# 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/model 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. ... follow credit/investment booms, are endogenous, predictable (*e.g.* Schularick and Taylor (2012))
  3. ... are anticipated by private agents but not avoided because of externalities (Chuck Prince's famous "*As long as the music is playing, you've got to get up and dance*")
  4. The economy is subject to technology and demand shocks
- Trade–off between price stability (short run) and financial stability (long run)

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

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  - *E.g.* "*crisis cost* $=$ $x$% *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

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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 inflation and output fluctuations
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 will 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
   + Global solution to account for the loan market's booms and busts

# 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 $q \in \{0,1\}$, hire $N_t(q)$, and adjust/resize their capital stock accordingly from $K_t$ to $K_t(q)$

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

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- The resizing of the capital stock is done with intra–period loans
- Mass $\mu$ of unproductive firms (with $q=0$) lend $K_t$ capital goods at rate $r_t^{\ell}$
- Mass $1-\mu$ of productive firms (with $q=1$) borrow $K_t(1) - K_t$ capital goods at rate $r_t^{\ell}$

# Loan market — Borrowers' participation constraint

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

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

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

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

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

▸ Details

# Loan market — Frictionless case

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

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

- 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 $q$s 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* with the loan rate $r_t^\ell$
- $r_t^\ell$ is unproductive firms' opportunity cost of absconding (*i.e.* their "skin in the game")

# Loan market — Equilibrium

- Supply from $q = 0$ firms: $\mu K_t$ 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

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- Trade takes place if and only if

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

▸ 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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Y Aggregate demand     M Markup     CA Capital Accumulation

- ... and by "managing" private agents' expectations $\mathbb{E}_{t-1}$ of future $Y_t$, $\mathcal{M}_t$, and $K_t$

# Aggregate outcome — Crisis versus normal times

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

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

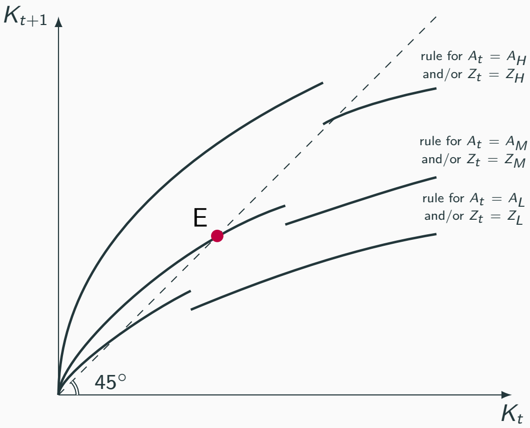
- **In normal times** capital is fully reallocated $\rightarrow$ the frictional economy resembles the frictionless one...

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

... 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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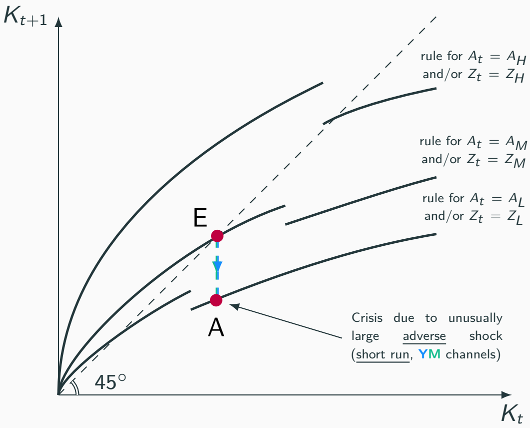


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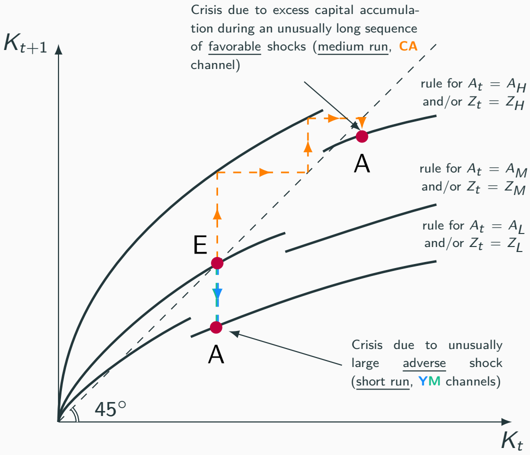
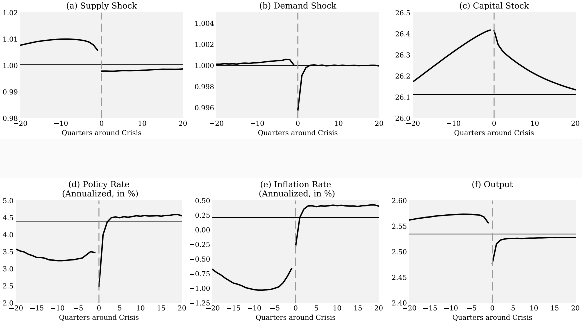



*Optimal decision rules* $K_{t+1}(K_t, A_t, Z_t)$

- 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 and/or demand shocks

◂ Parametrisation ◂ Techno vs demand shocks

# 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 less frequent than demand–driven ones

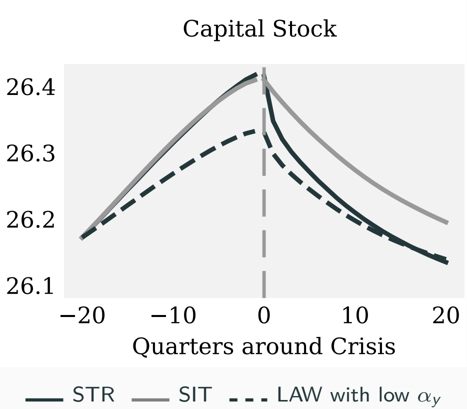
# Should central banks lean?

# Should central banks lean? — Monetary policy rules

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

→ We experiment with low/high values of $\alpha_y$

# Should central banks lean? — Counterfactuals with SIT and LAW




- Households accumulate less capital during booms under LAW than under SIT or STR
- LAW smoothes the business cycle → "insures" households against aggregate shocks → inhibits savings behavior
- LAW may prevent 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 $\alpha_y$ | [1.91] | 1.80 | 1.06 | -2.23 | 3.59 | 0.94 | 3.27 | 0.79 |
| LAW with high $\alpha_y$ | [0.50] | 1.78 | 0.28 | -2.27 | 3.17 | 1.23 | 2.63 | 0.93 |

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

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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 $\rightarrow$ 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: $\downarrow\ \sigma(Y_t) + \downarrow\ \sigma(K_t) + \uparrow\ \rho(Y_t, \mathcal{M}_t) \Rightarrow \downarrow \sigma\left(\frac{\alpha Y_t}{\mathcal{M}_t K_t}\right)$

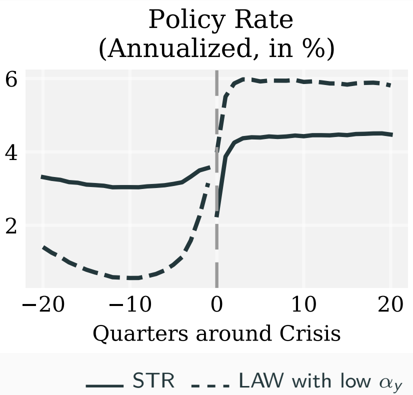
# Should central banks lean? Yes — Net welfare gain

| | PCE (in %) |
|---|---|
| STR | – |
| SIT | 0.0560 |
| LAW with low $\alpha_y$ | 0.0535 |
| LAW with high $\alpha_y$ | 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 $\alpha_y$ over SIT
- Result likely varies with prevalence of nominal rigidities (menu cost $\varrho$) versus financial frictions (mass $\mu$ of unproductive firms)

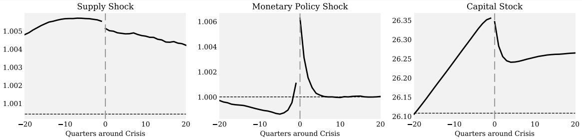
# Discussion

# Discussion — LAW does not necessarily require a higher policy rate



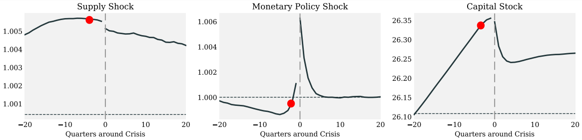

- During a boom, the policy rate may be lower under LAW than under STR
- Permanent income effects are smaller under LAW than under STR
- Aggregate demand increases by less during technology–driven booms
- Productivity gains are more deflationary under LAW than under STR and call for a lower rate
- The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

# 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
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- 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)

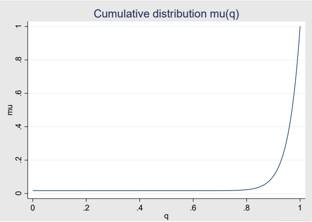
1. "Canonical" NK model with endogenous financial crises + micro–foundations to existing reduced form models
   - Crises follow investment booms due to favorable shocks
   - Monetary policy affects financial stability through YMCA channels
2. Benevolent central bank trades off the short run cost (deviations 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* | | |
| $\beta$ | 4% annual real interest rate | 0.989 |
| $\sigma$ | Logarithmic utility on consumption | 1.000 |
| $\nu$ | Inverse Frish elasticity equals 2 | 0.500 |
| $\vartheta$ | Steady state hours equal 1 | 0.757 |
| *Technology and price setting* | | |
| $\alpha$ | 64% labor share | 0.289 |
| $\delta$ | 6% annual capital depreciation rate | 0.015 |
| $\varrho$ | Same slope of the Phillips curve as with Calvo price setting | 105.000 |
| $\epsilon$ | 11% markup rate | 10.000 |
| *Aggregate shocks* | | |
| $\rho_a$ | Persistence of TFP | 0.950 |
| $\sigma_a$ | Standard deviation of TFP innovation (in %) | 0.700 |
| $\rho_z$ | Persistence in Smets and Wouters (2007) | 0.220 |
| $\sigma_z$ | Standard deviation of risk–premium innovation in Smets and Wouters (2007) (in %) | 0.230 |
| *Idiosyncratic productivity shocks* | | |
| $\lambda$ | 2pp spread in normal times | 23.000 |
| $\mu$ | The economy spends 10% of the time in a crisis | 0.0176 |

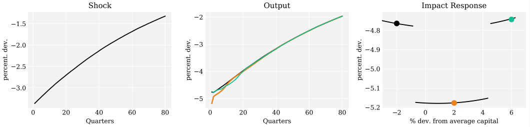
Back




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

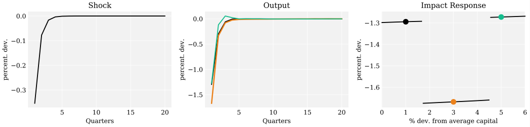
# The loan market is more fragile toward the end of a boom

Generalized IRF – Negative TFP shock




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

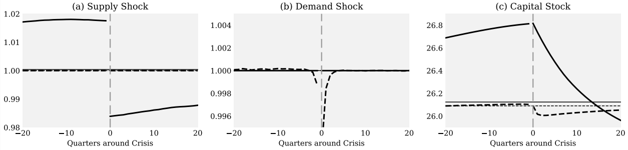
Generalized IRF — Negative demand shock




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

Back

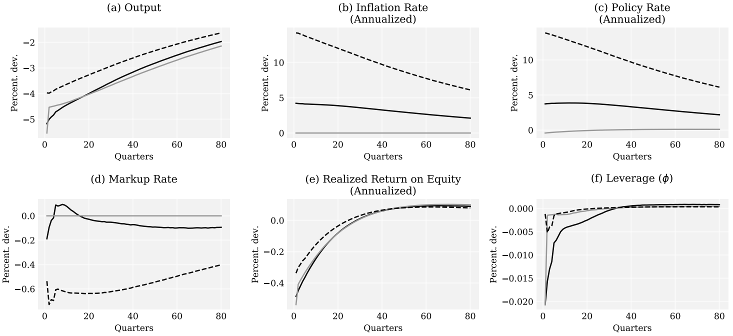
# Economies with either technology or demand shocks




- 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

Back

# Generalized IRF around steady state — Negative TFP shock




STR SIT LAW with low $\alpha_y$

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

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

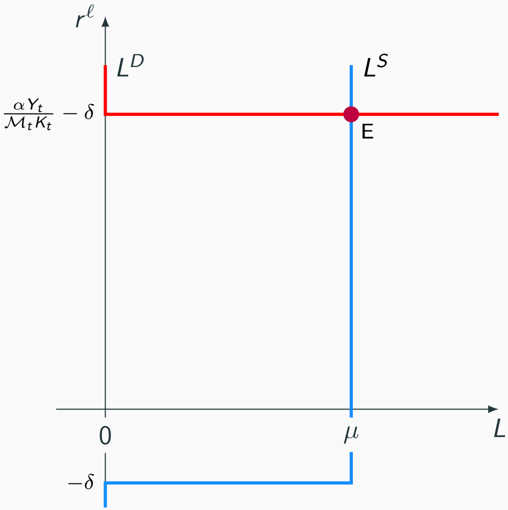
Since $Y_t = (1-\mu) Y_t(1)$, $K_t = (1-\mu) K_t(1)$ and $\frac{Y_t(1)}{K_t(1)} = A_t^{\frac{1}{\alpha}} \left( \frac{1-\alpha}{\mathcal{M}_t \omega_t} \right)^{\frac{1-\alpha}{\alpha}} = \frac{Y_t}{K_t}$, one gets:

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

$\Rightarrow$ 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

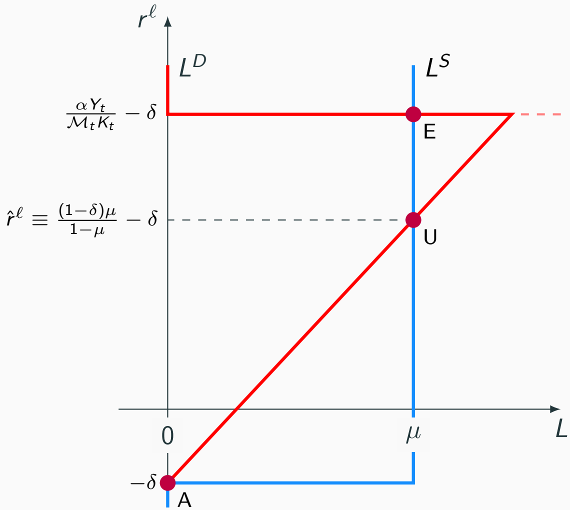
# Loan market equilibrium




Frictionless case

Back

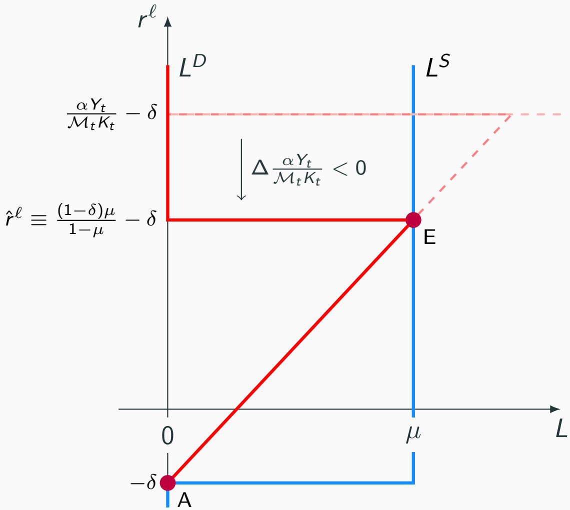
# Loan market equilibrium




Frictional case

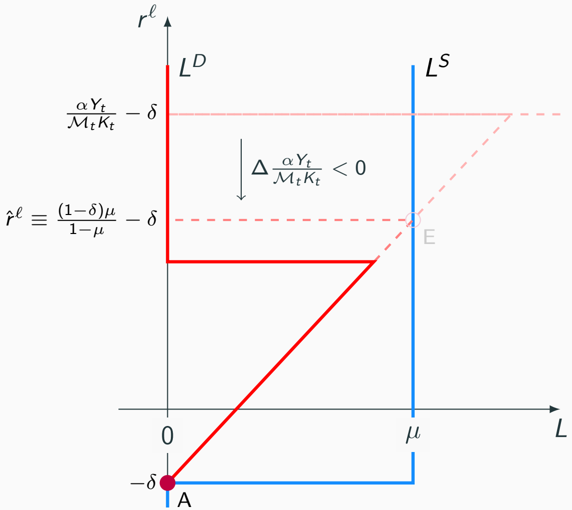
Back

# Loan market equilibrium




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

# Loan market equilibrium



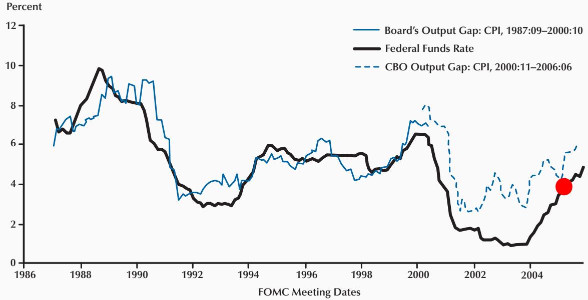

- Financial autarky
- When $\frac{\alpha Y_t}{\mathcal{M}_t K_t} < \hat{r}^\ell + \delta$ productive firms cannot afford the required loan rate $\rightarrow$ $E$ not sustainable

Back

# 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**

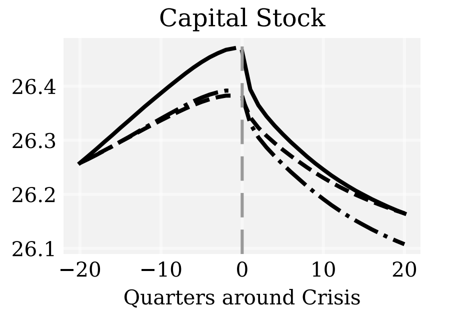



Poole (2007): "Understanding the Fed", Federal Reserve Bank of St. Louis Review, January/February 2007, 89(1), pp. 3-13.

◂ Back ◂ Current stance

# 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 $\alpha_y$ 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

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