Monetary policy and endogenous financial crises

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Should central banks "lean against the wind" (LAW)?

- What are the effects of monetary policy on financial stability? In a world where
  1. Financial crises lead to resource mis–allocation and inefficiently low output (*e.g.* Campello, Graham, Harvey (2010), Foster, Grim, Haltiwanger (2016) for the GFC)
  2. Financial crises follow unsustainable credit/investment booms, are endogenous, have a predictable component (*e.g.* Schularick and Taylor (2012))
  3. Private agents may anticipate crises but cannot stave them off on their own because of externalities (Chuck Prince's famous "*As long as the music is playing, you've got to get up and dance*")
- Should central banks act to avert crises? Trade–off between price stability (short run) and financial stability (long run)

Should central banks "lean against the wind" (LAW)?

- Pioneer cost–benefit analyses rest on reduced forms for the cost of financial instability (Woodford (2012), Filardo and Rungcharoenkitkul (2016), Svensson (2017), Gourio, Kashyap, Sim (2018))
  - *E.g.* "*crisis* = *x*% *fall in TFP*", "*crisis probability* = *logistic function of credit growth*"

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- What we do: NK model with micro–founded (partly) endogenous financial crises, which are costly due to capital mis–allocation

- What we find: LAW is overall (marginally) more desirable than strict inflation targeting (SIT) —even though SIT is also very effective in preventing crises

Roadmap

1. New Keynesian framework with micro–founded endogenous crises
2. Typical crisis dynamics
3. Should central banks lean?
4. Discussion
5. Takeaways

New Keynesian framework with micro–founded endogenous crises

Agents

1. Central bank sets nominal interest rate in response to technology and demand shocks
2. Households work, consume, save in 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 $\rightarrow$ resize by borrowing/lending in a loan market
   - + Loan market subject to frictions (MH+AI)
   - + Investment boom $\rightarrow$ capital overhang $\rightarrow$ low realised MPK $\rightarrow$ loan market collapse $\equiv$ crisis
   - + Global solution to account for the loan market's booms and busts

Agents — Intermediate goods firms

- A firm of type q sells intermediate goods at flexible price p_t, lives one period from $t-1$ to t, has technology

$$Y_t(q) = A_t(qK_t(q))^{\alpha} N_t(q)^{1-\alpha}, \text{ where } q \in \{0,1\} \text{ with prob } \mu \text{ vs } 1-\mu$$

- At the end of $t-1$, firms are identical, issue equity and purchase capital K_t
- At the beginning of t, firms learn their q, hire $N_t(q)$, and resize their capital stock from K_t to $K_t(q) \rightarrow$ requires capital reallocation across firms

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- Mass $1-\mu$ of productive firms (with $q=1$) borrow $K_t(1) - K_t$ capital goods at rate r_t^{ℓ}
- Mass μ of unproductive firms (with $q=0$) lend K_t capital goods at rate r_t^{ℓ}

Loan market — Borrowers' participation constraint

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

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

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

- The firm will borrow and rescale up to $K_t(1) \geq K_t$ only if aggregate MPK (net of capital depreciation) covers the loan rate, *i.e.*:

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

▸ Details

Loan market — Frictionless case

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

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

- Firms with $q = 0$ and $q = 1$ have the same return on equity

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

- Aggregate output is the same as in the standard NK model

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

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 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

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

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

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- Every firm chooses whether it borrows or lends → loan contract ensures that unproductive firms will lend rather than borrow
  - r_t^ℓ is unproductive firms' opportunity cost of borrowing/absconding
  - If $r_t^\ell = -\delta$, unproductive firms "have nothing to lose" → borrow/abscond for sure → no loan
- The fear that unproductive firms borrow restrains productive firms' ability to borrow ⇒ firms' borrowing limit *increases* with the loan rate r_t^ℓ

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 $\underbrace{r_t^\ell \leq \frac{\alpha}{\mathcal{M}_t}\frac{Y_t}{K_t} - \delta}_{\text{(PC)}}$ and 0 otherwise

▸ S–D schedules

Loan market — Equilibrium

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

$\Rightarrow$ Trade at $r_t^{\ell^*} = \dfrac{(1-\delta)\mu}{1-\mu} - \delta$ if $r^{\ell^*} \leq \dfrac{\alpha}{\mathcal{M}_t}\dfrac{Y_t}{K_t} - \delta$ and no trade otherwise

- A loan market with trade arises if and only if

$$\frac{\alpha}{\mathcal{M}_t}\frac{Y_t}{K_t} \geq \frac{(1-\delta)\mu}{1-\mu}$$

▸ S–D schedules

Loan market — Crisis probability

- 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 through the "YMCA" channels

Y Aggregate demand M Markup CA Capital Accumulation

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- ... and through private agents' expectations $\mathbb{E}_{t-1}$ (MP rule only, not MP surprises)

Aggregate outcome — Crisis versus normal times

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

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

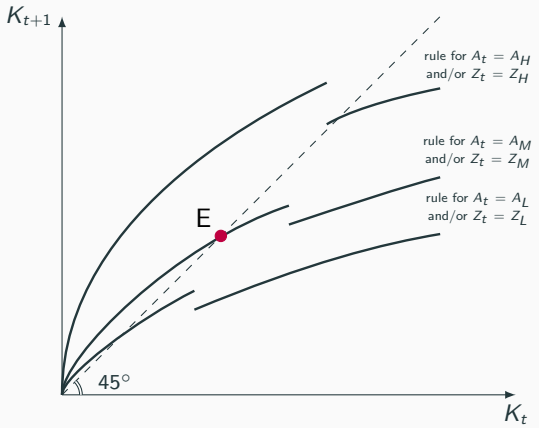
- **In normal times** capital is fully reallocated $\rightarrow$ the frictional economy resembles the frictionless one...

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

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

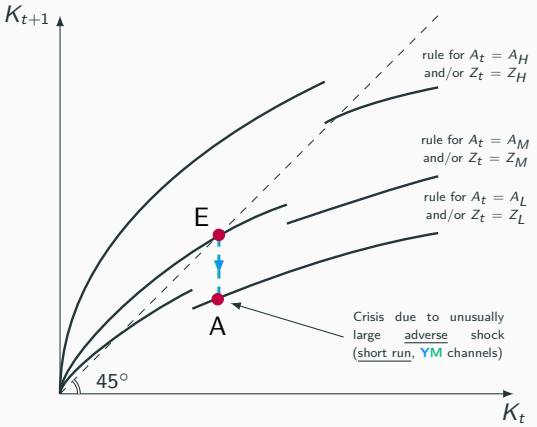
$\rightarrow$ Financial externalities: a higher K_t may precipitate the crisis

Aggregate outcome — Two polar types of crisis



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

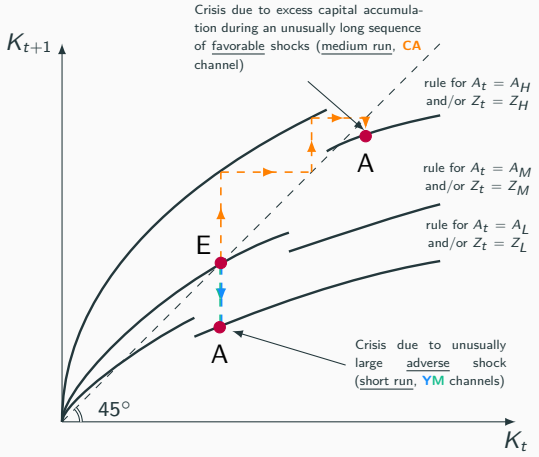
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Aggregate outcome — Two polar types of crisis

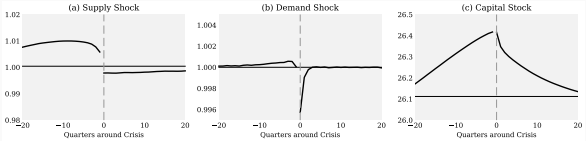


Optimal decision rules $K_{t+1}(K_t, A_t, Z_t)$

- Monetary policy affects financial stability in the short run, *e.g.* through its effects on aggregate demand during recessions (YM–channels)...
- ... and in the medium run, through its effects on capital accumulation (CA–channel)

Typical crisis dynamics

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 shocks and larger adverse demand shocks

◂ Parametrisation

Average crisis episodes — Statistics under STR

	% 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

- In our calibration, technology shocks are more persistent than demand shocks

$\Rightarrow$ Crises triggered by adverse technology shocks last longer and, therefore, are deeper

$\Rightarrow$ The economy spends more time in technology–driven crises, even though they are not as frequent as demand–driven ones

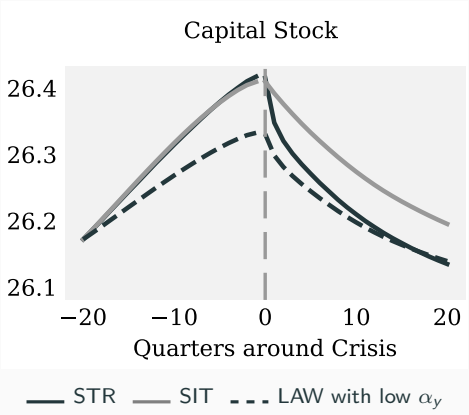
Should central banks lean?

Should central banks lean? — Monetary policy rules

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

$\rightarrow$ We experiment with low/high values of α_y

Should central banks lean? — Counterfactuals with SIT and LAW



- LAW smoothes the business cycle → insures households against aggregate shocks → inhibits savings behavior
- Households accumulate less capital during booms under LAW than under SIT or STR
- LAW prevents crises through the CA–channel

Should central banks lean? — Crisis statistics: SIT *vs* STR, LAW *vs* SIT

	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
LAW with low α_y	[1.91]	1.80	1.06	-2.23	3.59	0.94	3.27	0.79
LAW with high α_y	[0.50]	1.78	0.28	-2.27	3.17	1.23	2.63	0.93

- Strict inflation targeting (SIT) is quite effective → eliminates both demand–driven *and* mixed crises, *and* shuts down the M–channel

Should central banks lean? — Crisis statistics: SIT *vs* STR, LAW *vs* SIT

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- Under LAW, crises are shorter and less severe than under SIT... ◂ IRF negative TFP shock

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- Strict inflation targeting (SIT) is quite effective → eliminates both demand–driven *and* mixed crises, *and* shuts down the M–channel
- Under LAW, crises are shorter and less severe than under SIT... ◂ IRF negative TFP shock
- ... and even less frequent: $\downarrow \sigma(Y_t) + \downarrow \sigma(K_t) + \uparrow \rho(Y_t, \mathcal{M}_t) \Rightarrow \downarrow \sigma\left(\frac{\alpha Y_t}{\mathcal{M}_t K_t}\right)$

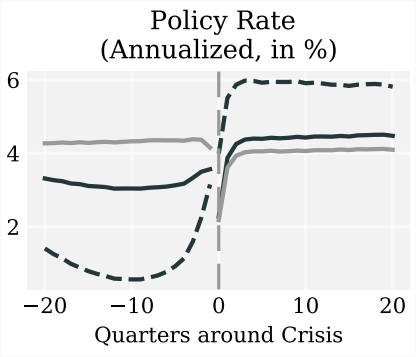
Should central banks lean? — Net welfare gain

	PCE (in %)
STR	–
SIT	0.0560
LAW with low α_y	0.0535
LAW with high α_y	0.0641

- Welfare losses due to nominal distortions ($\uparrow \ \sigma(\mathcal{M}_t)$) may be compensated by gains from milder/fewer crises ($\downarrow \sigma\left(\frac{\alpha Y_t}{\mathcal{M}_t K_t}\right)$)
- Marginal net welfare gain of LAW with high α_y over SIT
- Result likely varies with prevalence of nominal rigidities (menu cost ϱ) versus financial frictions (mass μ of unproductive firms)

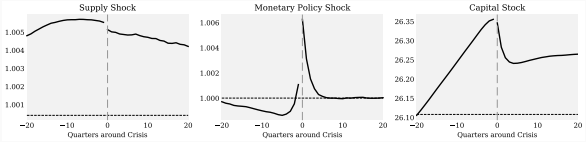
Discussion

Discussion — LAW 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 weigh more on aggregate demand under LAW than under STR
- Higher deflationary productivity gains call for a lower policy rate than under STR
- Stronger response to output under LAW is more than offset by lower output and the associated lower inflation

Discussion — Surprise deviations from STR and financial crises



- Surprise deviations from STR ("too low for too long") feed the investment boom
- Discretionary rate hikes toward the end of the boom trigger the crisis

Discussion — Surprise deviations from STR and financial crises



- Surprise deviations from STR ("too low for too long") feed the investment boom
- Discretionary rate hikes toward the end of the boom trigger the crisis

- What are the central bank's policy options at the end of a boom? ◂ *E.g* US's 2003–5 "Great Deviation"
  - ~~Discretionary rate hike?~~ → may trigger the crisis
  - ~~Further discretionary rate cut?~~ → may only postpone —not avert— the crisis
  - Model prescription: switch from STR to LAW?

Takeaways

Takeaways (so far)

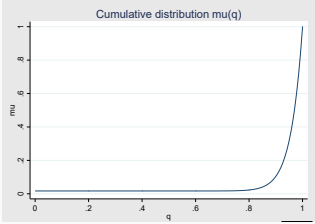
1. "Canonical" NK model with endogenous financial crises + micro–foundations to existing reduced form models
   - Crises follow investment booms due to favorable shocks
   - Monetary policy affects financial stability through YMCA channels
2. Benevolent central bank trades off the short run cost (deviations from first best) and medium/long run benefits (fewer/milder financial crises)
   - LAW must be rule–based, not discretionary
   - With prevalent technology–driven crises, LAW is (marginally) better than SIT

Backup Slides

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

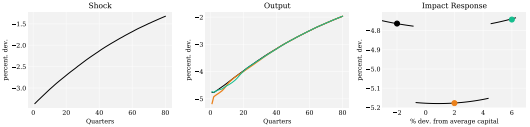
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$$\mu(q) = \mu + (1 - \mu)q^{\lambda}$$

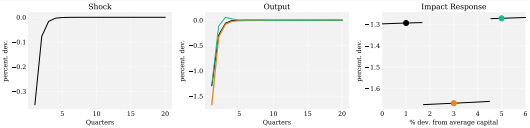
The loan market is more fragile toward the end of a boom

Generalized IRF – Negative TFP shock



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

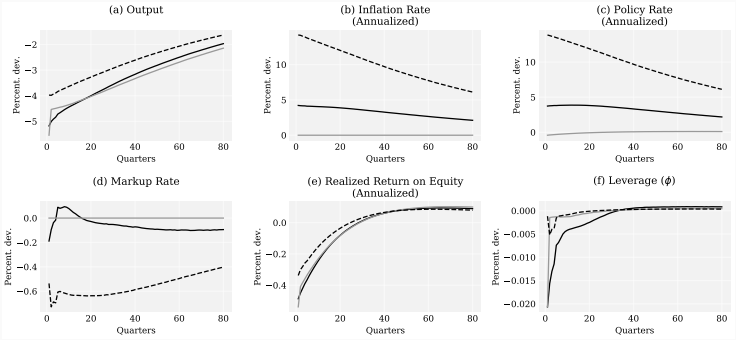
Generalized IRF — Negative demand shock



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

Back

Generalized IRF around steady state — Negative TFP shock



Back

Households

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

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

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

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

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

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

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

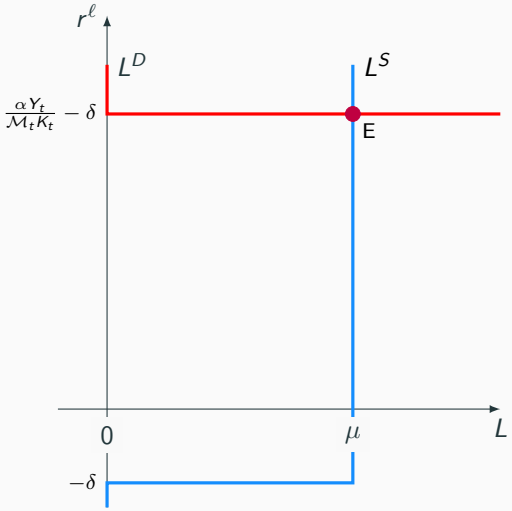
Since $Y_t = (1-\mu)Y_t(1)$, $K_t = (1-\mu)K_t(1)$ and $\frac{Y_t(1)}{K_t(1)} = A_t^{\frac{1}{\alpha}} \left(\frac{1-\alpha}{\mathcal{M}_t \omega_t}\right)^{\frac{1-\alpha}{\alpha}} = \frac{Y_t}{K_t}$, one gets:

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

$\Rightarrow$ 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

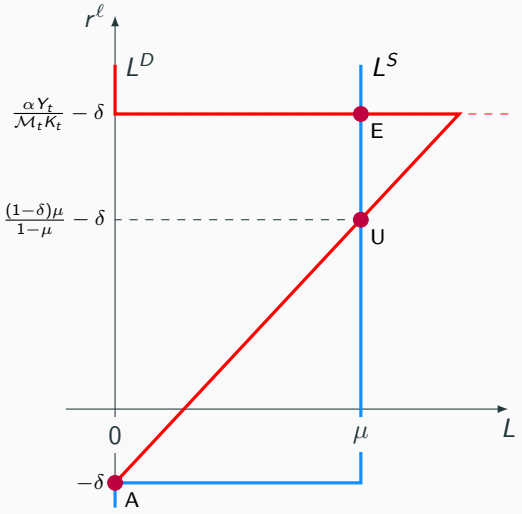
Loan market equilibrium



Frictionless case

Back

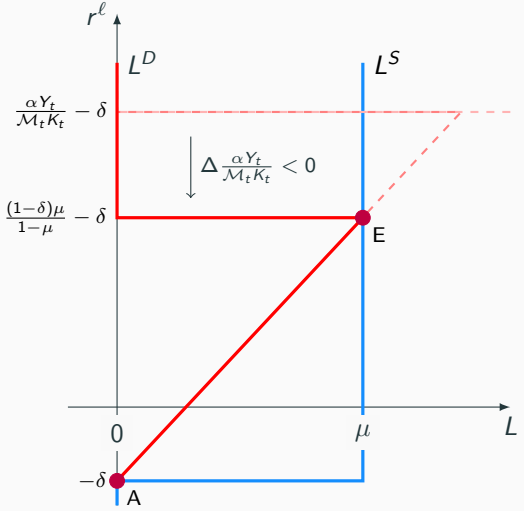
Loan market equilibrium



Frictional case

Back

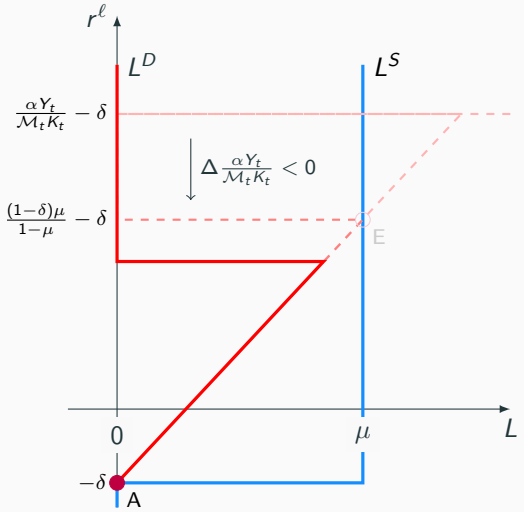
Loan market equilibrium



- The fall in MPK reduces borrowers ability to pay the loan rate required to preserve unproductive firms' incentives
- r_t^ℓ must be above $\frac{(1-\delta)\mu}{1-\mu} - \delta$ to entice unproductive firms to lend rather than borrow and abscond

Back

Loan market equilibrium



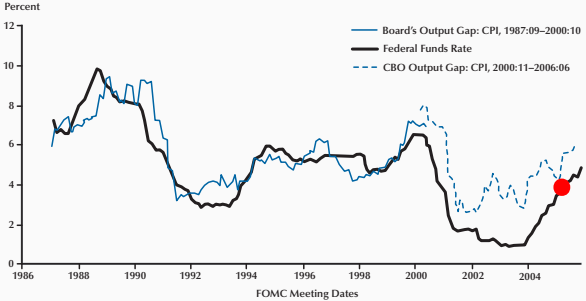
- Financial autarky
- When $\frac{\alpha Y_t}{\mathcal{M}_t K_t} < \frac{(1-\delta)\mu}{1-\mu}$ productive firms cannot afford the required loan rate $\rightarrow E$ not sustainable

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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

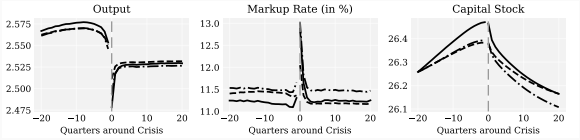


Poole (2007): "Understanding the Fed", Federal Reserve Bank of St. Louis Review, January/February 2007, 89(1), pp. 3-13.

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Cleaning also helps to curb booms

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



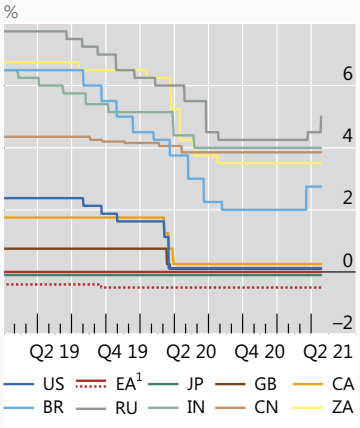
- Commitment to additional policy rate cuts during crises ("CLEAN") affects anticipations and precautionary savings
- CLEAN addresses the savings glut externalities and curbs the boom ahead of the crisis

List of equations

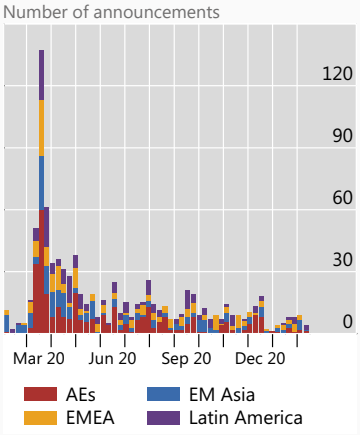
1. $Z_t = \mathbb{E}_t\left\{\Lambda_{t,t+1}(1+r_{t+1})\right\}$
2. $1 = \mathbb{E}_t\left\{\Lambda_{t,t+1}(1+r^k_{t+1})\right\}$
3. $\omega_t = \vartheta N_t^{\nu} C_t^{\sigma}$
4. $Y_t = A_t\left((1+\phi_t)(1-\mu)K_t\right)^{\alpha} N_t^{1-\alpha}$
5. $\omega_t = (1-\alpha)\dfrac{Y_t}{\mathcal{M}_t N_t}$
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. $1 + r_t \equiv \dfrac{1+i_{t-1}}{1+\pi_t}$

Monetary policy during the Covid–19 crisis

Evolution of monetary policy rates



Weekly announcements of policies



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

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.**

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)