Monetary policy and endogenous financial crises

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Research focus: relation between monetary policy and financial stability

- Monetary policy sometimes blamed (eg for sowing the seeds of the GFC), sometimes praised (eg for containing financial risks during Covid–19) for its effects on financial stability
- New–Keynesian (NK) model with micro–founded endogenous financial crises to discipline the discussion over what a central bank should/should not do
- Patterns of a typical financial crisis in the model match key stylized facts in the data
  - follows credit/investment boom (*e.g.* Schularick and Taylor (2012))
  - leads to resource mis–allocation and inefficiently low output (*e.g.* Campello, Graham, Harvey (2010), Foster, Grim, Haltiwanger (2016) for the GFC)

Roadmap

1. NK model with micro–founded endogenous crises
2. Typical path to crises
3. How does monetary policy affect financial stability?

NK model with micro–founded endogenous crises

Departures from the textbook NK model with sticky prices

1. Capital accumulation allows for gradual build–up of financial imbalances via savings
2. Financial frictions affect production and occasionally entail "crises"
3. Model solved globally to analyze dynamics far from steady–state

Agents

1. Central bank sets nominal rate in response to inflation and output fluctuations ◂ Central bank
2. Households work, consume, save in a safe bond ($\rightarrow i_t$) and firm equity ($\rightarrow$ MPK) ◂ Households
3. Monopolistic retailers sell differentiated final goods and set (sticky) prices ◂ Retailers
4. Competitive intermediate goods firms invest in capital, hire labor, sell goods to retailers

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4. Competitive intermediate goods firms invest in capital, hire labor, sell goods to retailers
   - + *Ex post* idiosyncratic productivity shocks $\rightarrow$ firms may adjust capital stock up/down by borrowing/lending in a loan market
   - + Loan market subject to frictions (MH+AI)
   - + Loan market may collapse $\equiv$ crisis $\rightarrow$ no capital adjustment/reallocation

Note: The equilibrium of the model may also be obtained with a story told in terms of financial intermediation via a banking sector

Agents — Intermediate goods firms

- Firms live one period, from the end of period $t-1$ until the end of period t
- At the end of $t-1$, they are identical, issue equity and purchase capital K_t
- At the beginning of t, they learn their technology $q \in \{0,1\}$, adjust/resize their capital stock from K_t to $K_t(q)$, take their hiring decision $N_t(q)$

$$Y_t(q) = A_t(qK_t(q))^{\alpha} N_t(q)^{1-\alpha}, \text{ where } q = 0 \text{ or } 1 \text{ with probability } \mu \text{ and } 1-\mu$$

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- Reshuffling of capital stock may be done via an intra–period loan market – if functions well:
  - Mass μ of unproductive firms (with $q=0$) lend K_t capital goods at rate r_t^{ℓ}
  - Mass $1-\mu$ of productive firms (with $q=1$) borrow $K_t(1)-K_t$ capital goods at r_t^{ℓ}

Loan market — Borrowers' participation constraint

- Firm $q = 1$ maximizes its real return on equity w.r.t. $K_t(1)$ and $N_t(1)$:

$$\max_{K_t(1), N_t(1)} \frac{p_t}{P_t} A_t K_t(1)^{\alpha} N_t(1)^{1-\alpha} - \omega_t N_t(1) + (1-\delta) K_t(1) - (1 + r_t^{\ell})(K_t(1) - K_t)$$

- Firm $q = 1$ borrows and resizes its capital from K_t to $K_t(1) \geq K_t$ only if the aggregate MPK_t (net of capital depreciation) covers the loan rate, *i.e.*:

$$MPK_t \equiv \frac{\alpha}{\mathcal{M}_t} \frac{Y_t(1)}{K_t(1)} \geq r_t^{\ell} + \delta \qquad \text{(PC)}$$

Details

Loan market — Frictionless benchmark

- Productive firms break even:

$$\frac{\alpha}{\mathcal{M}_t}\frac{Y_t(1)}{K_t(1)} = r_t^{\ell} + \delta$$

- Capital K_t is perfectly reallocated toward the firms with $q = 1$

$$\mu K_t = (1-\mu)(K_t(1) - K_t)$$

- Aggregate output is the same as in the standard NK model (*i.e.* case with $\mu = 0$)

$$Y_t = A_t K_t^{\alpha} N_t^{1-\alpha}$$

Loan market — Frictional case

MH: Firms may keep capital $K_t(q)$ idle, abscond, sell $(1-\delta)K_t(q)$ at the end of the period, and earn $P_t(1-\delta)K_t(q)$

AI: The qs are private information

$\Rightarrow$ Firms with $q = 0$ may mimic firms with $q = 1$, borrow capital and abscond, rather than lend their initial capital stock K_t and earn $P_t(1 + r_t^\ell)K_t$

Loan market — Lenders/borrowers' incentive–compatibility constraint

- The loan contract ensures that firms with $q = 0$ lend rather than borrow/abscond

$$\underbrace{P_t(1-\delta)K_t(1)}_{\text{borrows } K_t(1)-K_t \text{ and absconds}} \leq \underbrace{P_t(1+r_t^\ell)K_t}_{\text{lends}} \qquad \text{(IC)}$$

$$\Leftrightarrow \quad \frac{K_t(1)-K_t}{K_t} \leq \underbrace{\frac{r_t^\ell+\delta}{1-\delta}}_{\text{borrowing limit}} \quad \forall q \in \{0,1\}$$

- Firms' borrowing limit increases in r_t^ℓ – unproductive firms' opportunity cost of absconding (*i.e.* their "skin in the game")

Loan market — Equilibrium

- Supply from $q = 0$ firms: μK_t if $-\delta < r_t^\ell$ and 0 otherwise
- Demand from $q = 1$ firms: $(1-\mu)\underbrace{\frac{r_t^\ell + \delta}{1-\delta} K_t}_{K_t(1) - K_t}$ if $\underbrace{r_t^\ell \leq \frac{\alpha}{\mathcal{M}_t} \frac{Y_t(1)}{K_t(1)} - \delta}_{\text{(PC)}}$ and 0 otherwise
- Trade takes place if and only if

$$MPK_t \equiv \frac{\alpha}{\mathcal{M}_t} \frac{Y_t}{K_t} \geq \frac{(1-\delta)\mu}{1-\mu} \equiv \hat{r}^\ell + \delta$$

$$\text{where} \quad \mathcal{M}_t \equiv \frac{P_t}{p_t}$$

▸ S–D schedules

Aggregate outcome — Crisis versus normal times

- **In crisis times**
  - Financial autarky $\rightarrow$ unproductive firms keep their capital idle
  - Capital mis–allocation lowers aggregate productivity

$$Y_t = A_t \left((1-\mu) K_t \right)^{\alpha} N_t^{1-\alpha}$$

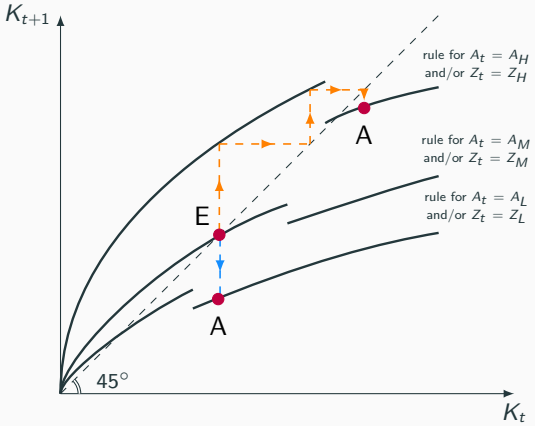
- **In normal times** capital is fully reallocated $\rightarrow$ the frictional economy resembles the frictionless one...

$$Y_t = A_t K_t^{\alpha} N_t^{1-\alpha}$$

... except that households may accumulate precautionary savings in anticipation of a crisis

$\rightarrow$ Financial externalities: a higher K_t may precipitate the crisis

Aggregate outcome — Two polar types of crisis



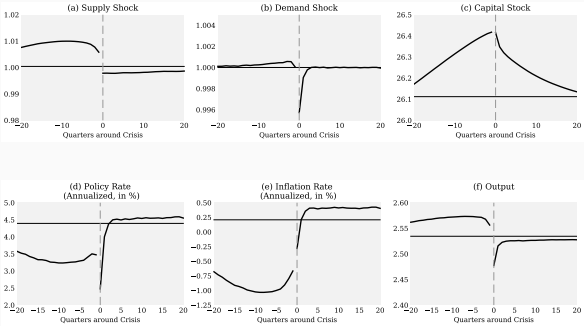
Optimal capital accumulation decision rules $K_{t+1}(K_t, A_t, Z_t)$

Real return on capital may decline below the crisis threshold because of

- unusually large adverse shocks
  $\rightarrow$ "exogenous crisis"
- excess capital accumulation during an unusually long sequence of favorable shocks
  $\rightarrow$ "endogenous crisis"

Typical path to crises

Average crisis episodes — Dynamics under standard Taylor rule (STR)



- Crises occur toward the end of a boom due to long sequences of positive technology and/or demand shocks ◂ Fragility
- Crises are triggered by relatively mild adverse TFP and/or demand shocks
- TFP shocks are prevalent in the build–up of crises ◂ Techno vs demand statistics

◂ Parametrisation ◂ Techno vs demand shocks

How does monetary policy affect financial stability?

Channels

- Probability that a crisis breaks out next period:

$$\mathbb{E}_{t-1}\left(\mathbb{1}\left\{\frac{\alpha Y_t}{\mathcal{M}_t K_t} < \frac{(1-\delta)\mu}{1-\mu}\right\}\right)$$

- The central bank affects financial stability by the way it

  (i) stabilizes aggregate output (Y) and inflation (M) in response to contemporaneous shocks $\rightarrow$ **short–term dimension**

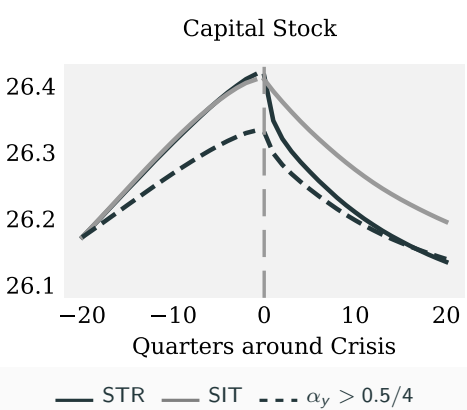
  (ii) affects capital accumulation (CA) along the business cycle $\rightarrow$ **long/medium–term dimension**

Probability of a crisis under alternative monetary policy regimes

	Crisis statistics				YMCA channels			
	% Crisis time	Length	% Nb crises	Output loss	$\sigma(Y_t)$	$\sigma(\mathcal{M}_t)$	$\sigma(K_{t-1})$	$\rho(Y_t, \mathcal{M}_t)$
STR	[10]	1.86	5.48	-2.73	4.36	1.07	4.39	-0.06
SIT	1.91	4.47	0.43	-5.84	4.49	0.00	4.90	0.00
$\alpha_y > 0.5/4$	[0.50]	1.78	0.28	-2.27	3.17	1.23	2.63	0.93

- SIT significantly reduces the time spent in crisis relative to STR $\rightarrow$ eliminates both demand–driven *and* mixed crises
- A stronger response to output can eliminate even more crises relative to STR than SIT

Financial stability gains of $\phi_y > 0.5/4$ in the short and long run



(i) Improved CA channel: Households accumulate less capital during booms than under SIT or STR since:

- expected real return on investment is lower
- are better insured against negative shocks (less need for precautionary savings)

(ii) Improved Y and M channels IRF negative TFP shock

- Y better stabilized in response to adverse shocks
- M declines more in response to adverse TFP shocks

Policy trade–off

- No financial frictions: stabilizing inflation (SIT) is optimal

$\Rightarrow$ Relative to SIT, in "normal" times, variations in macro–variables in response to demand and technology shocks under $\phi_y > 0.5/4$ are inefficient

- A benevolent central bank may choose $\phi_y > 0.5/4$ instead of SIT only if the financial stability gains exceed the losses in the face of business cycle fluctuations in normal times

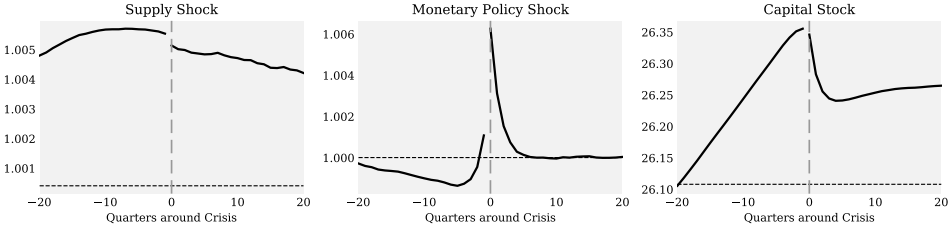
Breaking the "divine coincidence"

- No financial frictions: stabilizing inflation (SIT) is optimal
- Financial frictions: responding more strongly to output relative to STR may outperform SIT

Policy rules

	PCE (in %)
STR	–
SIT	0.0560
$\alpha_y > 0.5/4$	0.0641

What central banks should not do



(i) Keeping policy unexpectedly loose for a long time ("too low for too long") may feed an investment boom (in line with ◂ US's 2003–5 "Great Deviation" hypothesis)

(ii) Unexpected rate hikes toward the end of a boom may contract demand and trigger a crisis (in line with Schularick et al 2021)

Takeaways (so far)

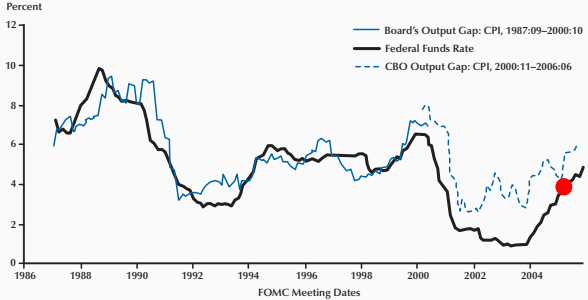
1. "Canonical" NK model with endogenous financial crises + micro–foundations to existing reduced form models
   - Crises follow investment booms due to favorable shocks
   - Monetary policy affects financial stability through YMCA channels
2. Benevolent central bank trades off the short–term cost (deviations from first best in normal times) and medium/long–term benefits (fewer/milder financial crises)
   - With prevalent technology–driven crises, a stronger response to output than under STR may be warranted
   - Unexpectedly keep rates low for long, or unexpectedly tighten policy on the heals of booms may trigger financial crises

Backup Slides

The “Great Deviation” (John Taylor)

Figure 1

Greenspan Years: Federal Funds Rate and Taylor Rule
(CPI $p^* = 2.0$, $r^* = 2.0$) $a = 1.5$, $b = 0.5$



Poole (2007): "Understanding the Fed", Federal Reserve Bank of St. Louis Review, January/February 2007, 89(1), pp. 3-13.

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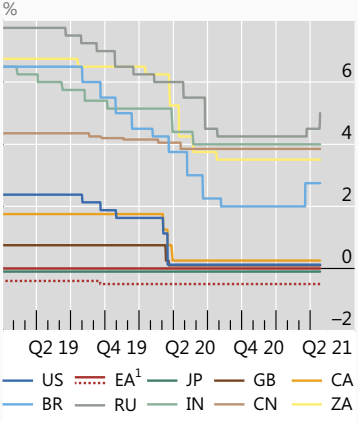
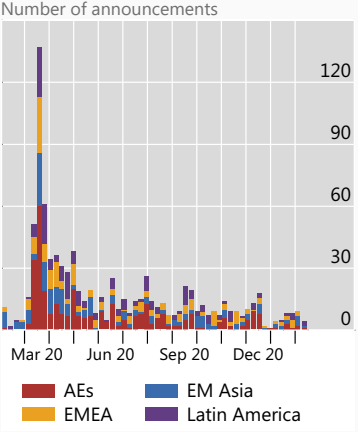
Current stance

Monetary policy during the Covid–19 crisis

Evolution of monetary policy rates



Weekly announcements of policies



Revised Fed's statement on longer-run goals and monetary policy strategy

2. **Employment,** inflation, ~~employment,~~ and long-term interest rates fluctuate over time in response to economic and financial disturbances. **Monetary policy plays an important role in stabilizing the economy in response to these disturbances. The Committee's primary means of adjusting the stance of monetary policy is through changes in the target range for the federal funds rate. The Committee judges that the level of the federal funds rate consistent with maximum employment and price stability over the longer run has declined relative to its historical average. Therefore, the federal funds rate is likely to be constrained by its effective lower bound more frequently than in the past. Owing in part to the proximity of interest rates to the effective lower bound, the Committee judges that downward risks to employment and inflation have increased. The Committee is prepared to use its full range of tools to achieve its maximum employment and price stability goals.** ~~Moreover, monetary policy actions tend to influence economic activity and prices with a lag. Therefore, the Committee's policy decisions reflect its longer-run goals, its medium-term outlook, and its assessments of the balance of risks, including risks to the financial system that could impede the attainment of the Committee's goals.~~

5. **Monetary policy actions tend to influence economic activity, employment, and prices with a lag.** In setting monetary policy, the Committee seeks **over time** to mitigate **shortfalls of employment from the Committee's assessment of its maximum level and** deviations of inflation from its longer-run goal ~~and deviations of employment from the Committee's assessments of its maximum level~~. **Moreover, sustainably achieving maximum employment and price stability depends on a stable financial system. Therefore, the Committee's policy decisions reflect its longer-run goals, its medium-term outlook, and its assessments of the balance of risks, including risks to the financial system that could impede the attainment of the Committee's goals.**

Monetary policy rule

$$1 + i_t = \underbrace{\frac{1}{\beta}(1+\pi_t)^{1.5}\left(\frac{Y_t}{Y}\right)^{0.125}}_{\text{STR (Taylor (1993))}}$$

Back to agents

Households

$$\mathbb{E}_0 \left[\sum_{t=0}^{\infty} \beta^t \left(\frac{C_t^{1-\sigma}}{1-\sigma} - \vartheta \frac{N_t^{1+\nu}}{1+\nu} \right) \right]$$

$$P_t C_t + B_{t+1} + P_t K_{t+1} \leq P_t \omega_t N_t + (1 + i_{t-1}) B_t + P_t (1 + r_t^k) K_t + \mathcal{X}_t$$

$$\beta \mathbb{E}_t \left[\left(\frac{C_{t+1}}{C_t} \right)^{-\sigma} \frac{1 + i_t}{1 + \pi_{t+1}} \right] = Z_t$$

$$\beta \mathbb{E}_t \left[\left(\frac{C_{t+1}}{C_t} \right)^{-\sigma} (1 + r_{t+1}^k) \right] = 1$$

$$\vartheta N_t^{\nu} C_t^{\sigma} = \omega_t$$

Back to agents

Retailers

$$\mathbb{E}_0\left[\sum_{t=0}^{\infty}\Lambda_{0,t}\left(\frac{P_t(j)}{P_t}Y_t(j)-\frac{p_t}{P_t}Y_t(j)-\frac{\varrho}{2}Y_t\left(\frac{P_t(j)}{P_{t-1}(j)}-1\right)^2\right)\right]$$

$$Y_t(j)=\left(\frac{P_t(j)}{P_t}\right)^{-\epsilon}Y_t$$

$$(1+\pi_t)\pi_t=\mathbb{E}_t\left(\Lambda_{t,t+1}\frac{Y_{t+1}}{Y_t}(1+\pi_{t+1})\pi_{t+1}\right)-\frac{\epsilon-1}{\varrho}\left(1-\frac{\epsilon}{\epsilon-1}\frac{1}{\mathcal{M}_t}\right)$$

where

$$\mathcal{M}_t\equiv\frac{P_t}{p_t}$$

Back to agents

Firms

$$\max_{K_t(1),N_t(1)} \frac{p_t}{P_t} A_t K_t(1)^{\alpha} N_t(1)^{1-\alpha} - \omega_t N_t(1) + (1-\delta)K_t(1) - (1+r_t^{\ell})(K_t(1) - K_t)$$

Substituting the FOC w.r.t. $N_t(1)$ into the firm's profits yields

$$\max_{K_t(1)} \frac{\alpha}{\mathcal{M}_t} \frac{Y_t(1)}{K_t(1)} K_t(1) + (1-\delta)K_t - (r_t^{\ell} + \delta)(K_t(1) - K_t)$$

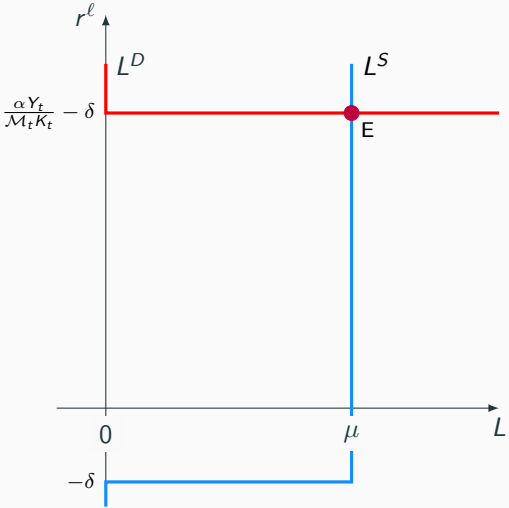
Since $Y_t = (1-\mu)Y_t(1)$, $K_t = (1-\mu)K_t(1)$ and $\frac{Y_t(1)}{K_t(1)} = A_t^{\frac{1}{\alpha}} \left(\frac{1-\alpha}{\mathcal{M}_t \omega_t}\right)^{\frac{1-\alpha}{\alpha}} = \frac{Y_t}{K_t}$, one gets:

$$\max_{K_t(1)} \left(\underbrace{\frac{\alpha}{\mathcal{M}_t} \frac{Y_t}{K_t}}_{\text{MPK}} - (r_t^{\ell} + \delta) \right) K_t(1)$$

$\Rightarrow$ The firm will resize its capital stock to $K_t(1) \geq K_t$ if MPK $\equiv \frac{\alpha}{\mathcal{M}_t} \frac{Y_t}{K_t} \geq r^{\ell} + \delta$

Back to Loan market

Loan market equilibrium



Frictionless case

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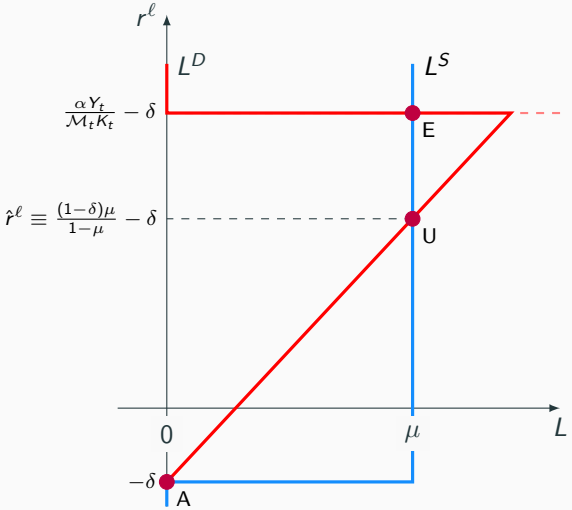
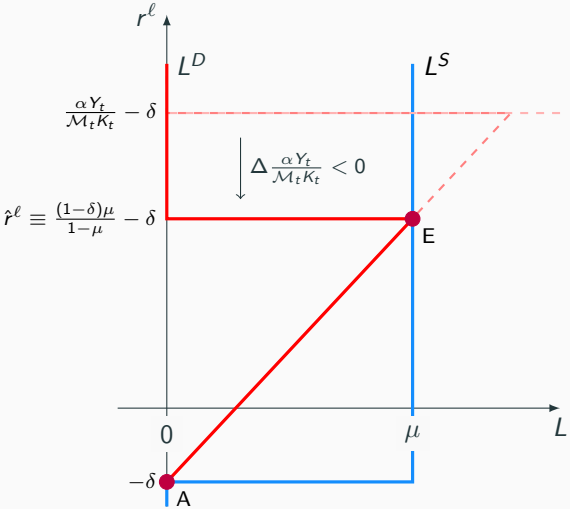
Loan market equilibrium



Frictional case

Back

Loan market equilibrium



- The fall in MPK reduces borrowers ability to pay the loan rate required to preserve unproductive firms' incentives
- r_t^ℓ must be above $\hat{r}^\ell$ to entice unproductive firms to lend rather than borrow and abscond

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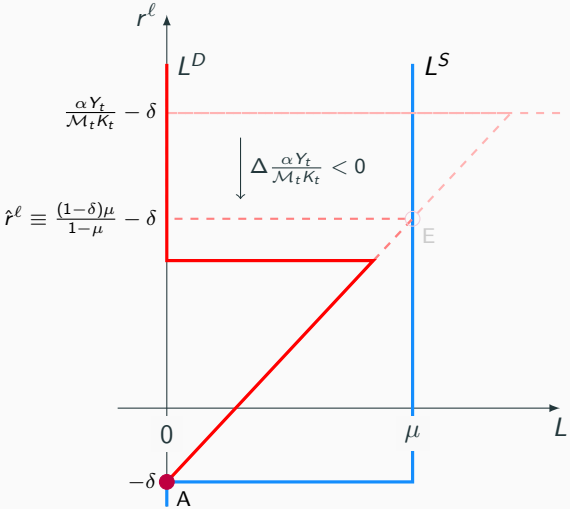
Loan market equilibrium



- Financial autarky
- When $\frac{\alpha Y_t}{\mathcal{M}_t K_t} < \hat{r}^\ell + \delta$ productive firms cannot afford the required loan rate $\rightarrow E$ not sustainable

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List of equations

1. $Z_t = \mathbb{E}_t\left\{\Lambda_{t,t+1}(1+r_{t+1})\right\}$
2. $1 = \mathbb{E}_t\left\{\Lambda_{t,t+1}(1+r^k_{t+1})\right\}$
3. $\omega_t = \vartheta N_t^{\nu} C_t^{\sigma}$
4. $Y_t = A_t\left((1+\phi_t)(1-\mu)K_t\right)^{\alpha} N_t^{1-\alpha}$
5. $\omega_t = (1-\alpha)\dfrac{Y_t}{\mathcal{M}_t N_t}$
6. $r^k_t + \delta = \alpha\dfrac{Y_t}{\mathcal{M}_t K_t}$
7. $(1+\pi_t)\pi_t = \mathbb{E}_t\left(\Lambda_{t,t+1}\dfrac{Y_{t+1}}{Y_t}(1+\pi_{t+1})\pi_{t+1}\right) - \dfrac{\epsilon-1}{\varrho}\left(1-\dfrac{\epsilon}{\epsilon-1}\cdot\dfrac{1}{\mathcal{M}_t}\right)$
8. $1+i_t = \dfrac{1}{\beta}(1+\pi_t)^{\alpha_\pi}\left(\dfrac{Y_t}{Y}\right)^{\alpha_y}$
9. $Y_t = C_t + K_{t+1} - (1-\delta)K_t$
10. $\phi_t = \begin{cases} \dfrac{\mu}{1-\mu} & \text{, if } r^k_t + \delta \geq \dfrac{(1-\delta)\mu}{1-\mu} \\ 0 & \text{, otherwise} \end{cases}$
11. $\Lambda_{t,t+1} \equiv \beta\dfrac{C_{t+1}^{-\sigma}}{C_t^{-\sigma}}$
12. $1+r_t \equiv \dfrac{1+i_{t-1}}{1+\pi_t}$

Parametrisation

Parameter	Target	Value
Preferences		
β	4% annual real interest rate	0.989
σ	Logarithmic utility on consumption	1.000
ν	Inverse Frish elasticity equals 2	0.500
ϑ	Steady state hours equal 1	0.757
Technology and price setting		
α	64% labor share	0.289
δ	6% annual capital depreciation rate	0.015
ϱ	Same slope of the Phillips curve as with Calvo price setting	105.000
ϵ	11% markup rate	10.000
Aggregate shocks		
ρ_a	Persistence of TFP	0.950
σ_a	Standard deviation of TFP innovation (in %)	0.700
ρ_z	Persistence in Smets and Wouters (2007)	0.220
σ_z	Standard deviation of risk–premium innovation in Smets and Wouters (2007) (in %)	0.230
Idiosyncratic productivity shocks		
λ	2pp spread in normal times	23.000
μ	The economy spends 10% of the time in a crisis	0.0176

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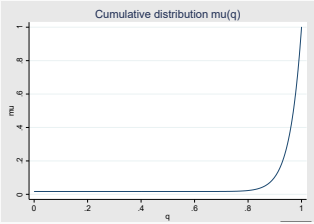

$$\mu(q) = \mu + (1-\mu)q^{\lambda}$$

Monetary policy rule

$$1 + i_t = \frac{1}{\beta}(1 + \pi_t)^{1.5} \left(\frac{Y_t}{Y}\right)^{\alpha_y}$$

$\rightarrow$ We experiment with values of α_y higher than under STR, i.e. $\alpha_y > 0.5/4$

Back to analysis

Average crisis statistics under STR — Demand versus TFP shocks

	% Crisis time	Length	% Nb crises	Output loss
Baseline model	[10.00]	1.86	5.48	−2.73
Model with TFP shocks only	5.53	7.67	0.72	−5.39
Model with demand shocks only	1.25	1.05	1.19	−2.65

- Technology–driven crises last longer and, therefore, are deeper
  - Because technology shocks are more persistent than demand shocks
- The economy spends more time in technology–driven crises, even though they are less frequent than demand–driven ones

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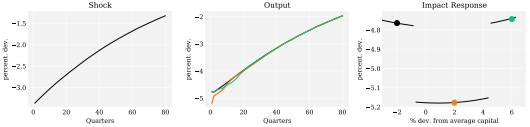
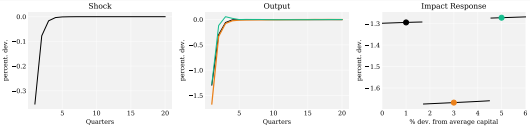
The loan market is more fragile toward the end of a boom

Generalized IRF – Negative TFP shock



K_0 is 2% below $\overline{K}$ — K_0 is 2% above $\overline{K}$ — K_0 is 6% above $\overline{K}$

Generalized IRF — Negative demand shock



K_0 is 1% above $\overline{K}$ — K_0 is 3% above $\overline{K}$ — K_0 is 5% above $\overline{K}$

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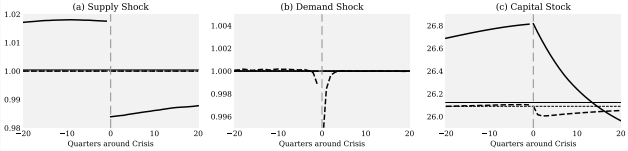
Economies with either technology or demand shocks



- Investment booms are caused by long sequence of favorable technology shocks
- Demand–driven booms are not accompanied with productivity gains and positive demand shocks are short–lived $\rightarrow$ crises tend to break out before capital builds up

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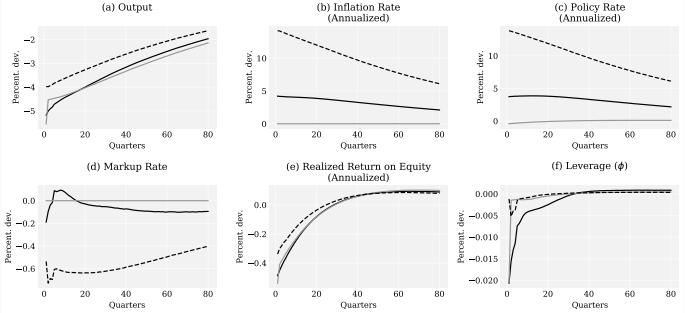
Generalized IRF around steady state — Negative TFP shock



STR SIT LAW with low α_y

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Crisis statistics: technology– and demand–driven crises

	% Crisis time	Length	% Nb crises	Output loss
Crisis due to TFP shocks				
STR	5.45	7.58	0.72	−5.39
SIT	1.91	4.48	0.43	−5.84
LAW–ϕ	0.86	5.43	0.16	−4.13
LAW–$y^{(L)}$	1.06	3.07	0.35	−3.80
LAW–$y^{(M)}$	0.67	3.52	0.19	−3.43
LAW–$y^{(H)}$	0.34	3.16	0.11	−3.39
Crisis due to demand shocks				
STR	1.24	1.05	1.18	−2.65
SIT	0.00	0.00	0.00	0.00
LAW–ϕ	0.00	1.00	0.00	−2.84
LAW–$y^{(L)}$	0.00	0.00	0.00	0.00
LAW–$y^{(M)}$	0.00	0.00	0.00	0.00
LAW–$y^{(H)}$	0.00	0.00	0.00	0.00

Note: The subset of crises specifically due to technology (resp. demand) shocks correspond to the crises that would have broken out even in the absence of demand (resp. technology) shocks.

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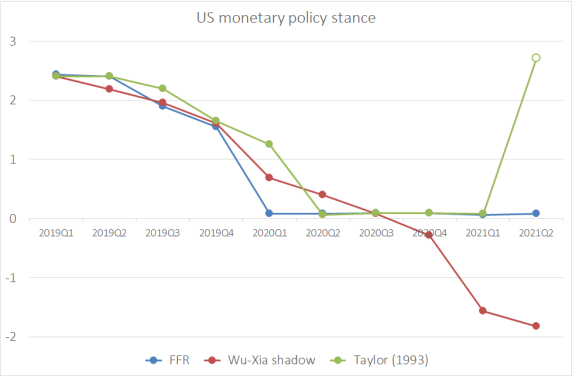
Current US monetary policy stance



Sources: Wu-Xia Shadow Federal Funds Rate - Federal Reserve Bank of Atlanta (atlantafed.org) and Simple Monetary Policy Rules: Archives (clevelandfed.org)

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Related literature

- Monetary policy and financial stability

  Woodford (2012), Smets (2014), Filardo and Rungcharoentkitkul (2016), Svensson (2017), Gourio, Kashyap, Sim (2018), Borio, Disyatat, Rungcharoentkitkul (2019), Ajello, Laubach, Lopez–Salido, Nakata (2019)

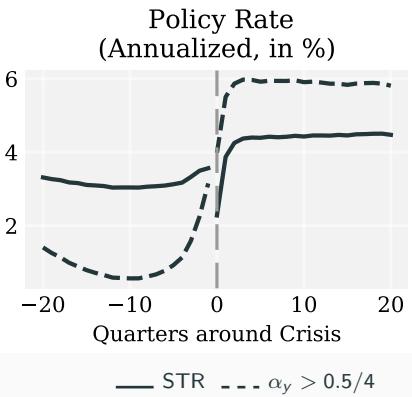
- Quantitative non–linear DGSE models with endogenous financial crises

  Boissay, Collard, Smets (2016), Gertler, Kiyotaki, Prestipino (2020)

- Capital mis–allocation during financial crises

  Midrigan and Xu (2014), Foster, Grim, Haltiwanger (2016), Gopinath, Kalemli–Ozcan, Karabargounis, Villegas–Sanchez (2017)

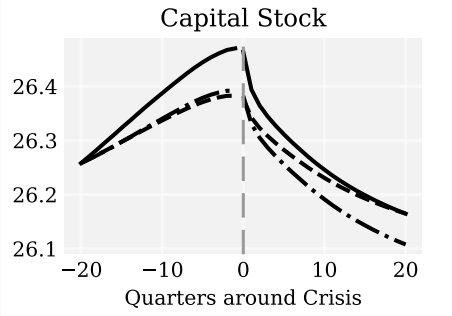
Discussion – Curbing booms does not necessarily require a higher policy rate



- During a boom, the policy rate may be lower under LAW than under STR
- Permanent income effects are smaller under LAW than under STR
- Aggregate demand increases by less during technology–driven booms
- Productivity gains are more deflationary under LAW than under STR and call for a lower rate
- The rate cut due to lower inflation more than offsets the rate hike due to the higher coefficient on output in the LAW rule

Discussion – Cleaning also helps to curb booms

$$1 + i_t = \underbrace{\frac{1}{\beta}(1+\pi_t)^{1.5}\left(\frac{Y_t}{Y}\right)^{0.125}}_{\text{STR}} - \underbrace{\frac{0.0083}{4} \times \mathbb{1}\left\{\frac{\alpha Y_t}{\mathcal{M}_t K_t} < \frac{(1-\delta)\mu}{1-\mu}\right\}}_{\text{CLEAN component}}$$



STR LAW with low α_y CLEAN

- Commitment to additional policy rate cuts during crises ("CLEAN") affects anticipations and precautionary savings
- CLEAN addresses the savings glut externalities and curbs the boom ahead of the crisis