The Macroeconomics of Shadow Banking

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February, 2016

Shadow banking, what is it good for?

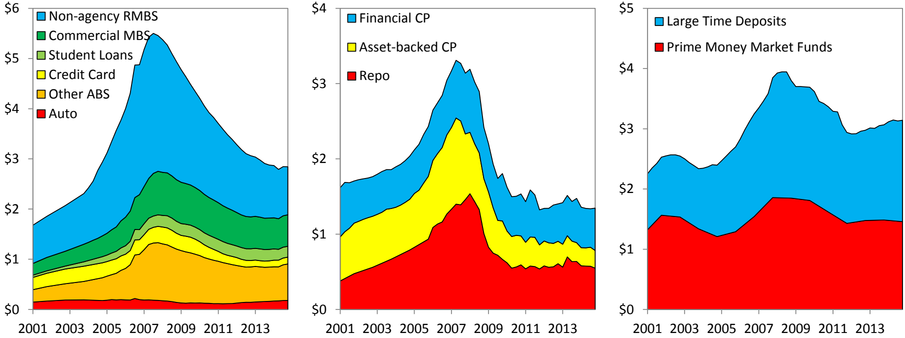
Three views:

1. Regulatory arbitrage
   - avoid capital requirements, exploit implicit guarantees
2. Neglected risks
   - package risky investments as safe, pass on to unsuspecting investors
3. Liquidity transformation
   - create money-like liquid instruments from a broader set of assets

All reform proposals take an implicit stance

The liquidity transformation view of shadow banking

Securitized loans ⇒ Intermediated funding ⇒ Liquidity provision



Trillions of USD outstanding

1. Shadow banking turns risky assets into liquid liabilities
   ⇒ expands credit to the economy and liquidity provision to households/institutions
2. Bigger booms, deeper busts
   ⇒ tradeoff between growth and fragility

Our framework

1. Investors demand liquid securities to consume in high marginal-utility states (liquidity events)
   - liquidity $\Leftrightarrow$ no adverse selection $\Leftrightarrow$ overcollateralization

2. Intermediaries invest in assets and finance with
   - money safe $\Rightarrow$ always liquid (e.g. government money market fund)
   - equity residual $\Rightarrow$ illiquid (e.g. "toxic waste" CDO tranche)
   - shadow money safe except in a crash $\Rightarrow$ liquid most of the time (e.g. Financial CP, ABCP, private-label repo, etc.)

3. Collateral constrains liquidity provision:

$$\text{Money} \times 1 + \begin{matrix}\text{Shadow}\\ \text{money}\end{matrix} \times \left(1 - \begin{matrix}\text{Crash}\\ \text{loss}\end{matrix}\right) \leq \begin{matrix}\text{Value of}\\ \text{assets in a}\\ \text{crash}\end{matrix}$$

   - tradeoff between quantity and stability of the liquidity supply

4. Uncertainty drives demand for fragile vs. stable liquidity

Related literature

1. **Banking:** Diamond and Dybvig (1983); Gorton and Pennacchi (1990); Allen and Gale (1998); Gorton and Ordoñez (2012); Dang, Gorton, and Holmström (2010); Gennaioli, Shleifer, and Vishny (2013); Hanson, Shleifer, Stein, Vishny (2014)
2. **Macro-finance:** Bernanke and Gertler (1989); Bernanke, Gertler, and Gilchrist (1999); Kiyotaki and Moore (1997); Adrian and Shin (2010); Garleanu and Pedersen (2011); He and Krishnamurthy (2013); Brunnermeier and Sannikov (2014); Adrian and Boyarchenko (2012); Geanakoplos (2003); Gertler and Kiyotaki (2010, 2013); Sannikov (2014); Maggiori (2013); Kurlat (2012); Bigio (2013)
3. **Demand for safety/liquidity:** Holmström and Tirole (1998); Kiyotaki and Moore (2012); Brunnermeier and Sannikov (2011); Greenwood, Hanson, and Stein (2012); Krishnamurthy and Vissing-Jorgensen (2012); Caballero and Farhi (2013)
4. **Funding liquidity and collateral runs:** Brunnermeier and Pedersen (2009); Gorton and Metrick (2011)
5. **Unconventional monetary policy:** Gertler and Karadi (2011); Ashcraft, Garleanu, and Pedersen (2011); Kiyotaki and Moore (2012); Krishnamurthy and Vissing-Jorgensen (2013)
6. **Empirical asset pricing:** Adrian, Etula, and Muir (2011); Pedersen and Frazzini (2010, 2012); Sunderam (2013)

MODEL ROADMAP

1. **Static model to illustrate core mechanism**
2. Dynamic model for amplification, cycles, and effects of policy

Static model: preferences and endowment

1. Three dates, 0 , 1 and 2. Investors subject to liquidity events

$$U_0 = \max E_0 \left[z_1 C_1 + C_2 \right]$$

- $z_1 \in \{1, \psi\}$, where $z_1 = \psi$ privately-observed liquidity event
- $z_1 = \psi$ with probability h, i.i.d. across investors
- Gains from trade between $z_1 = \psi$ and $z_1 = 1$ investors

2. Promises require collateral. Endowed with asset that pays

$$Y_2 = \begin{cases} 1 + \mu_Y, & \text{prob.} \quad 1 - \lambda_0 \quad \text{(normal times)} \\ 1 - \kappa_Y, & \text{prob.} \quad \lambda_0 \quad \text{(crash)} \end{cases}$$

- normalize $E_0[Y_2] = 1$, λ_0 measures uncertainty
- normalize $q_0 = 1$, assets are the numeraire

Static model: liquidity

1. At date 1 public signal reveals updated crash prob. $\lambda_1 \in \{\lambda^L, \lambda^H\}$
2. Some investors can acquire a private signal revealing asset payoff Y_2
3. Informed trading $\Rightarrow$ adverse selection $\Rightarrow$ illiquidity costs
4. Costs specially high for liquidity-event investors:

Assumption 1: *Investors in a liquidity event trade only securities that they can sell for their present value under public information.*

5. Liquidity requires no information acquisition: trading profit $<$ cost
6. Profit higher when (i) can trade security with high exposure to Y_2, (ii) uncertainty λ_1 is high

$\Rightarrow$ Implications

- Liquid security must have low enough exposure to asset payoff
- Exposure limit tighter when uncertainty λ_1 is high
- Security that is liquid when $\lambda_1 = \lambda^L$, might be illiquid when $\lambda_1 = \lambda^H$

Static model: securities

Intermediaries (firms) buy assets at date 0 and tranche into securities

- security x with yield μ_x, crash exposure κ_x:

$$r_2^x = \begin{cases} 1+\mu_x, & \text{if} \quad Y_2 = 1+\mu_Y \quad \text{(normal times)} \\ 1-\kappa_x, & \text{if} \quad Y_2 = 1-\kappa_Y \quad \text{(crash)} \end{cases}$$

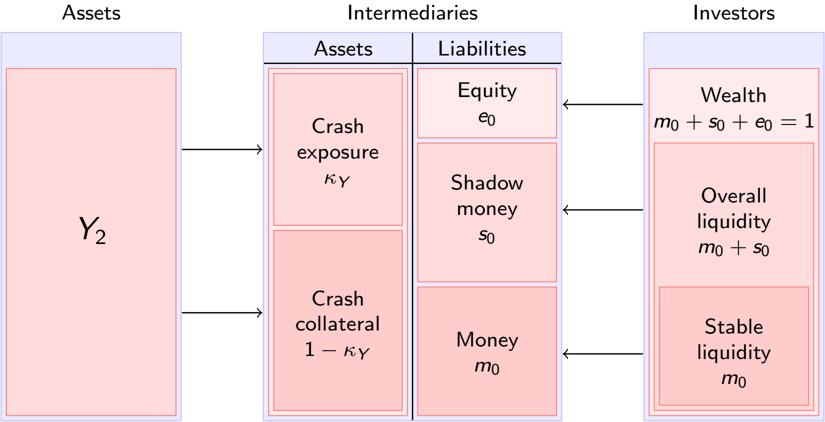
Proposition 1 *Intermediaries optimally issue the following three securities:*

i. *money m with $\kappa_m = 0$ is liquid for $\lambda_1 \in \{\lambda^L, \lambda^H\}$ (always-liquid);*
ii. *shadow money s with $\kappa_s = \overline{\kappa}$ is liquid if $\lambda_1 = \lambda^L$ (fragile-liquid);*
iii. *equity e with $\kappa_e = 1$ is illiquid,*

where $0 < \overline{\kappa} < 1$ under appropriate parameter restrictions.

$\Rightarrow$ These securities are issued because the have the highest crash exposure within their liquidity profile. They economize on collateral.

Balance sheet view



Static model: equilibrium

Equilibrium allocation solves

$$\max_{m_0, s_0 \geq 0} \; E_0\left[h(\psi - 1)\, C_1 + Y_2\right]$$

subject to $m_0 + s_0 \leq 1$, the liquidity constraint

$$C_1 \quad \leq \quad \begin{cases} m_0 + s_0 & \text{if} \quad \lambda_1 = \lambda^L, \quad \text{prob.} \quad 1 - p_H(\lambda_0) \\ m_0 & \text{if} \quad \lambda_1 = \lambda^H, \quad \text{prob.} \quad p_H(\lambda_0), \end{cases}$$

and the collateral constraint

$$m_0 + s_0(1 - \overline{\kappa}) \quad \leq \quad 1 - \kappa_Y.$$

Equilibrium security issuance:

i. if $p_H(\lambda_0) \leq \overline{\kappa}$, then $m_0 = 0$ and $s_0 = \frac{1-\kappa_Y}{1-\overline{\kappa}}$
(low uncertainty, liquidity supply large but fragile);

ii. if $p_H(\lambda_0) > \overline{\kappa}$, then $m_0 = 1 - \kappa_Y$ and $s_0 = 0$
(high uncertainty, liquidity supply small but stable);

$\Rightarrow$ Trade-off between quantity and stability of the liquidity supply

MODEL ROADMAP

1. Static model for core mechanism
2. **Dynamic model for amplification, cycles, and effects of policy**

Investors

Investors maximize

$$V_0 = \max \; E_0 \left[\int_0^{\infty} e^{-\rho t} W_t \left(\psi dc_t^{\psi} dz_t + c_t dt \right) \right], \tag{1}$$

- $dz_t = 1$ denote a liquidity event, Poisson with intensity h
- $dc_t^{\psi} \leq \overline{c}_t^{\psi}$ where $\overline{c}_t^{\psi} \sim Exp(\eta)$ i.i.d.
  * leads to decreasing demand for liquidity
  * each additional dollar of liquidity more likely to go unused
- both dz_t and $\overline{c}_t^{\psi}$ independent across investors

Capital accumulation

1. Two technologies: A high-growth risky; B low-growth safe

$$
\begin{aligned}
dk_t^a/k_t^a &= \left[\phi^a\left(\iota_t^a\right) - \delta\right]dt - \kappa^a dZ_t \\
dk_t^b/k_t^b &= \left[\phi^b\left(\iota_t^b\right) - \delta\right]dt
\end{aligned}
$$

   - investment ι_t^a, ι_t^b; adjustment cost $\phi'' < 0$; depreciation δ
   - $dZ_t \sim$ compensated (mean-zero) Poisson "crash", exposure $\kappa^a > 0$
   - intensity λ_t, measures uncertainty

2. Output $y_t = y^a k_t^a + y^b k_t^b$

   - productivity $y^a > y^b$
   - capital mix becomes slow-moving state variable

$$
\chi_t = \frac{k_t^a}{k_t^a + k_t^b}
$$

Time-varying uncertainty

1. Latent true probability of a crash $\tilde{\lambda}_t \in \{\lambda^L, \lambda^H\}$

   - follows two-state Markov chain with generator unconditional mean $\overline{\lambda}$ and overall transition rate φ

   - agents learn from crashes (dZ_t) and Brownian "news" (dB_t)

2. Bayesian learning $\Rightarrow$ time-varying uncertainty $\lambda_t = E_t[\tilde{\lambda}_t]$

   - low after a long quiet period (Great Moderation)

   - high after a crash (Reinhart-Rogoff)

   - jumps most from moderately low levels ("Minsky moment")

$$d\lambda_t = \varphi\left(\overline{\lambda} - \lambda_t\right) dt + \Sigma_t \left(\nu dB_t + \frac{1}{\lambda_t} dZ_t\right),$$

$\Sigma_t \equiv Var_t\left(\tilde{\lambda}_t\right) = \left(\lambda^H - \lambda_t\right)\left(\lambda_t - \lambda^L\right)$

ν is the precision of the Brownian signal

Markets

1. Assets claims to one unit of capital. Asset prices $q_t^i = q^i(\lambda_t, \chi_t)$

$$dq_t^i / q_t^i = \mu_{q,t}^i dt + \sigma_{q,t}^i dB_t - \kappa_{q,t}^i dZ_t, \; i = a, b \tag{2}$$

2. Intermediaries again tranche assets into securities. With two shocks (dZ_t, dB_t), a generic security x's return has form

$$dr_t^x = \mu_{x,t} dt + \sigma_{x,t} dB_t - \kappa_{x,t} dZ_t. \tag{3}$$

Now we take the securities and liquidity profiles from before as given

i. money m with $\kappa_{m,t} = \sigma_{m,t} = 0$ is liquid with probability 1 (always-liquid);

ii. shadow money s with $\kappa_{s,t} = \overline{\kappa}$ and $\sigma_{s,t} = 0$ is liquid with probability $1 - p_H(\lambda_t)$, where $p_H'(\lambda_t) > 0$ (fragile-liquid);

iii. equity e with $\kappa_{e,t} = 1$ and $|\sigma_{e,t}| > 0$ is illiquid.

Demand for liquidity and securities expected returns

$$\rho V_t dt \quad = \quad \max_{m_t, s_t, dc_t^{\psi}, c_t} \; E_t\left[W_t\left(\psi dc_t^{\psi} dz_t + c_t dt\right)\right] + \; E_t\left[dV_t\right]$$

subject to $c_t^{\psi} \leq \overline{c}_t^{\psi}$ and the budget and liquidity constraints

$$\frac{dW_t}{W_t} \quad = \quad dr_t^e + m_t(dr_t^m - dr_t^e) + s_t(dr_t^s - dr_t^e) - c_t dt - dc_t^{\psi} dz_t$$

$$dc_t^{\psi} \quad \leq \quad \begin{cases} m_t + s_t & \text{prob.} \quad 1 - p_H(\lambda_t) \\ m_t & \text{prob.} \quad p_H(\lambda_t) \,. \end{cases}$$

Risk-neutrality implies the problem simplifies to

$$\rho \quad = \quad \max_{m_t, s_t} \; h(\psi - 1)\left[[1 - p_H(\lambda_t)] \int_0^{\infty} \min\{\overline{c}_t^{\psi}, m_t + s_t\} dF\left(\overline{c}_t^{\psi}\right) + p_H(\lambda_t) \int_0^{\infty} \min\{\overline{c}_t^{\psi}, m_t\} dF\left(\overline{c}_t^{\psi}\right)\right] + \mu_{W,t}.$$

where $F(\overline{c}_t^{\psi}) = Exp(\eta)$ the liquidity size distribution

Demand for liquidity and securities expected returns

Proposition (Securities expected returns)

The liquidity premium

$$\mu_{e,t} - \mu_{m,t} = h(\psi - 1)\left([1 - p_H(\lambda_t)] e^{-\eta(m_t + s_t)} + p_H(\lambda_t) e^{-\eta m_t} \right)$$

The shadow-money money spread

$$\mu_{s,t} - \mu_{m,t} = h(\psi - 1) p_H(\lambda_t) e^{-\eta m_t}.$$

The aggregate discount rate

$$\mu_{W,t} = \left[\rho - \frac{h}{\eta}(\psi - 1)\right] + \frac{1}{\eta}(\mu_{e,t} - \mu_{m,t}).$$

A lower liquidity premium reduces the cost of consuming in a high marginal utility state, increasing savings.

Intermediaries

Intermediaries maximize present value of profits

$$0 = \max_{m,s,k^a,k^b,\iota^a,\iota^b} \left[\left(y^a - \iota^a\right) k^a + \left(y^b - \iota^b\right) k^b \right] dt + E_t\left[dA_t\right]$$
$$+A_t\left[m(\mu_{e,t} - \mu_{m,t}) + s(\mu_{e,t} - \mu_{s,t}) - \mu_{e,t}\right] + E_t\left[dV_t\right],$$

subject to the collateral constraint

$$m_t + s_t(1-\overline{\kappa}) \quad \leq \quad 1 - \kappa_{A,t}, \ [\theta_t]$$

Aggregate collateral is value weighted sum of asset collateral values

$$1 - \kappa_{A,t} \quad = \quad \chi_t^q \underbrace{\left(1-\kappa_k^a\right)\left(1-\kappa_{q,t}^a\right)}_{1-\kappa_t^a} + \left(1-\chi_t^q\right) \underbrace{\left(1-\kappa_{q,t}^b\right)}_{1-\kappa_t^b},$$

- collateral values depend on the endogenous price exposure.
- θ low when B supply high or demand for shadow money high

Intermediaries: asset prices and investment

1. Intermediaries can scale up their balance sheets by issuing more securities and buying more assets. We get two PDEs:

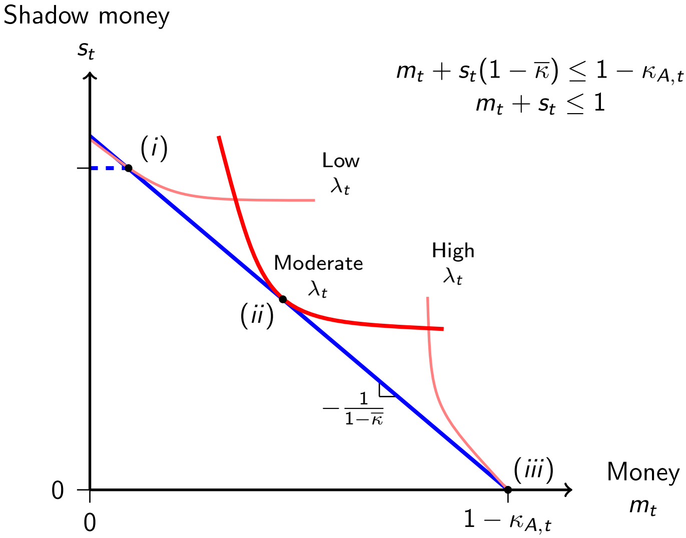
$$q_t^i = \frac{y^i - \iota_t^i}{\left(\mu_{W,t} - \theta_t\left[\left(1-\kappa_t^i\right) - \left(1-\kappa_{A,t}\right)\right]\right) - \left[\mu_{q,t}^i + \kappa_k^i \kappa_{q,t}^i \lambda_t + \phi\left(\iota_t^i\right) - \delta\right]}$$

   - Collateral rich asset B discounted at lower rate than asset A
   - Difference higher when collateral premium θ is high
   - Asset B tends to appreciate in a crash, $1 - \kappa_{q,t}^b > 1$ ($\theta \uparrow$)

2. Intermediaries set investment, driven by standard q-theory:

$$1 = q_t^i \phi'\left(\iota_t^i\right), \qquad i = a, b.$$

Intermediaries and the supply of liquidity



Intermediaries and the supply of liquidity

Proposition (Equilibrium security issuance)

Let $\mathcal{M}_t \equiv \frac{1}{\eta} \log \left(\frac{\overline{\kappa}}{1-\overline{\kappa}} \frac{1-p_H(\lambda_t)}{p_H(\lambda_t)} \right)$*. Then in equilibrium issuance follows*

i. *(boom) if* $\mathcal{M}_t > \min \left\{ \frac{\kappa_{A,t}}{\overline{\kappa}}, \frac{1-\kappa_{A,t}}{1-\overline{\kappa}} \right\}$,

$$m_t = \max \left\{ 0, 1 - \frac{\kappa_{A,t}}{\overline{\kappa}} \right\} \text{ and } s_t = \min \left\{ \frac{1-\kappa_{A,t}}{1-\overline{\kappa}}, \frac{\kappa_{A,t}}{\overline{\kappa}} \right\} ;$$

ii. *(recovery) if* $0 \leq \mathcal{M}_t \leq \min \left\{ \frac{\kappa_{A,t}}{\overline{\kappa}}, \frac{1-\kappa_{A,t}}{1-\overline{\kappa}} \right\}$,

$$m_t = 1 - \kappa_{A,t} - (1 - \overline{\kappa}) \mathcal{M}_t \text{ and } s_t = \mathcal{M}_t \text{ ; and}$$

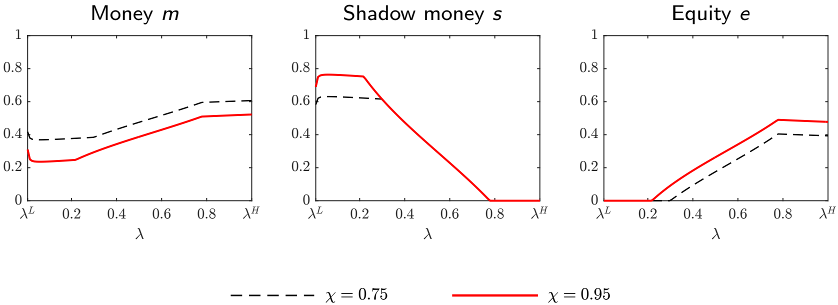
iii. *(bust) if* $\mathcal{M}_t < 0$, $m_t = 1 - \kappa_{A,t}$ *and* $s_t = 0$.

$\mathcal{M}_t$ measures marginal value of first unit of shadow money

RESULTS

1. Parameter values in paper
2. Model in closed form up to prices
3. Solve for prices $q^i(\chi, \lambda), i = a, b$ numerically using projection methods

Security markets

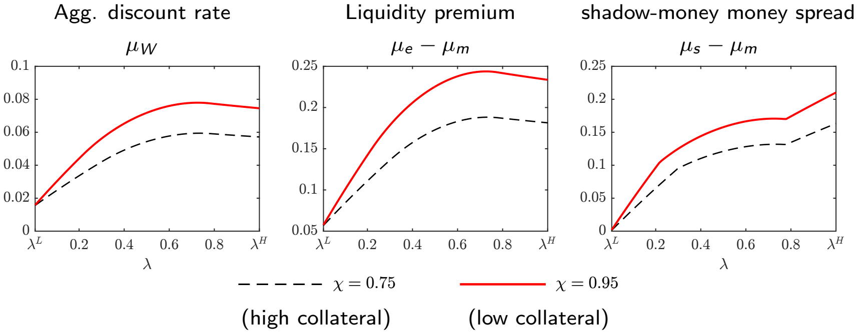


(high collateral) (low collateral)

1. Shadow banking booms in low uncertainty-low collateral states
   - crowds out money creation in booms
   - disappears when uncertainty rises from a low level (e.g. August 07)

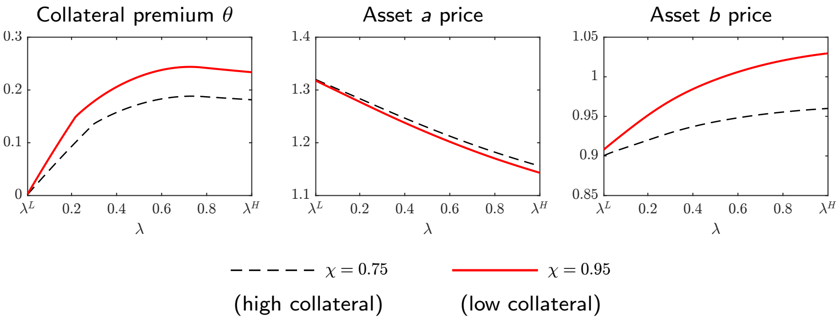
2. Money is produced most when collateral is abundant (low χ).

Discount rates



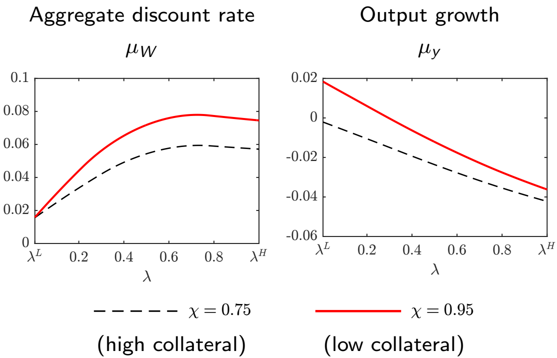
1. Higher uncertainty causes the shadow-money money spread to rise, shadow banking contracts, lower liquidity supply causes liquidity premium and overall discount rate to rise
2. Discount rates are more uncertainty-sensitive when shadow banking activity is high (low uncertainty, low collateral)

Asset markets



1. Higher uncertainty causes the collateral premium to rise, lowers the price of the risky asset and raises the price of the safe asset
2. Riskier asset mix χ means less collateral, lowers q^a and raises q^b

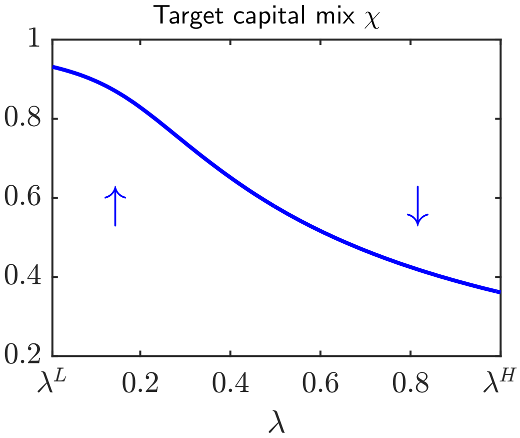
The macroeconomy



1. Growth more uncertainty-sensitive when shadow banking is high (collateral and uncertainty are low)

2. Real boom coincides with shadow banking boom

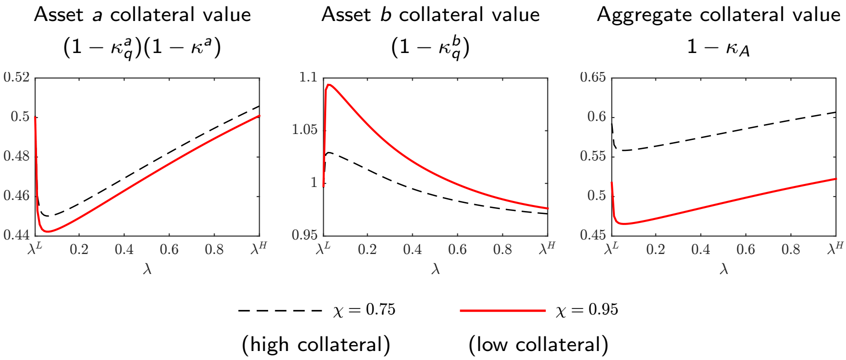
The macro cycle



1. Capital mix drifts towards risky asset during shadow banking boom
2. Capital mix drifts towards safe asset during bust

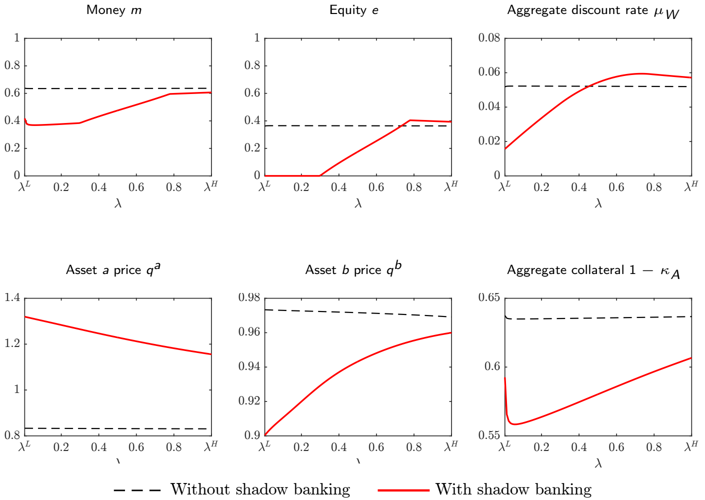
$\Rightarrow$ Fragility buildup in booms, collateral mining in bust

Collateral runs



1. Collateral values fall as prices fall $\Rightarrow$ prices fall more, etc.
2. Amplifies liquidity contraction
3. Flight to quality implies safe assets have excess collateral

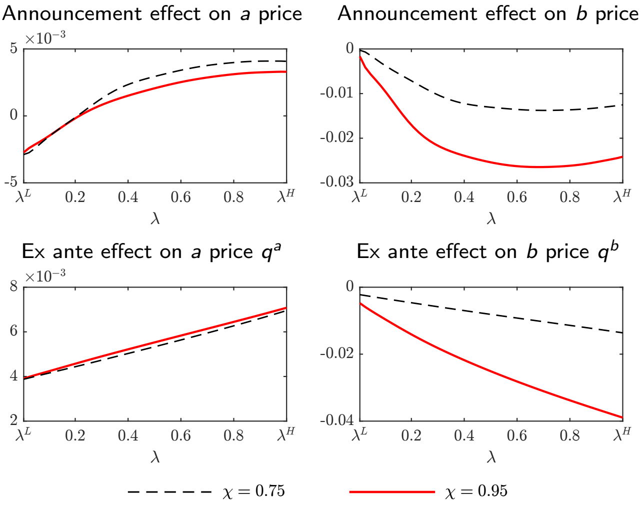
Cycles are a product of shadow banking



EFFECTS OF POLICY INTERVENTIONS

QE1 - Large-Scale Asset Purchases

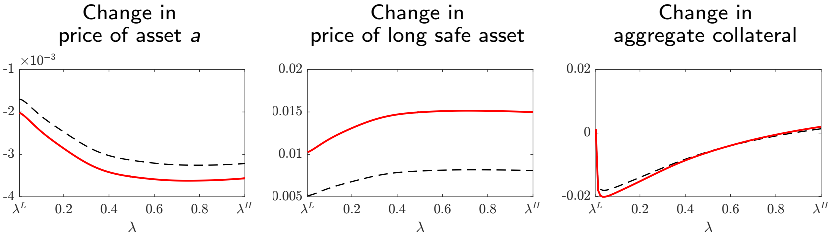
1. Fed buys risky *a* and sells safe *b* asset (Ricardian)



(high collateral) (low collateral)

QE2 - Operation Twist

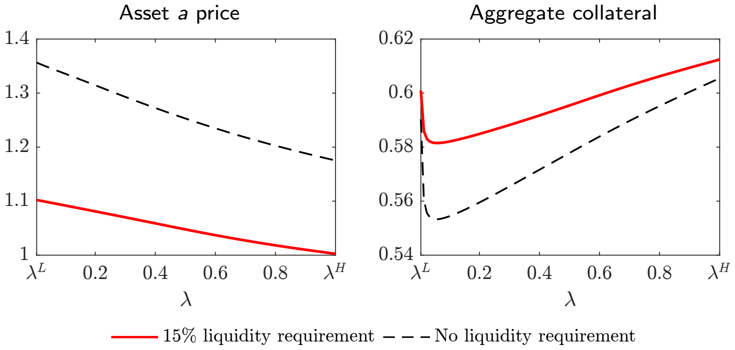
1. Fed buys long-term safe bonds and sells short-term safe bonds.
   - long-term safe bond acts as crash hedge due to flight to quality
   - short-term safe bond safe but not a hedge



2. OT reduces the supply of collateral $\Rightarrow$ liquidity provision falls
   $\Rightarrow$ discount rates rise, especially for risky/productive assets

Liquidity requirements

1. Limit liquidity mismatch: $m_t + s_t \leq \bar{l}$



3. Mitigate collateral runs, enhance financial stability
4. *But* higher discount rates, lower prices

Monetary policy normalization

1. Pre-crisis view: short-term rate captures monetary policy stance
2. Our framework:

$$\textit{Tbill rate} = \begin{pmatrix} \textit{aggregate} \\ \textit{discount rate} \end{pmatrix} - \theta_t \begin{pmatrix} \textit{collateral value} \\ \textit{of Tbill} \end{pmatrix}$$

$\Rightarrow$ Tbill rate can be low if collateral premium θ_t is high and policy *tight*

3. Reverse repo facility
   - "... should help to establish a floor on the level of overnight rates." (Dudley, 2013)
   - accommodative, even though pushes the safe rate up
   - releases collateral to financial system ($\theta_t \searrow$)

Takeaways

1. Liquidity transformation and the macro cycle
   - tradeoff between quantity and fragility of liquidity provision
2. Shadow banking expands liquidity supply in booms
   - lower discount rates, more investment, more growth
   - increases economic and financial fragility
3. Framework has implications for
   - monetary policy, financial stability regulation

Is it better to have been liquid and lost than never to have been liquid at all?

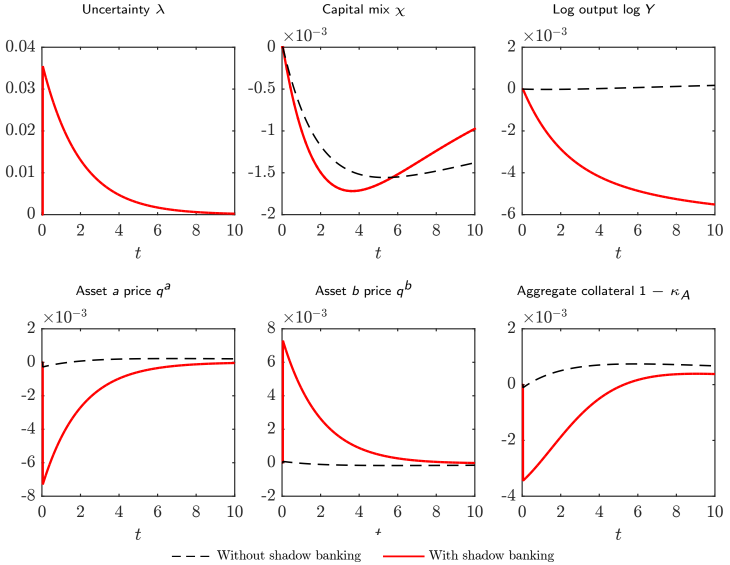
APPENDIX

Benchmark parameters

This table contains the benchmark values for the model parameters used to produce results for the dynamic model. The investment cost function is parameterized as $\phi(\iota) = 1/\gamma\left(\sqrt{1+2\gamma\iota}-1\right)$. We use the specification implied by the static model for the probability that shadow money becomes illiquid. i.e. $p_H(\lambda) = \left(\lambda - \lambda^L\right) / \left(\lambda^H - \lambda^L\right)$.

Description	Parameter	Value
Technology:		
Asset cash flows	y^a, y^b	$0.138, 0.1$
Depreciation rate	δ	0.1
Exogenous aggregate growth	μ_0	0.01
Adjustment cost parameter	γ	3
Asset crash exposures	κ^a, κ^b	$0.5, 0$
Information sensitivity constraint:		
Crash exposure limit for fragile liquid securities	$\overline{\kappa}$	0.7
Uncertainty:		
Low/high uncertainty states	λ^L, λ^H	$0.005, 1$
Average uncertainty	$\overline{\lambda}$	0.0245
Uncertainty rate of mean reversion	φ	0.5
Uncertainty news signal precision	$1/\sigma$	0.1
Preferences and liquidity events:		
Liquidity event frequency	h	0.28
Liquidity event marginal utility	ψ	5
Average size of liquidity event	$1/\eta$	0.33
Subjective discounting parameter	ρ	0.37

Uncertainty shock impulse responses



Crash shock impulse responses