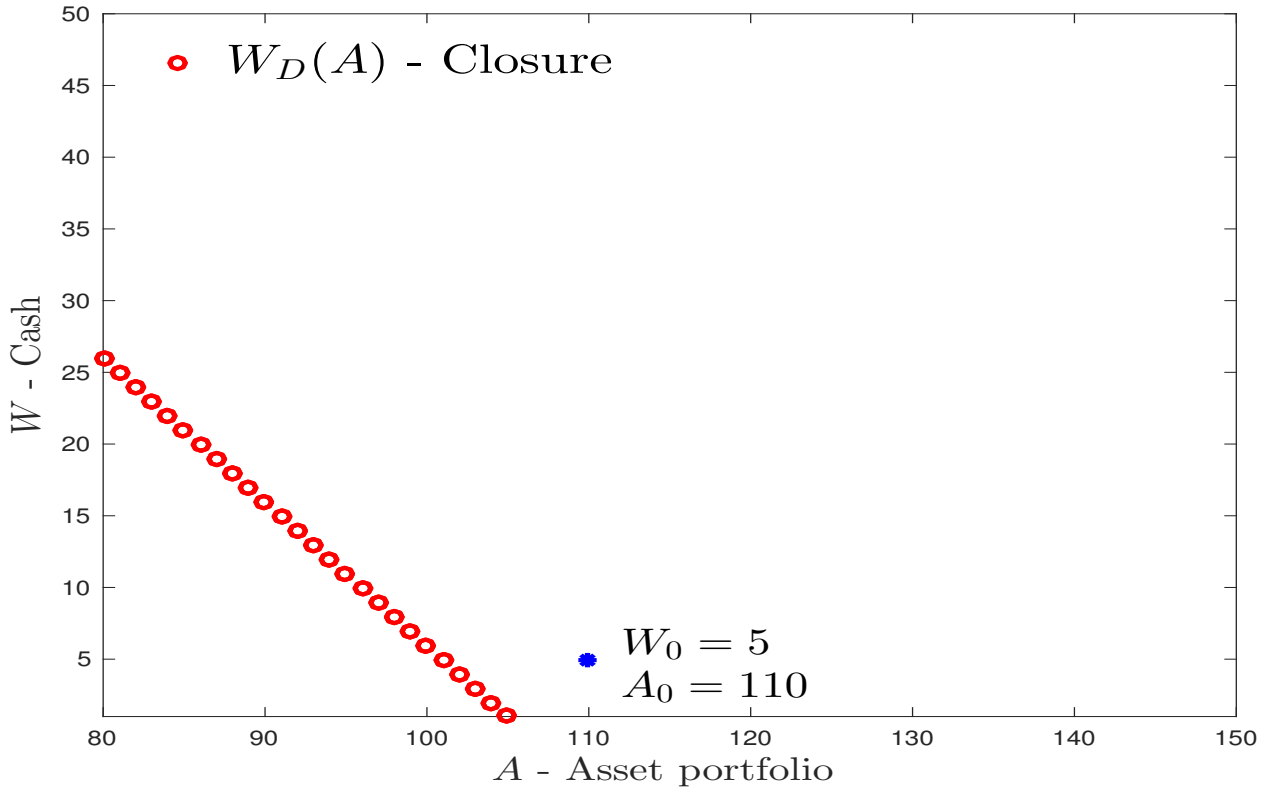
- Bank holds cash to avoid liquidation or costly issuance of equity

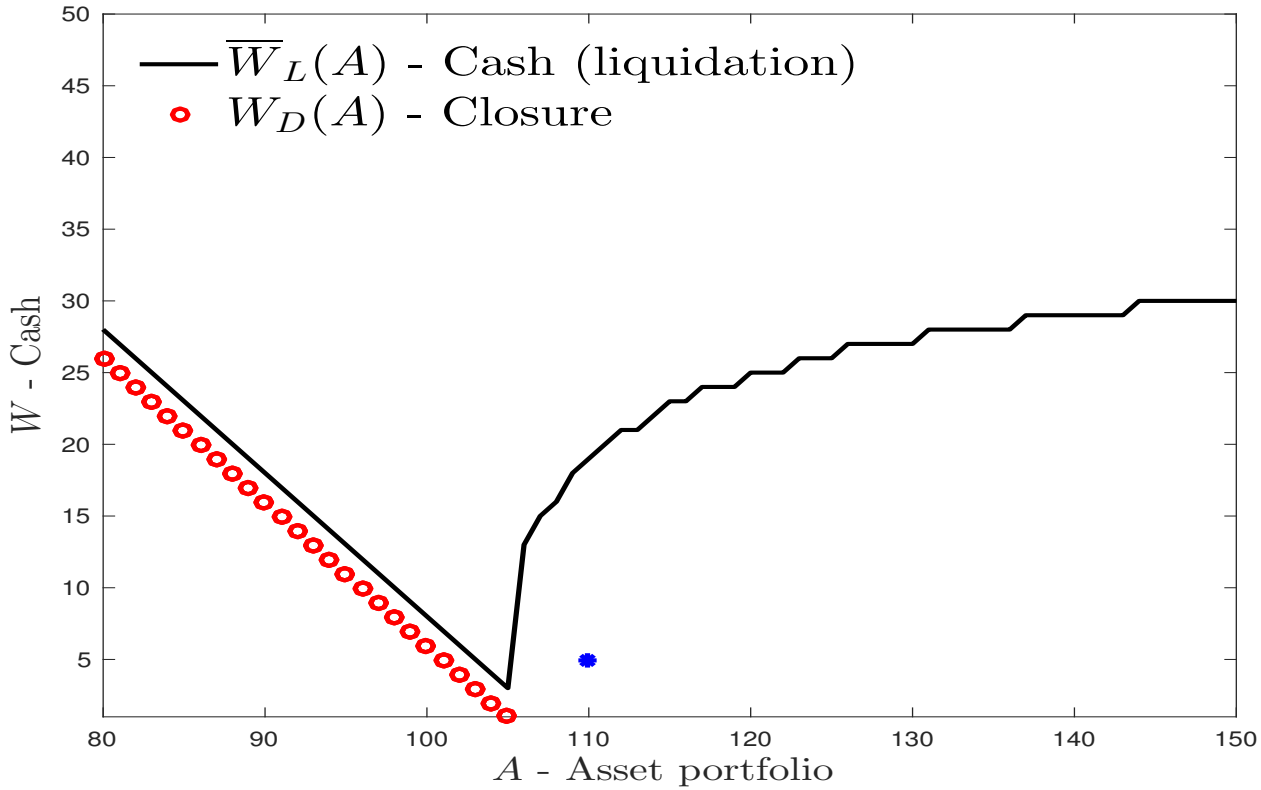
Counterfactual: Map (I)



Closure by resolution authorities when

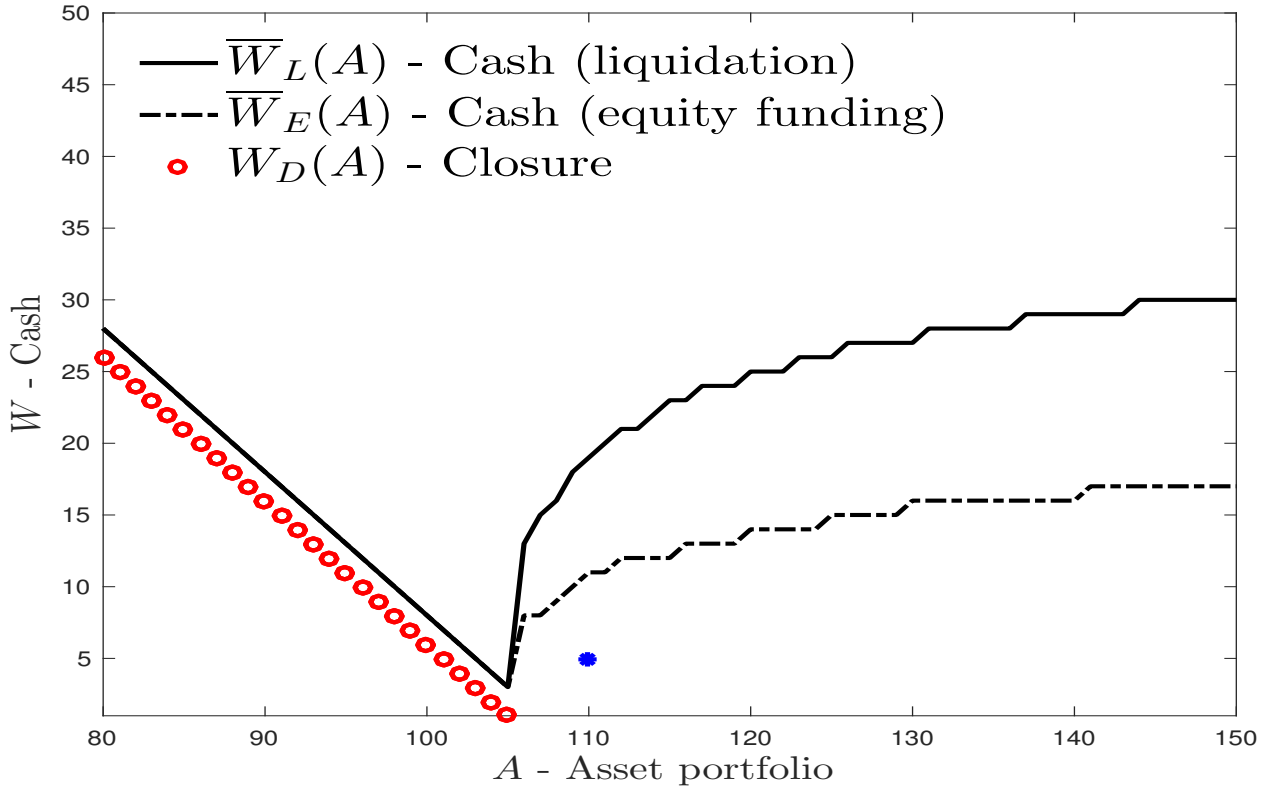
$$\frac{\text{Equity Book Value}}{\text{Assets}} = \frac{\max(A + W - P_D - P, 0)}{A + W} \leq 5\%$$

Counterfactual: Map (II)



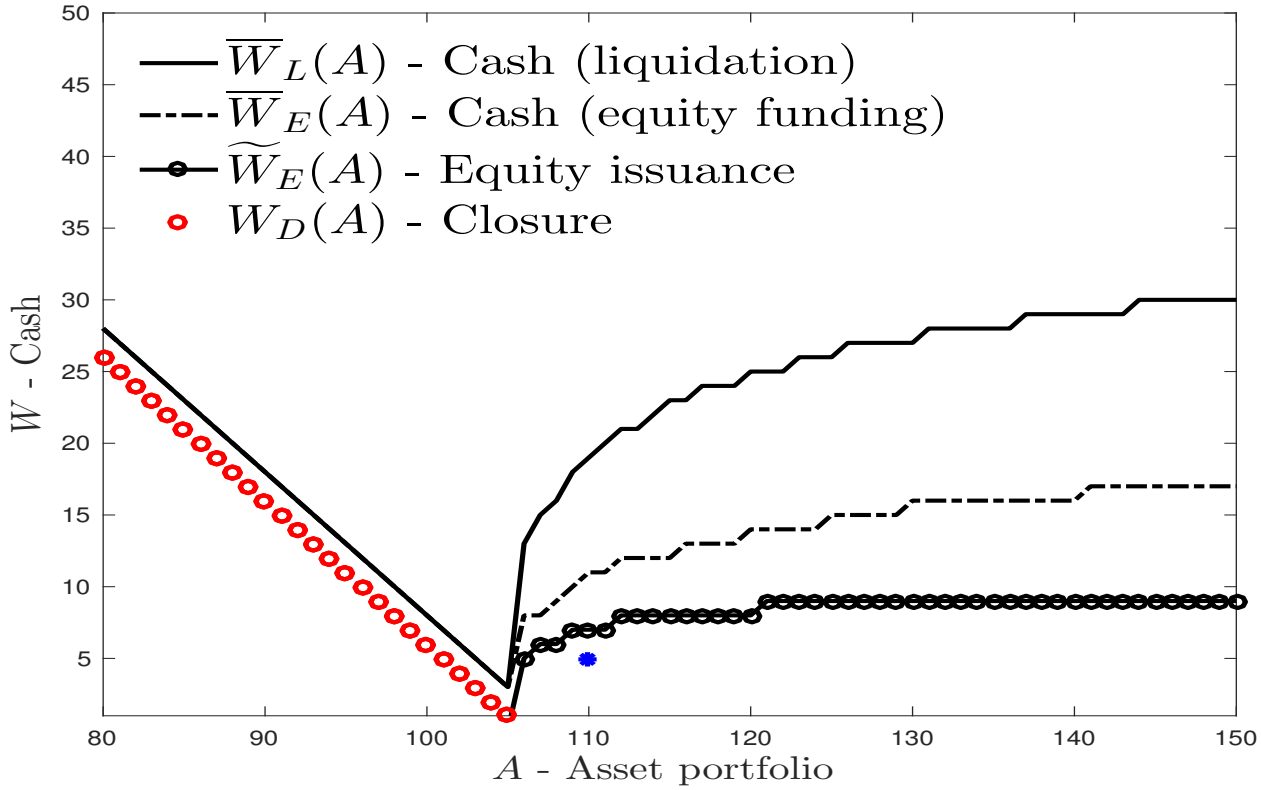
- **Liquidation:** the bank cannot issue equity when $A > 105$ and $W = 0$
- Bank's cash buffer decisions as a function of the state of the economy

Counterfactual: Map (III)



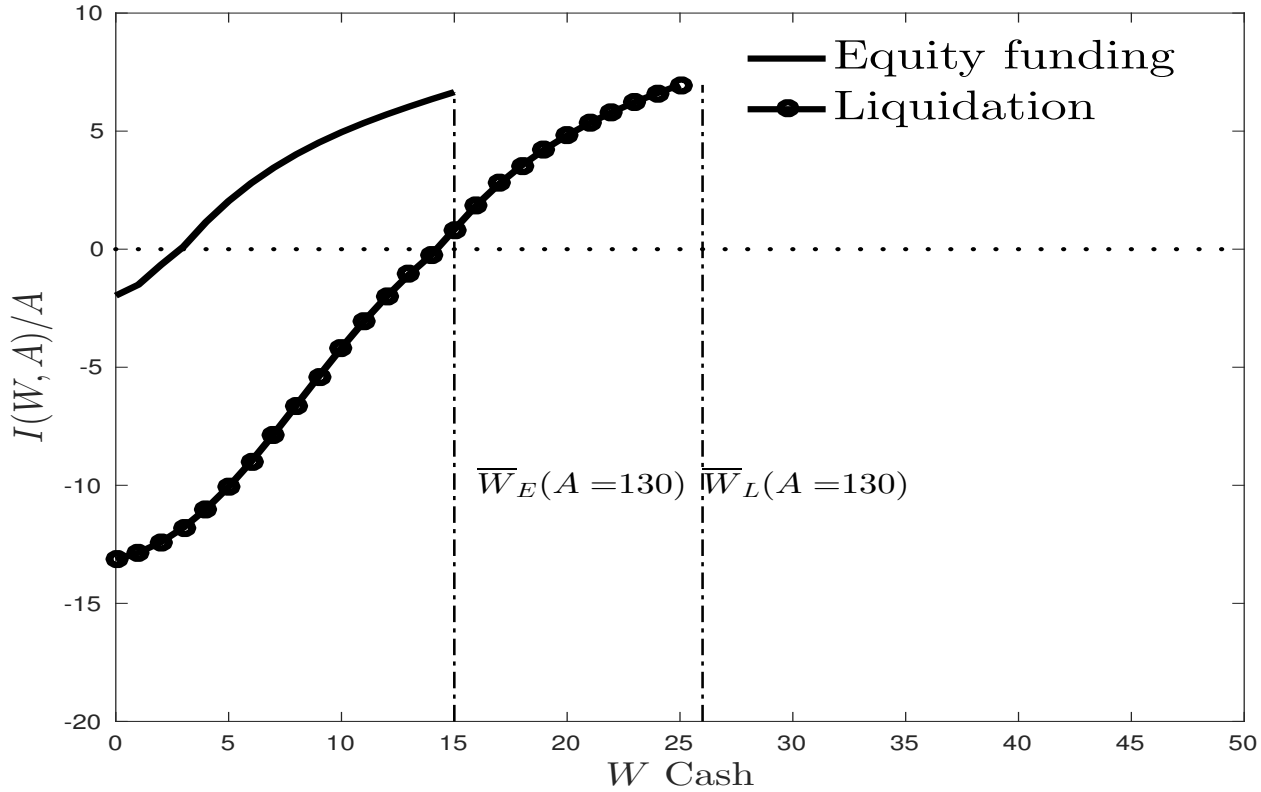
Equity funding: the bank holds less cash balance when can issue equity

Counterfactual: Map (IV)



Equity issuance: the bank issues more equity at higher asset levels to alleviate the illiquidity problem

Counterfactual: Investment



- When the bank runs of out cash $\rightarrow$ asset sales (negative intestment)
- Larger asset sales when the cost of issuing equity is extremely high (liquidation)

Central Bank

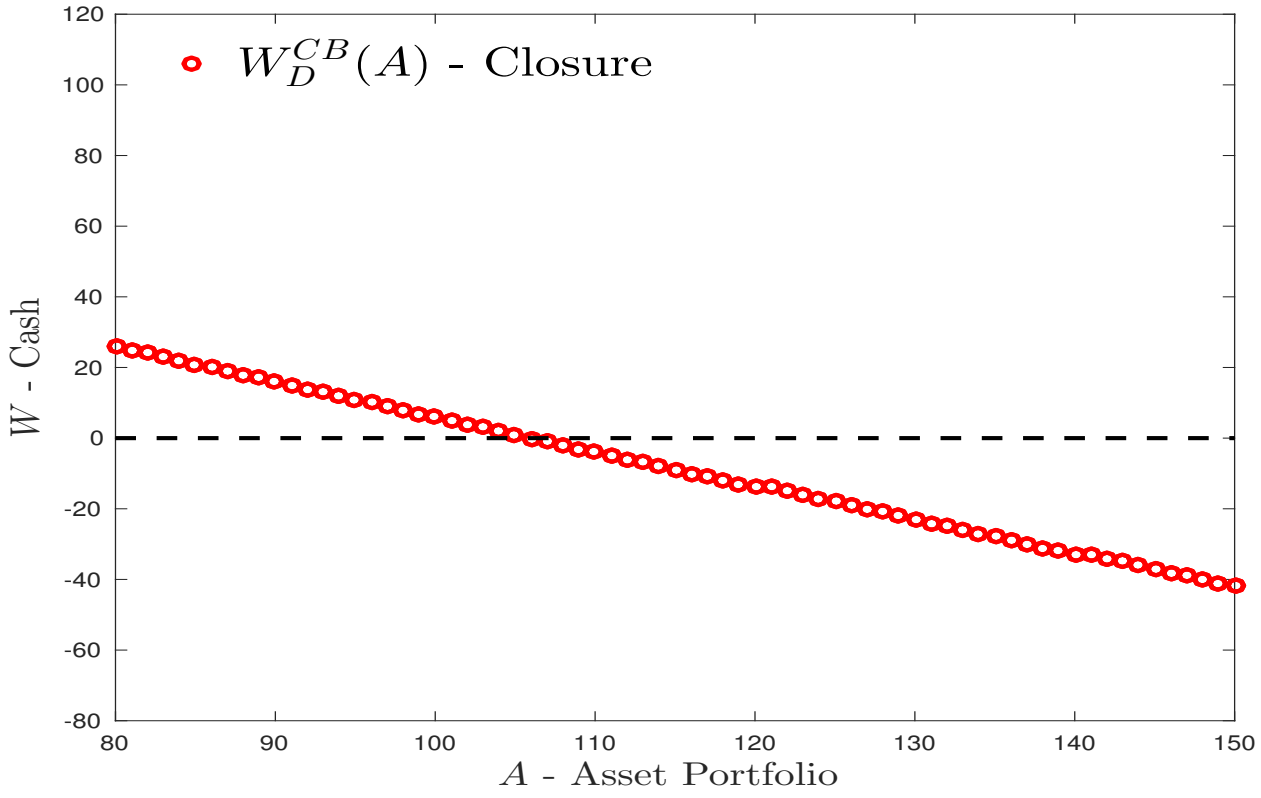
Two constraints:

1. Bank's borrowing capacity with CB is

$$0 > \underbrace{\underline{W}(A)}_{\text{CB liquidity}} \geq -(1 - \underbrace{\Theta}_{\text{Haircut}})A$$

2. Bank has to be solvent

CB: Map with $\Theta = 50\%$ (I)



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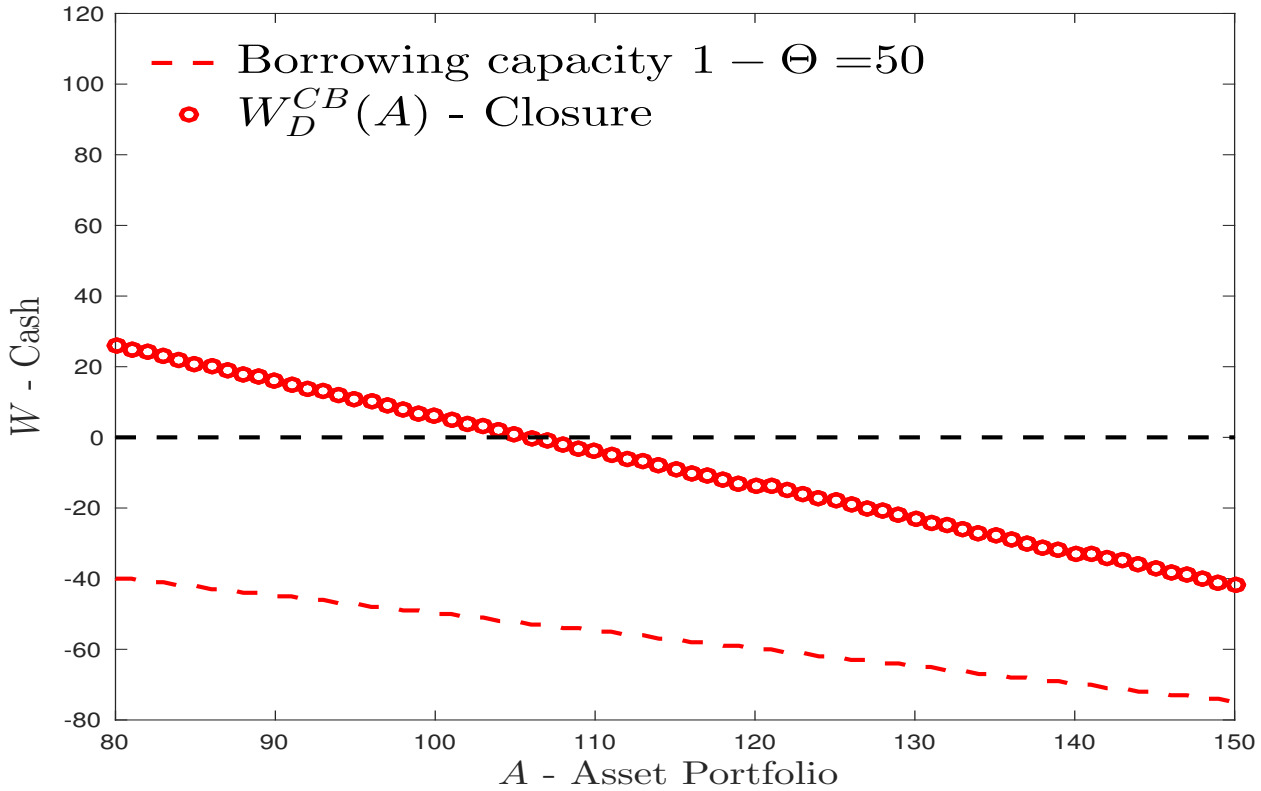

Borrowing capacity with CB

$$-(1 - \underbrace{\Theta}_{\text{Haircut}})A$$

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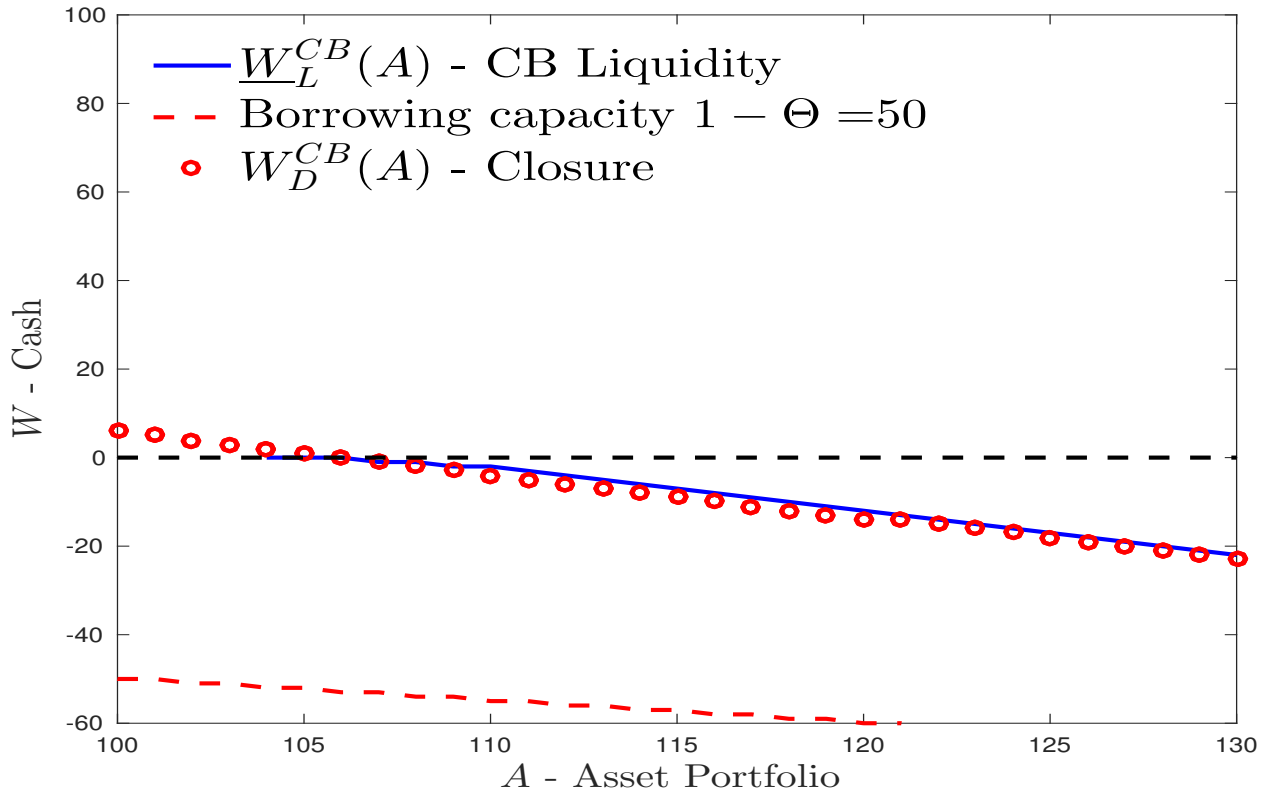

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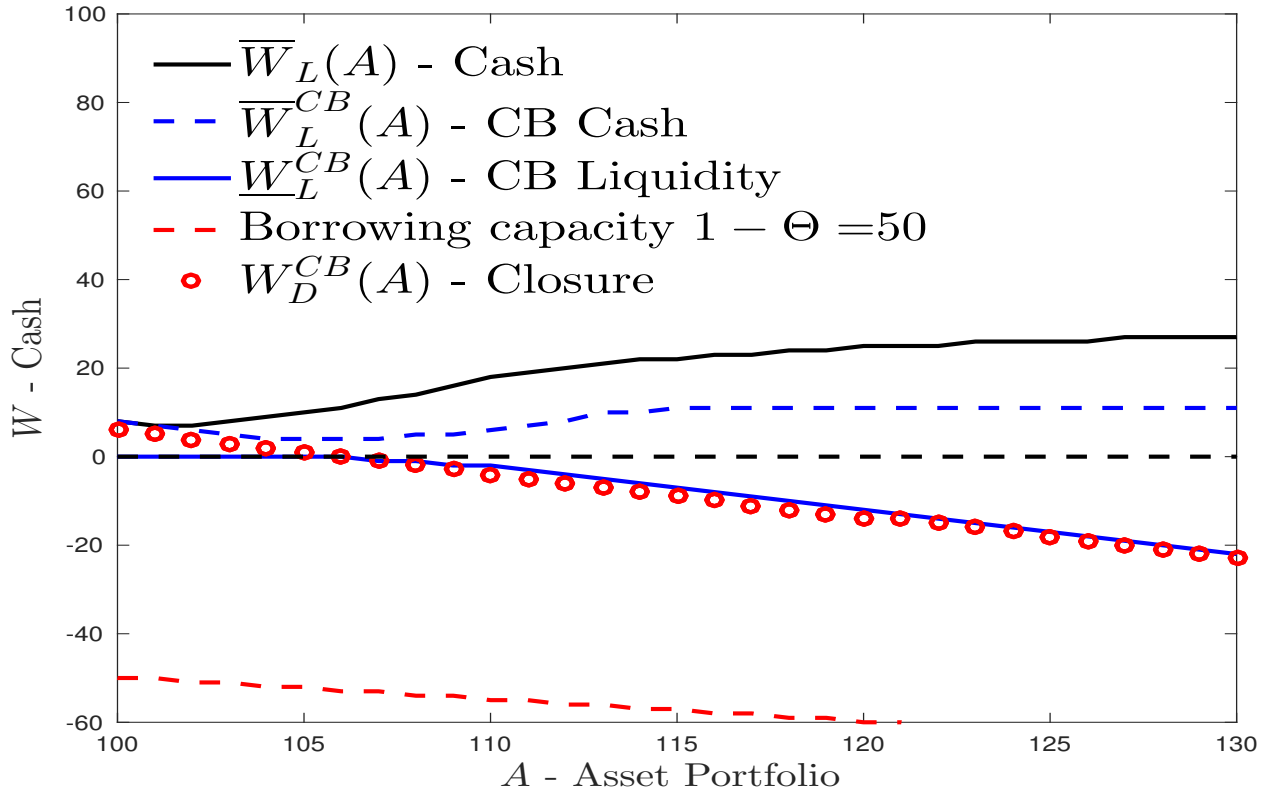
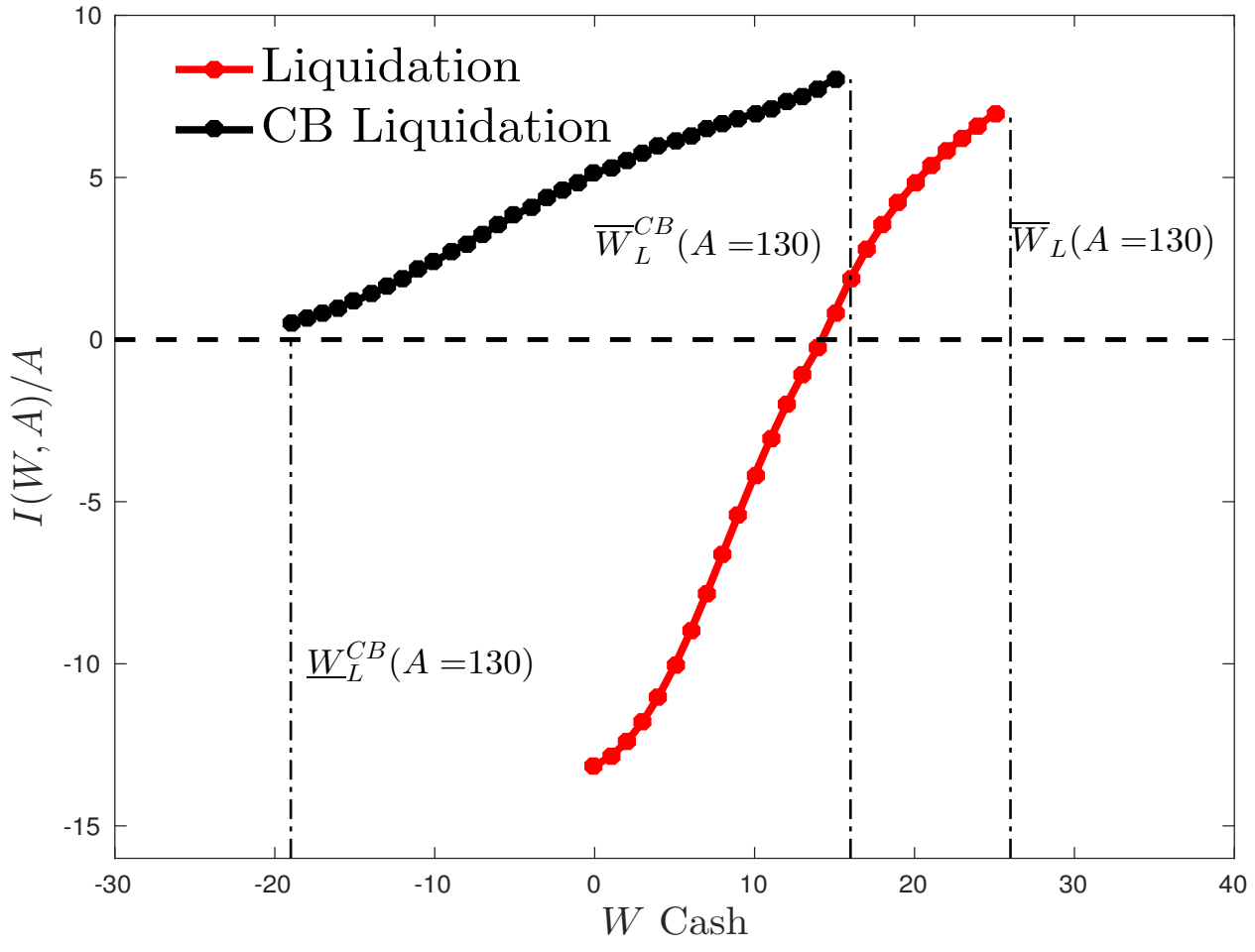


Lower cash buffers in the presence of CB

CB: Investment



Higher loan portfolio investments in "bad states" (relative to the counterfactual)

CB: Effects of CB policies (I)

Table: $W_0 = 5$, $A_0 = 110$, $P = 70$, $P_D = 30$ and $\overline{E} = \max(W_0 + A_0 - P - P_D, 0) = 15$

	(1)	(2)	(3)	(4)
	Θ (%)	$E(W_0, A_0)$	P_D Spread (%)	$E\left[\frac{I^*(W_0,A_0)}{A_0}\right]$ (%)
Liquidation				
	100	15.48	11.94	-5.08
	50	19.01	6.23	15.29
Equity financing				
	100	21.93	1.07	16.45
	50	26.22	0.52	17.39

CB: Effects of CB policies (II)

- CB policies generally lead to
  1. Greater investment in new loans and lower asset liquidations
  2. Larger equity values
  3. Lower credit spreads
  4. Lower cash buffers than would be desirable

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- CB policies generally lead to
  1. Greater investment in new loans and lower asset liquidations
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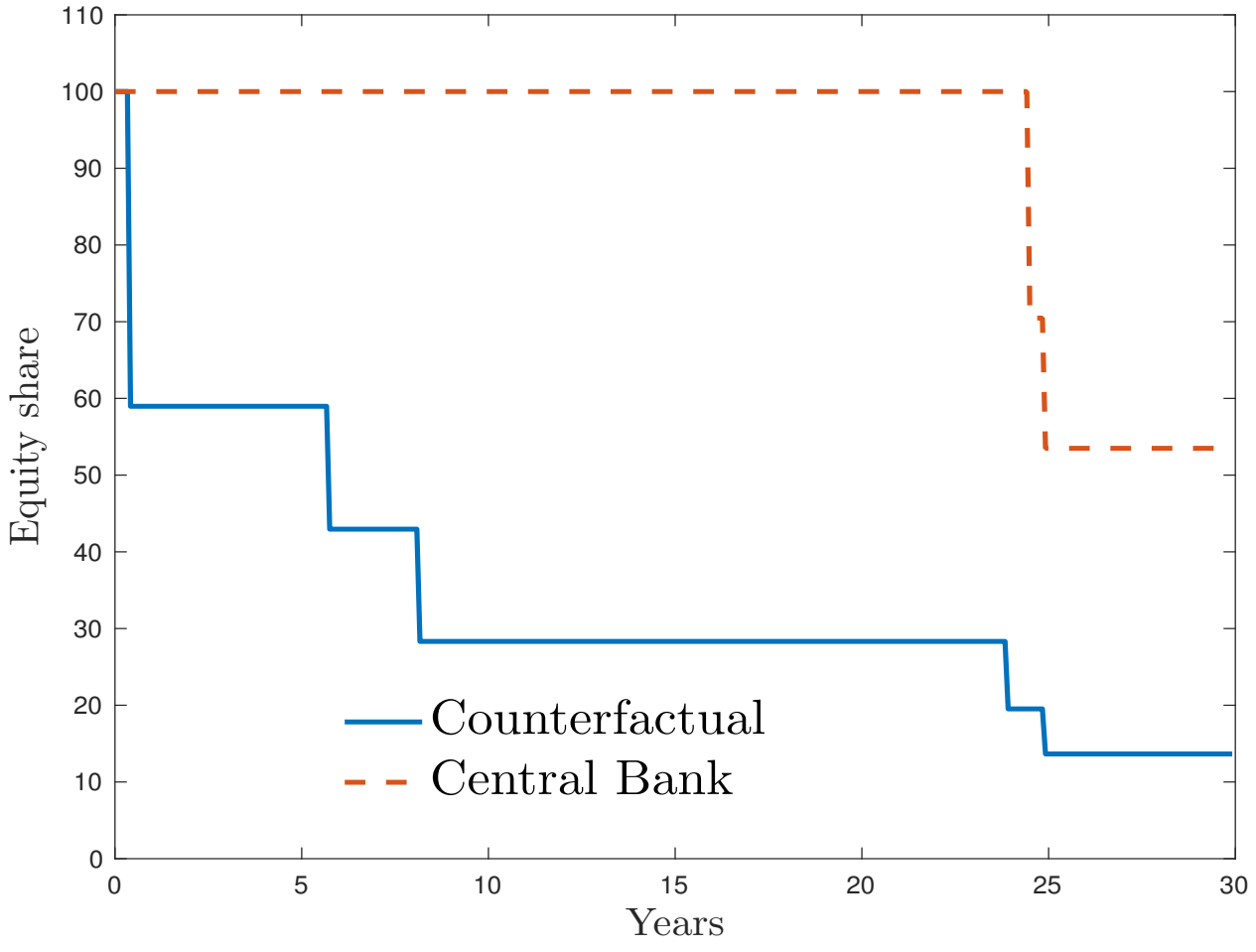
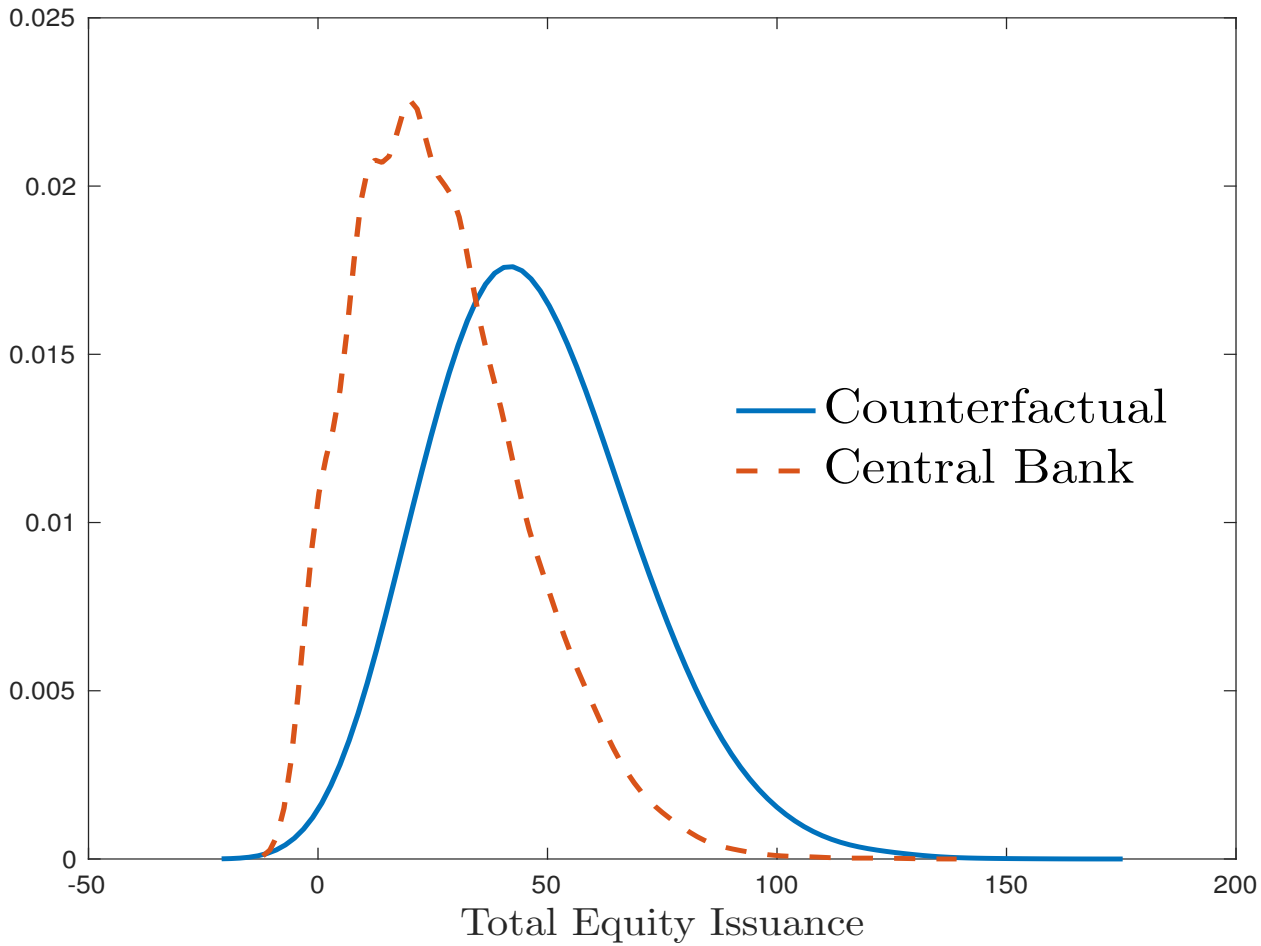
- What about incentives of the bank to issue equity or cut dividends?
  - Monte carlo simulation of the model ($50,000$ paths for 30 years)

CB: Equity share of insider equity holders



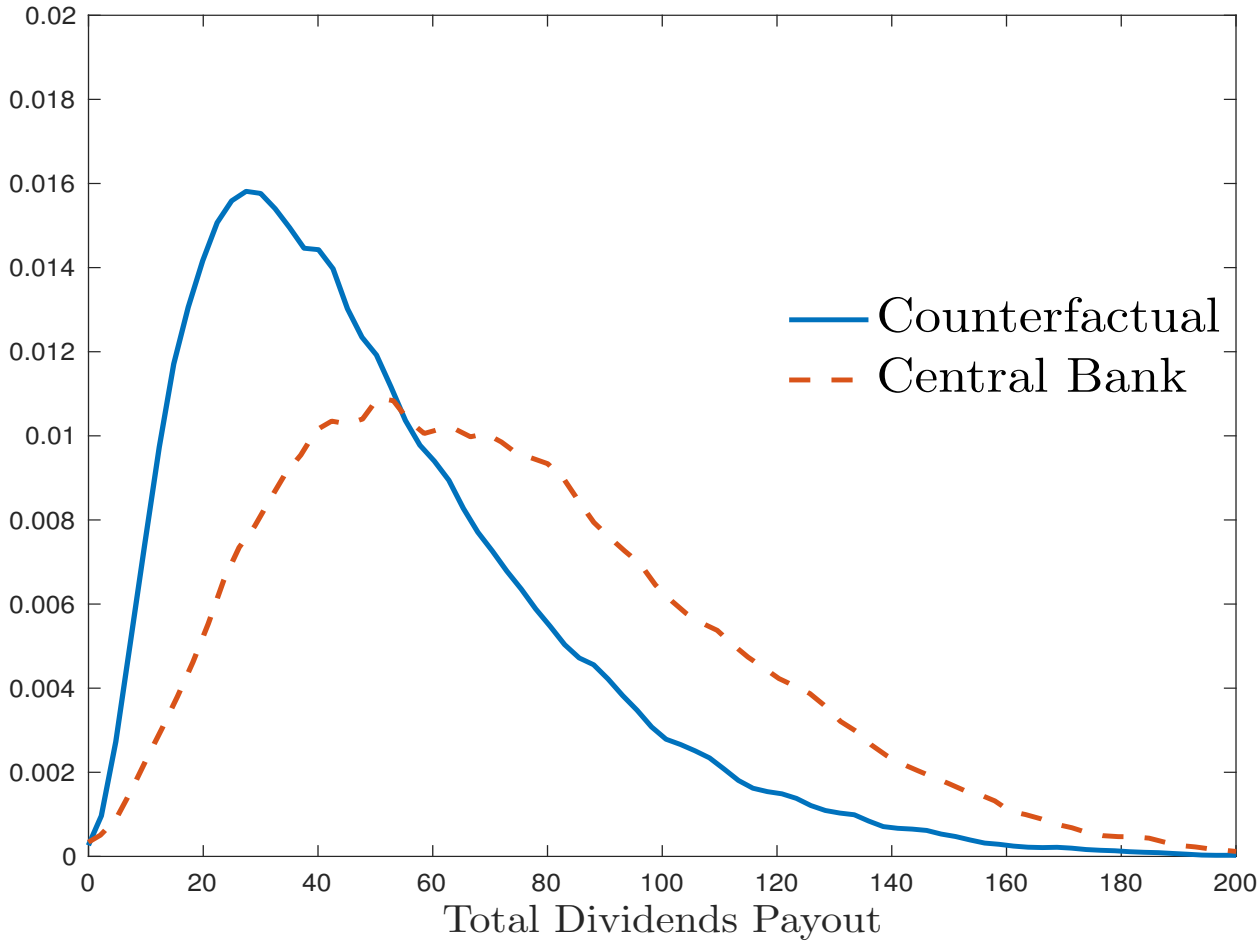
Possible path: In the presence of CB less dilution of the stakes of the incumbent equity holders

CB: Distribution of equity issuance after 30 years



When the bank has access to the CB liquidity, fewer issuances of equity ($\rightarrow$ region shifts to the left)

CB: Distribution of dividends payout of incumbent equity holders



When the bank has access to the CB liquidity, higher dividend payouts to current equity holders

Policy experiments (I)

Table: $W_0 = 5$, $A_0 = 110$, $P = 70$, $P_D = 30$ and $\overline{E} = \max(W_0 + A_0 - P - P_D, 0) = 15$

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	$E(W_0, A_0)$	P_D Spread (%)	$E\left[\frac{I^*(W_0,A_0)}{A_0}\right]$ (%)
Liquidation			
Base case	**19.01**	**6.23**	**15.29**
$s^{CB} = 1.5\%$ (**0.5**%)	17.87	7.95	15.02
$\Theta = 80\%$ (**50**%)	18.89	6.62	14.57
Closure = 6%(**5**%)	17.63	6.75	12.95

- $\uparrow$ penalty rate s^{CB} increases credit spreads by more than 1.5% and decreases equity values

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- $\uparrow \Theta$ decreases expected investment
- $\uparrow$ capital requirements decreases expected investment

Policy experiments (II)

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Conclusions

- We provide a dynamic framework for bank's cash buffer and asset size decisions with and without a CB
- CB policies lead to greater loan portfolio investments and lower credit spreads
- CB policies lead banks to hold lower cash balances
- CB policies reduce the incentives of the bank to issue equity or cut dividends
- We provide an empirical measure of borrowing capacity of banks at the CB liquidity facilities

Thanks!

Additional slides

1 − Θ: ECB collateral and liquidity

ECB accepts

- debt securities (conditional on eligibility criteria)
- some type of loans

Table: October 2008 - Dec. 2016 - * Over collateral ** Over assets

	Mean	St. Dev.	P10	P90
Collateral (euro mil.)	5,985	11,656	0	17,115
Sov. Debt Securities* (%)	17.58	27.84	0.00	57.66
Other Debt Securities* (%)	67.45	33.63	1.46	100.00
Loans* (%)	14.97	26.06	0.00	53.06
Implied ECB Haircut (%)	8.97	55.06	2.10	19.62
Liquidity (euro mil.)	2,101	5,202	0	6,308
Dummy Liquidity	47.92	49.96	0.00	100.00
Liquidity** (%)	2.21	3.92	0.00	7.57
Liquidity* (%)	21.58	30.45	0.00	74.80

$1 - \Theta$: Debt securities (I)

- **Data (quarterly):**
  1. ECB eligibility: ECB haircut at ISIN-level
  2. Securities Holding Statistics: quarterly ISIN-level holdings by investor sector (including MFIs) at country level (i.e. ISIN-level holdings of german banking sector)
- **Merge** $(1) + (2)$:
  - Identify whether an ISIN is eligible
  - Compute securities holdings shares of each country MFI sector split in (IBSI balance sheet items):
    - Issuer sector (Sovereign, MFIs, ...)
    - Issuer geographical location (domestic, euro area, other euro area)

$1 - \Theta$: Debt securities (II)

Table: ECB Eligibility and Haircuts (numbers in %)

IBSI categories	ECB Eligible			ECB Haircut θ		
Issuer	Mean	P10	P90	Mean	P10	P90
Sovereign						
Domestic	97.86	94.19	100.00	2.80	1.81	3.25
Other Euro Area	94.69	90.15	99.57	3.41	2.10	4.66
Extra Euro Area	28.29	3.53	51.32	3.79	2.29	5.67
Non MFI						
Domestic	56.37	16.13	80.65	10.61	5.11	21.30
Other Euro Area	68.32	46.19	83.81	9.30	5.55	13.68
Extra Euro Area	27.13	9.96	38.82	9.90	5.12	17.90
MFI						
Domestic	74.10	47.20	90.82	8.16	5.26	11.86
Other Euro Area	72.04	50.61	87.83	8.13	5.84	10.85
Extra Euro Area	50.05	26.09	75.62	6.49	4.48	8.40

$$\Theta_{i,j,t} = \text{Eligible}_{i,j,t} \times \theta_{i,j,t} + (1 - \text{Eligible}_{i,j,t}) \times 100\%$$

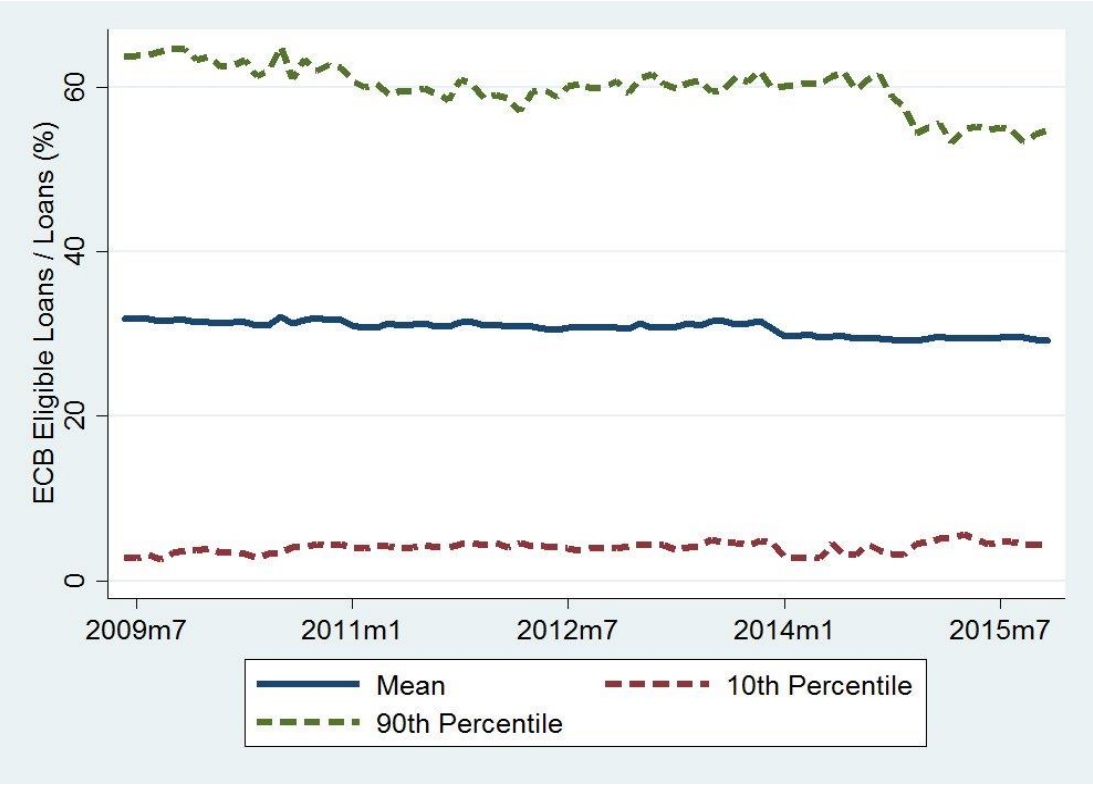
MFI sector country i, security debt type j and quarter t

$1 - \Theta$: Loans (I)

- Rely on ECB eligibility criteria for loans:
  - Compute (weighted) average ECB haircut for the item loans in IBSI
- ECB eligible loans easily identifiable on IBSI loan items:
  - **Issuer:** public sector, non-financial corporations (non-MFIs), international and supranational institutions
  - **Place of establishment:** euro area
  - **Currency:** euro
- We cannot use other eligibility criteria
  - Credit assessment: ECB haircuts depends on on the credit quality
  - Minimum size of loans (i.e. euro $500,000$)

$1 - \Theta$: Loans (II)

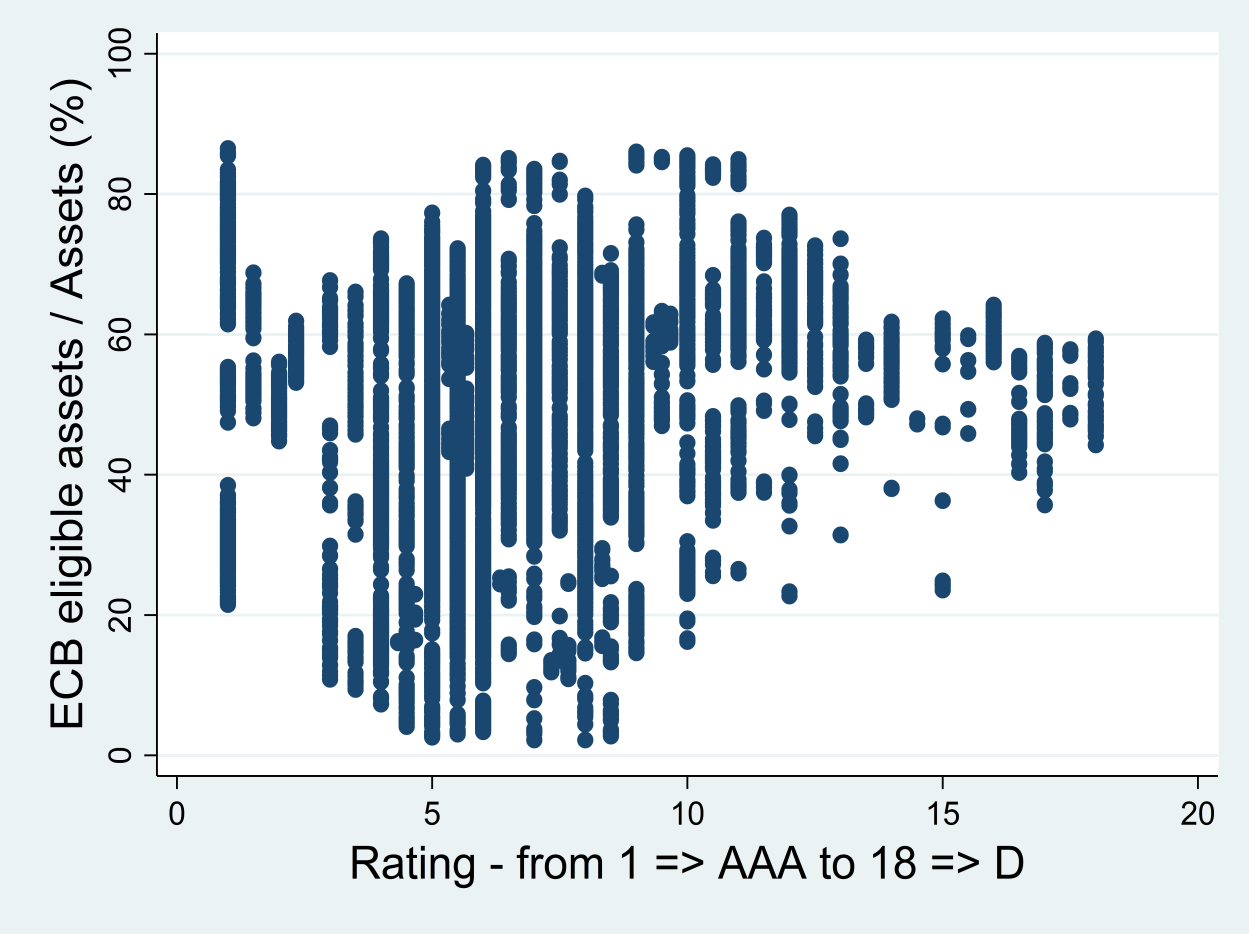
- Significant cross-sectional variation of ECB eligible loans



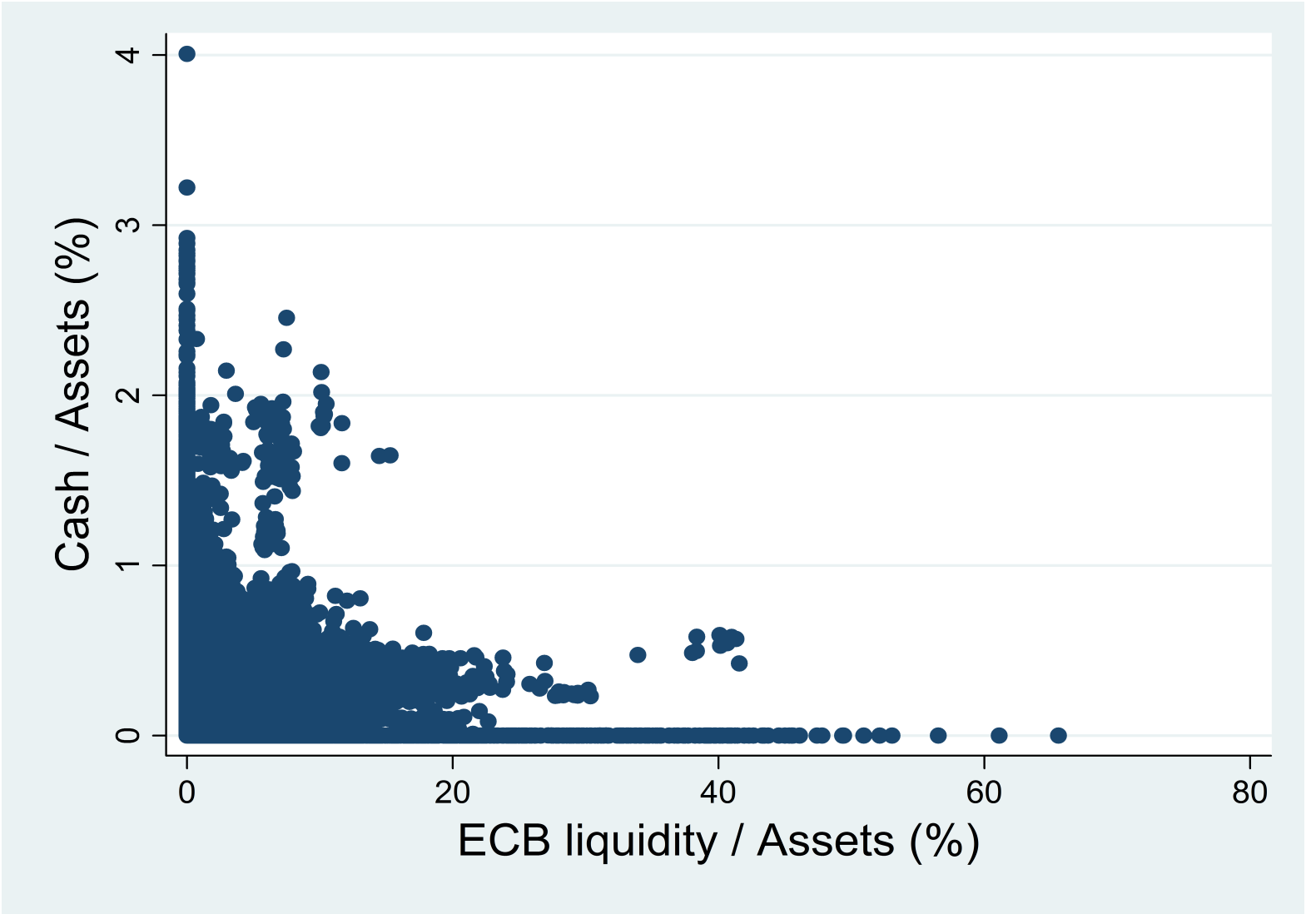
$\Theta_{j,t} = \text{Eligible}_{j,t} \times \theta_{j,t} + (1 - \text{Eligible}_{j,t}) \times 100\%$ "Upper bound"

loan type j and quarter t but $\text{Eligible}_{j,t} = 0$ or 100%

Is $1 - \Theta$ related to bank's risk? Not really



Model assumption: Cash vs ECB liquidity



Model: Debt structure

- Stationary debt structure (C, P, m) as in Leland (1998,JF)
  - aggregate face value P and coupon payment C
  - each bond has maturity m
  - debt expirations are uniformly spread across time over $(t, t+dt)$ $\frac{1}{m}dt$ fraction of the bonds matures
- Maturing bonds are replaced with bonds with (C, P, m)
- Over $(t, t+dt)$ the debt cash flow is (from equity holders' point view)

$$-C + \frac{1}{m}\left[D(W, A, m; s) - P\right]$$

- $D(W, A, m; s)$ market value of new bond (s spread)
- when bond price drops, equity holders face losses

Dividend's payout and equity funding

- **Dividends' payout**

$$\underbrace{E(W,A)}_{\text{Equity value}} = E(\overline{W}(A),A) + \underbrace{(W-\overline{W}(A))}_{\text{Cash distribution}} \qquad W > \overline{W}(A) > 0$$

where $\overline{W}(A)$ is the payout boundary

- **Equity funding:** M liquidity amount after equity issuance

$$E(0,A) = E(M,A) - (1 + \underbrace{\gamma}_{\text{Marginal cost}})M \quad \text{no CB}$$

$$E(\underline{W}(A),A) = E(\underline{W}(A)+M,A) - (1+\gamma)M \quad \text{with CB}$$

where $\underline{W}(A) < 0$ is the CB boundary

Numerical approach

Iterative procedure for a sequence of fixed boundary problems:

1. At time T
   - Equity and debt value correspond to book values
   - The bank does not hold or borrow cash
2. At time $T-1$ the inaction region $(\overline{W}(A), \underline{W}(A))$ is relaxed
   - 2.1 Jointly solve the PDEs associated with the equity $E(W, A)$ and debt $D(W, A)$ subject to the boundary conditions at ($\overline{W}(A)$ and $\underline{W}(A)$) (FD method)
   - 2.2 Compute the optimal investment policy I^*
   - 2.3 **Boundary update procedure** - verify whether smooth pasting conditions at $\overline{W}(A)$ and $\underline{W}(A)$ are satisfied
     - 2.3.1 **No:** update the inaction region and solve 2.1 with 2.2
     - 2.3.2 **Yes:** convergence
3. Move backward and repeat the procedure 2 for any time t to get a sequence of regions of inaction