The I Theory of Money

Markus Brunnermeier & Yuliy Sannikov

Princeton University

Updates: http://www.princeton.edu/~markus/research/papers/i_theory_slides.pdf

Motivation

- Unified framework to study financial and monetary stability
- Combines **intermediation (credit)** and **money - inside money**
- Value of money endogenous - store of value, liquidity
  - (Samuelson, Bewley, Kiyotaki-Moore…)
- Fisher (1933) **deflationary spiral** after *negative* productivity shock
  - Negative shock hits **asset** side of intermediaries' balance sheets and is amplified through leverage and volatility dynamics
  - Decline in inside money, leads to deflationary pressure that hits intermediaries' balance sheet on the **liability** side

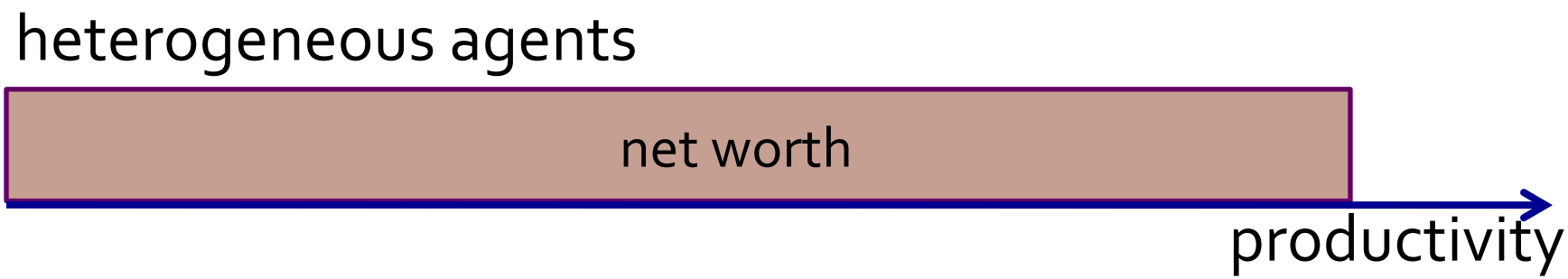
Difference to literature!

- **Inside money** and **outside money**
  - "Endogenous" money multiplier = f(health of intermediary sector)
- Monetary policy (interest rates, open market operations)
  - Fills in demand for money when money multiplier contracts
  - Redistribution from/towards intermediary sector
  - Difference to New Keynesian framework

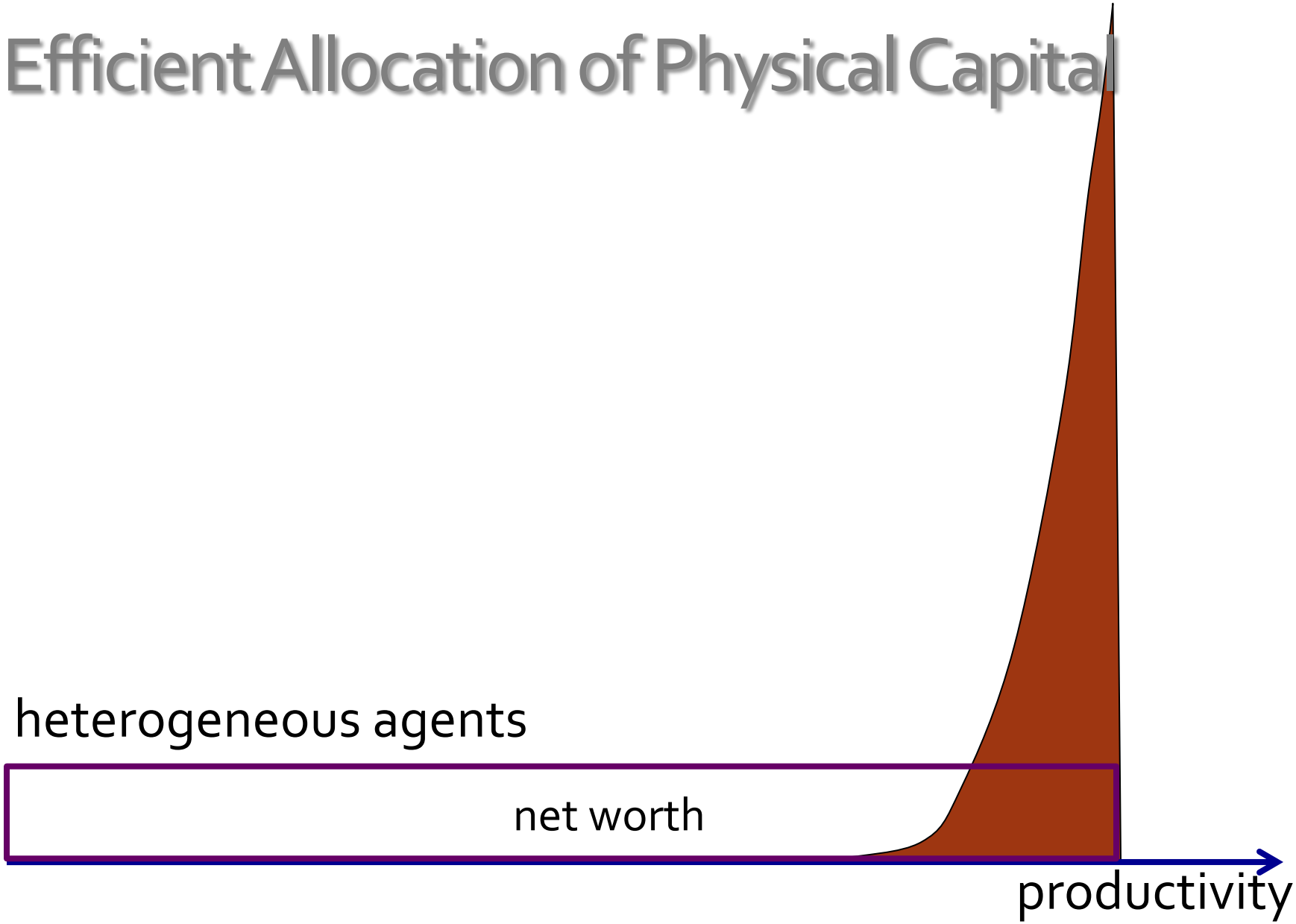
Some Literature

- Medium of exchange — (new) monetarists
- Store of value & liquidity
  - Samuelson's OLG — Consumption smoothing
  - Bewley — Precaution savings for
    - Scheinkman & Weiss — uninsurable endowment shocks
    - Homstrom & Tirole — to keep project running
    - Kiyotaki & Moore (2008) — new investment opportunity + "resell constraint"
- Financial stability & monetary policy
  - Diamond & Rajan (2006)
  - Stein (2010)
  - Curdia & Woodford (2010) — New Keynesian framework
- Economies with financial frictions
  - Bernanke,Gertler & Gilchrist, Kiyotaki & Moore, Geanakoplos, He & Krishnamurthy, Brunnermeier & Sannikov 2010

Outline of Modeling Ideas



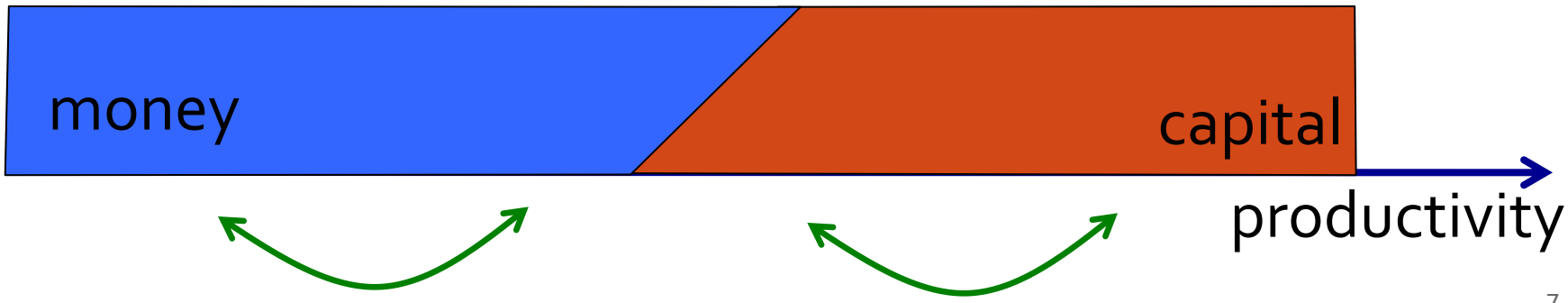
Efficient Allocation of Physical Capital



Allocation with Extreme Financial Constraint

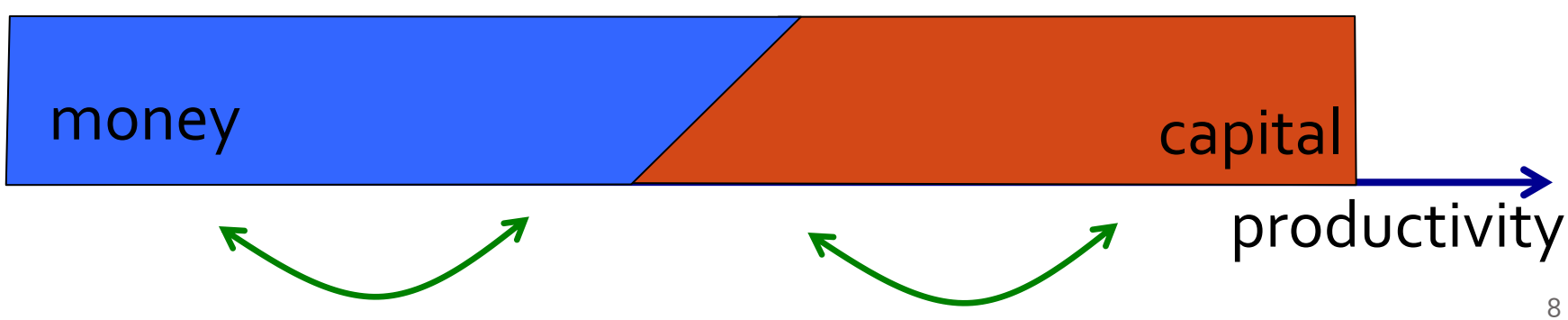
Switching Types and Money

- Money (gold) intrinsically worthless
- Agents willing to hold money if someone (productive agents becoming unproductive) will want to hold money later



Switching Types and Money

- Money (gold) intrinsically worthless
- Agents willing to hold money if someone (productive agents becoming unproductive) will want to hold money later
- Inefficiencies
  - Allocation (money does not generate any income)
  - Underinvestment (price of capital and hence investment is low)



Two polar cases

Economy	Assets	Value of fiat money
Frictions (severe)	No claims	high
Frictionless	Issue claims • Debt • Equity	low

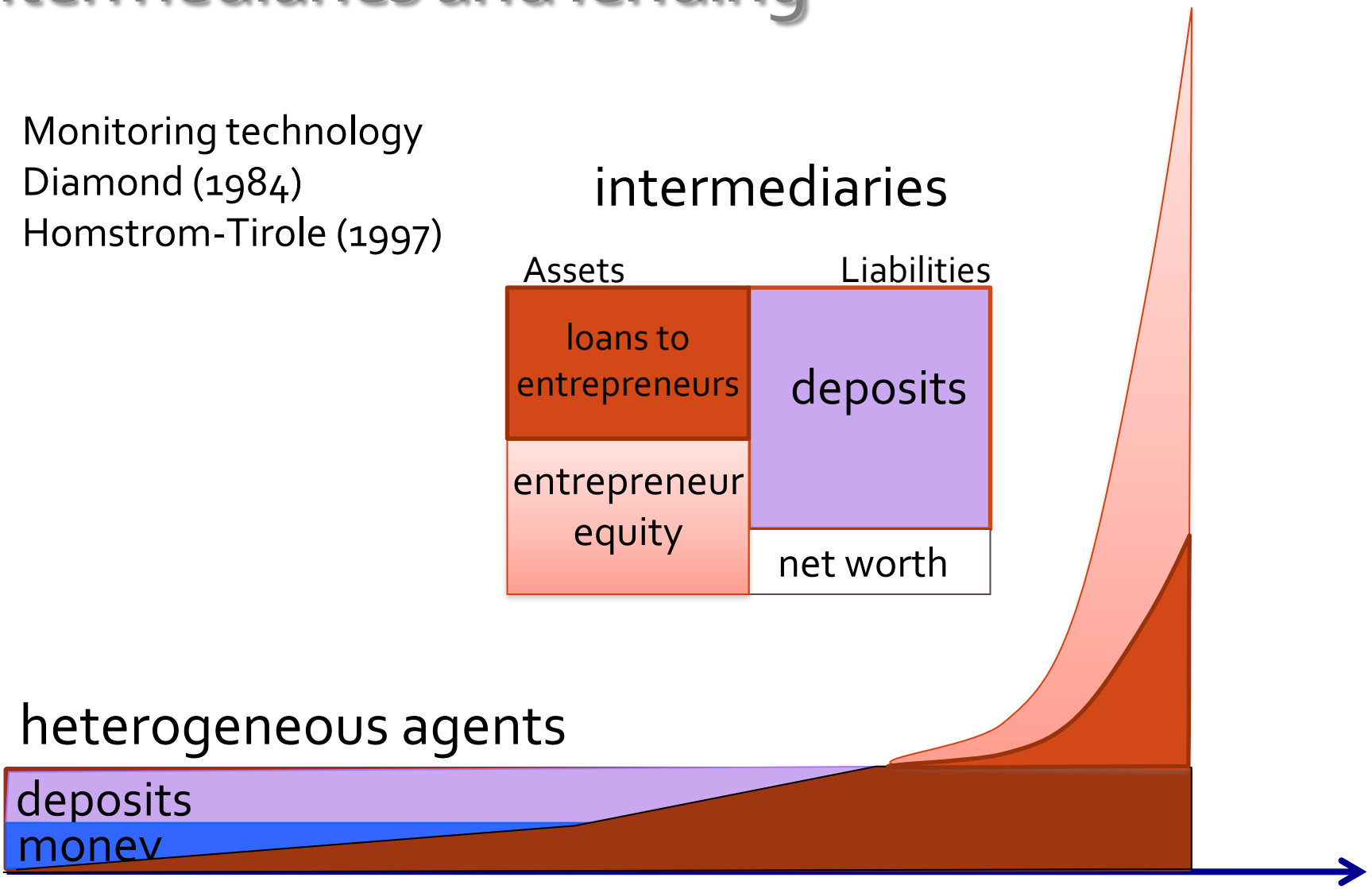
Two polar cases introducing intermediaries

Economy	Assets	Value of fiat money		Intermediaries' capitalization
Frictions (severe)	No claims	high		defunct
Frictionless	Issue claims • Debt • Equity	low		perfect

- Role of intermediaries
  - Relax financing constraint by monitoring productive agents
  - Have to take on productive agent's equity risk (so that they have incentive to monitor)
  - Intermediation depends on their ability to absorb risk
    net worth of intermediaries

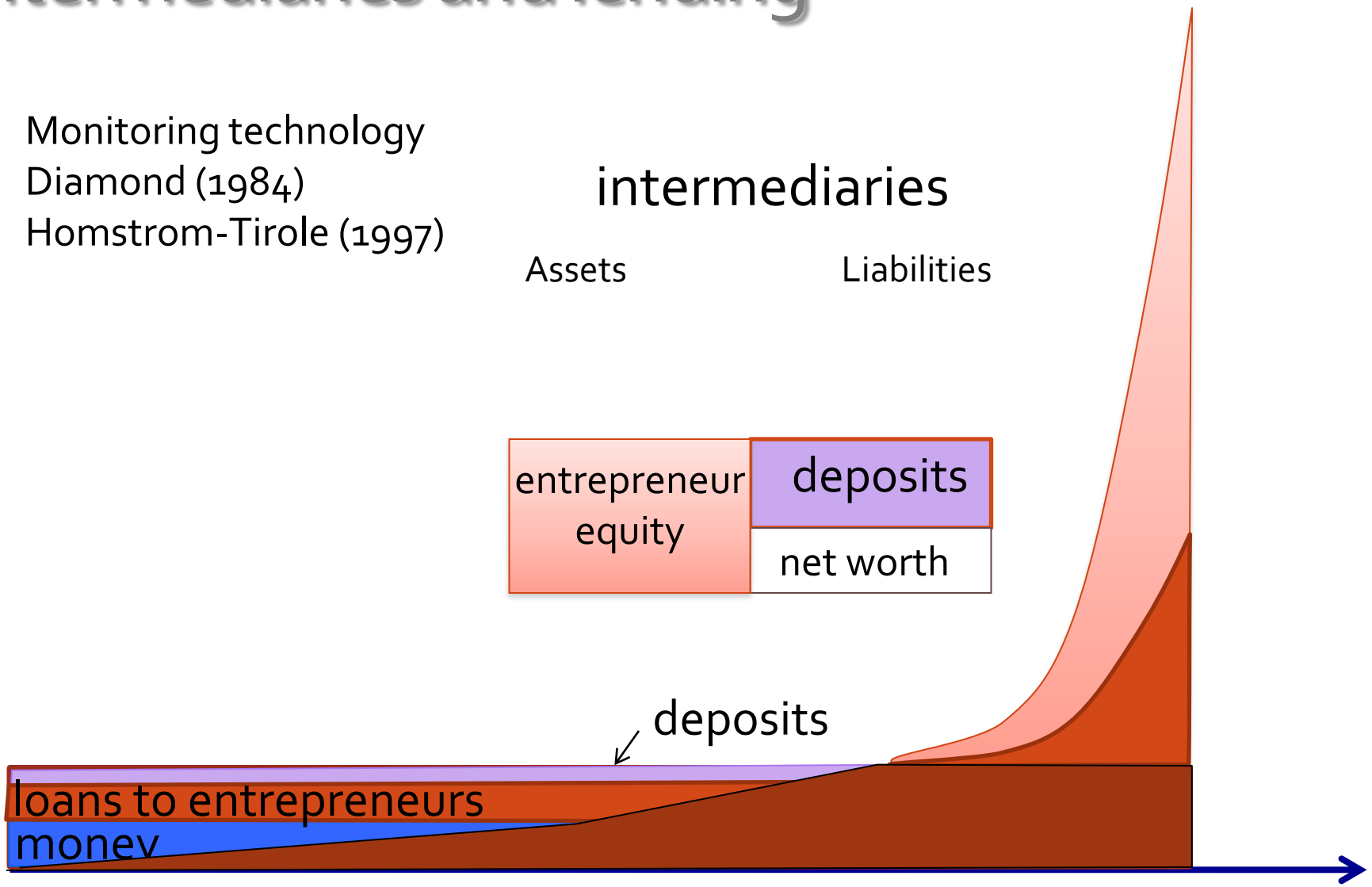
Intermediaries and lending

- Monitoring technology
  Diamond (1984)
  Homstrom-Tirole (1997)



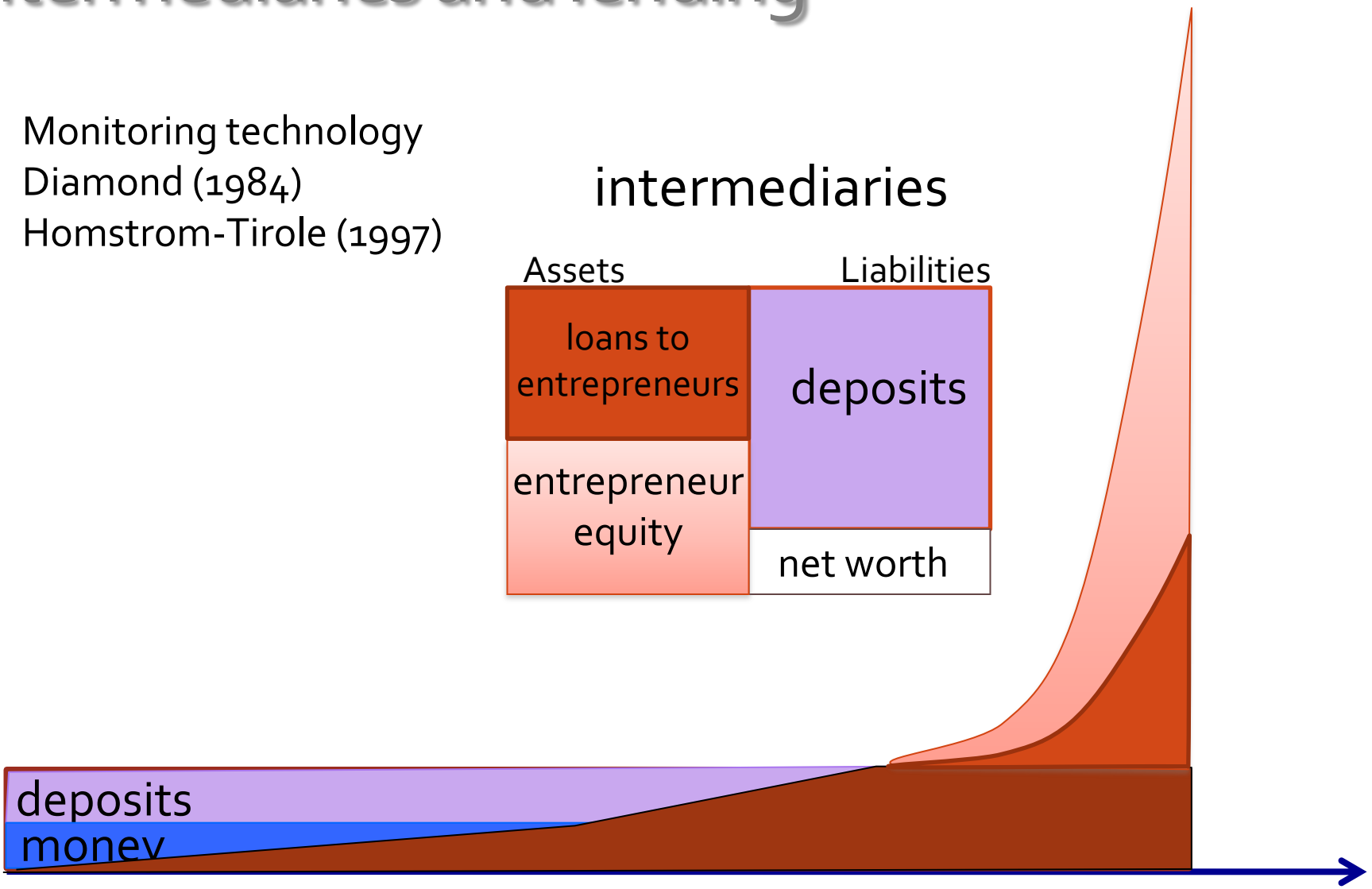
Intermediaries and lending

- Monitoring technology
  Diamond (1984)
  Homstrom-Tirole (1997)

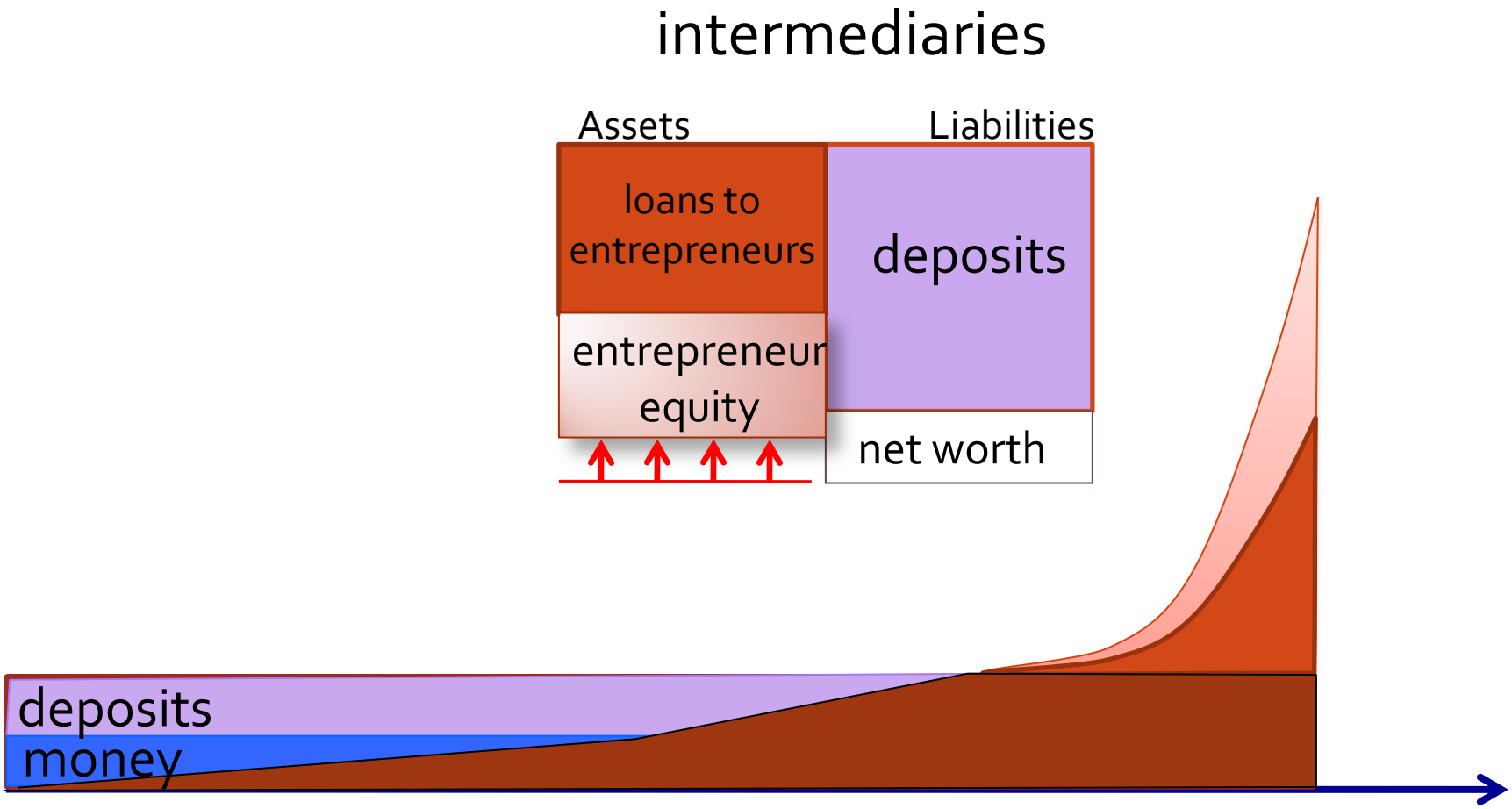


Intermediaries and lending

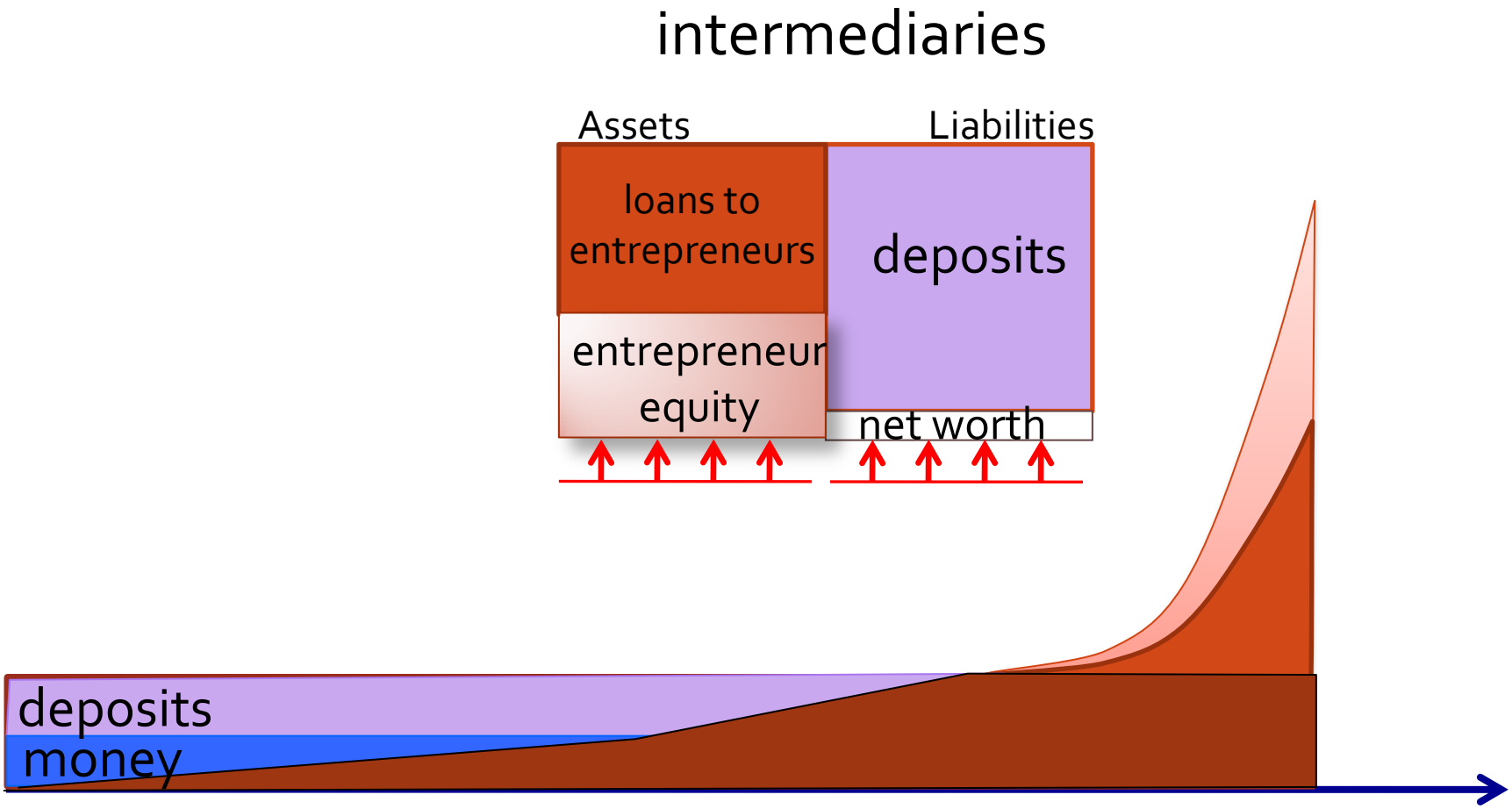
- Monitoring technology
  Diamond (1984)
  Homstrom-Tirole (1997)



Negative Macro Shocks

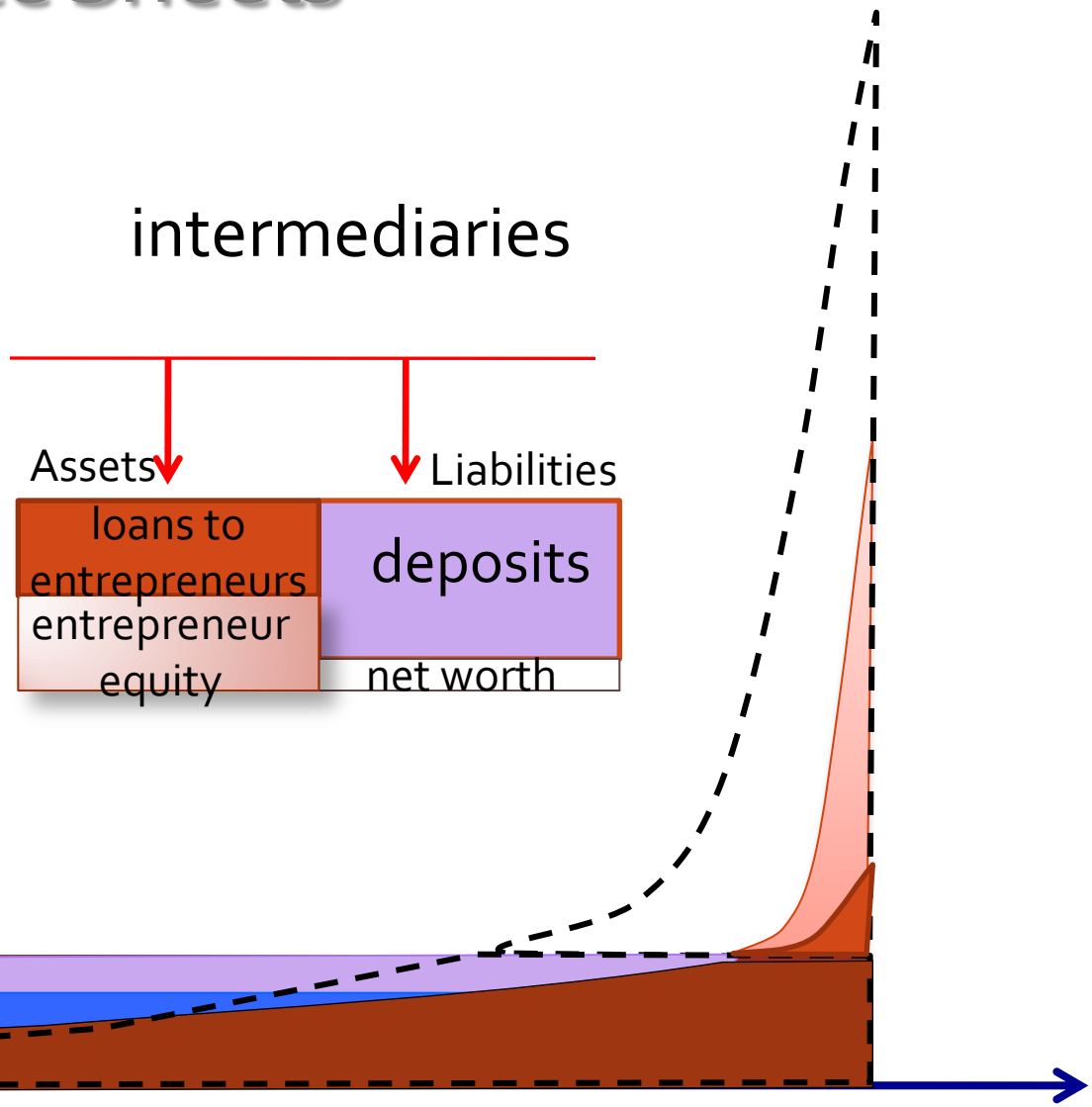


Negative Macro Shocks



Shrinking Balance Sheets

- Intermediary net worth ↓
- Lending to entrepreneurs ↓
- Value of capital q ↓
- Deposit/inside money ↓
- Value of outside money p ↑
- Multiplier ↓



Overview

- **Passive** monetary policy: "Gold standard"
  - Quantity of outside money fixed
  - Interest rate zero
  - When a negative macro shock hits intermediaries
    - quantity of inside money shrinks
    - value of outside money increases - deflationary spiral
    - intermediaries are hit on the liability side
- **Active** Monetary Policy
  - Introduce long-term bond
    - Short-term interest rate policy
    - Value of long-term bonds rises in downturns – substitute for reduction of inside money
    - Asset purchase and OMO
  - Redistributional effects
- Comparison to New Keynesian and Monetarism

The Model: Technology

consumption rate

Output: $y_t^{\omega} = a^{\omega} k_t^{\omega} = (c_t^{\omega} + i_t^{\omega}) k_t^{\omega}$

investment rate

Capital: $dk_t^{\omega} = (\Phi(i_t^{\omega}) - \delta^{\omega}) k_t dt + d\varepsilon_t^{\omega}$

$\Phi(0) = 0, \Phi' > 0, \Phi'' < 0$

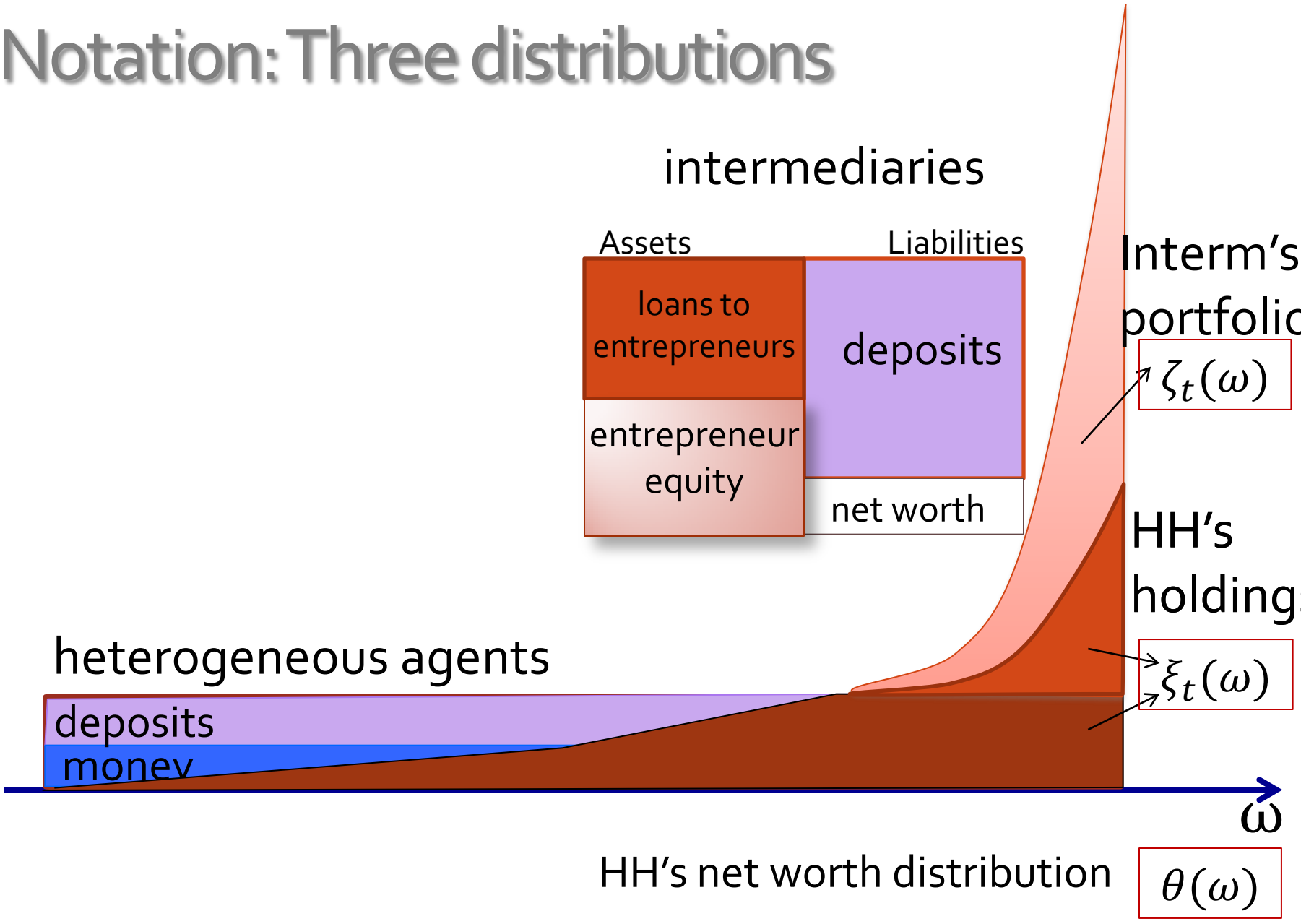
$Cov[\varepsilon_t^{\omega}, \varepsilon_t^{\omega\prime}]$

heterogeneous agents

ω

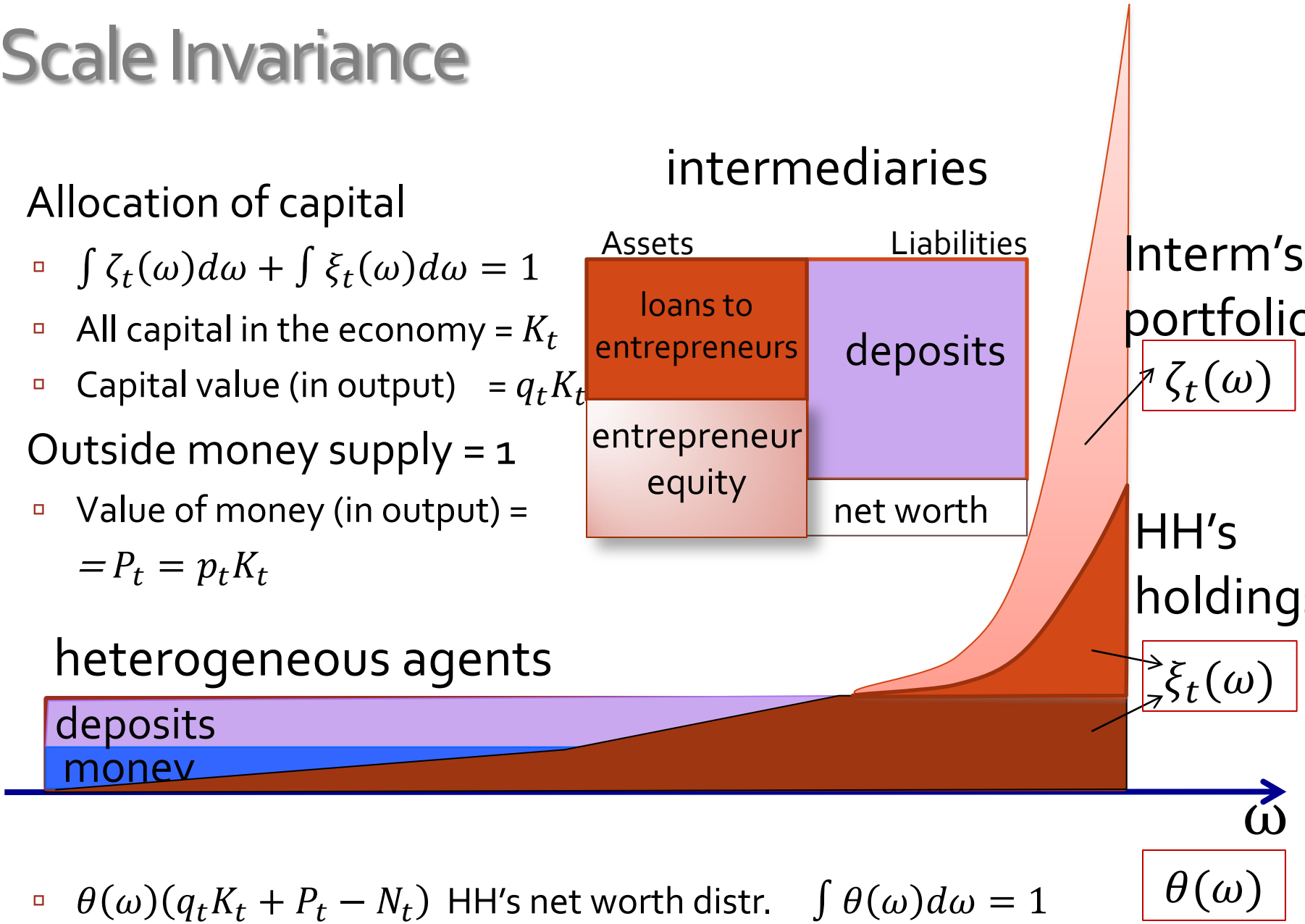
Outside money (gold) is in fixed supply

Notation: Three distributions



Scale Invariance

- Allocation of capital
  - $\int \zeta_t(\omega)d\omega + \int \xi_t(\omega)d\omega = 1$
  - All capital in the economy = K_t
  - Capital value (in output) $= q_t K_t$
- Outside money supply = 1
  - Value of money (in output) = $= P_t = p_t K_t$



- $\theta(\omega)(q_t K_t + P_t - N_t)$ HH's net worth distr. $\int \theta(\omega)d\omega = 1$

The Model: Preferences

- All agents have logarithmic utility with discount rate

$$E\left[\int_0^\infty e^{-\rho t}\log c_t\, dt\right]$$

- Retirement: intermediary gets utility boost, when it decides to become a household forever
- Implications of log utility:
  - Consumption $= \rho \times net\ worth$
  - Required return $= Cov[asset\ risk, net\ worth\ risk]$
  - Consumption is independent of investment opportunity
  - Asset demands are myopic
    (no Mertonian hedging demand, no precautionary motive)

Equilibrium Definition

- For each history of shocks $\{\{d\varepsilon_s^\omega\}_\omega, s \in [0,t]\}$
  - q_t the price of physical capital
  - $P_t = p_t K_t$ the value of money
  - $\zeta_t(\omega), \xi_t(\omega)$ the allocation of capital
  - i_t^ω the rate of entrepreneurs investment
  - rates of consumption of all agents
  - Retirement rate of intermediaries

  such that
  - Given prices all agents choose portfolios & consumption to maximize utility, intermediaries choose optimally when to retire
  - Markets for capital, money and consumption goods clear

Derivation - Roadmap

- Individual choices
  - $c_t = \rho *$ net worth
  - i_t^{ω}
  - Required excess return = Cov [asset risk, net worth risk]
    - Postulate: $dq_t = \mu_t^q dt + d\varepsilon^q$ and $dp_t = \mu_t^p dt + d\varepsilon_t^p$
- Market clearing
  - Endogenously determines $\mu_t^q, d\varepsilon_t^q, \mu_t^p, d\varepsilon_t^q$
- Derive $\mu_t^q, d\varepsilon_t^q, \mu_t^p, d\varepsilon_t^q$ as functions of η
- Need low of motion of η
  - Depends on postulated price processes q_t and p_t (fixed point)

Internal investment decision

$$dk_t^\omega = (\Phi(i_t^\omega) - \delta^\omega)dt + d\varepsilon_t^\omega$$

- Given the price of capital q_t, the optimal investment solves

$$\max_i \Phi(i)q_t - i \Rightarrow i^*(q_t)$$

- Determines for each HH ω
  - $c^\omega(q_t) = a^\omega - i^*(q_t)$
  - $g^\omega(q_t) = \Phi(i^*(q_t)) - \delta^\omega$

Return on physical capital

- If $dq_t = \mu_t^q q_t dt + q_t d\varepsilon_t^q \leftarrow$ endogenous

$$dr_t^\omega = \left(\underbrace{\frac{c^\omega(q_t)}{q_t}}_{\text{dividend yield}} + \underbrace{g^\omega(q_t) + \mu_t^q + Cov\left[d\varepsilon_t^\omega, d\varepsilon_t^q\right]}_{\text{capital gains rate}} \right) dt + \underbrace{(d\varepsilon_t^\omega + d\varepsilon_t^q)}_{\text{risk (endogenous + exogenous)}}$$

Return on Money

- In the "long-run"

$$\frac{dK_t}{K_t} = \underbrace{\int (\zeta(\omega) + \xi(\omega)) g^{\omega}(q_t) d\omega}_{\mu_t^K} + \underbrace{\int \zeta(\omega) + \xi(\omega)\, d\varepsilon_t^{\omega}}_{d\varepsilon_t^K}$$

If $dp_t = \mu_t^p p_t dt + p_t d\varepsilon_t^p \leftarrow$ endogenous

then a dollar invested in money earns return

$$dr_t^M = (\mu_t^K + \mu_t^p + Cov[d\varepsilon_t^K, d\varepsilon_t^p])dt + \underbrace{d\varepsilon_t^K + d\varepsilon_t^p}_{d\varepsilon_t^M}$$

Intermediaries' "Risk Balance Sheet"

Assets	Liabilities
$q_t K_t \int \zeta_t(\omega)\left(d\varepsilon_t^q + d\varepsilon_t^\omega\right)d\omega$	$\left(q_t K_t \int \zeta_t(\omega)d\omega - N_t\right)d\varepsilon_t^M$
	$N_t d\varepsilon_t^N$

$$dN_t = -\rho N_t dt + N_t dr_t^M + q_t K_t \int \zeta_t(\omega) Cov\left[d\varepsilon_t^q + d\varepsilon_t^\omega - d\varepsilon_t^M, d\varepsilon_t^N\right]d\omega\, dt + q_t K_t \int \zeta_t(\omega)\left(d\varepsilon_t^q + d\varepsilon_t^\omega - d\varepsilon_t^M\right)d\omega$$

$$d\eta_t = d(N_t/K_t) = \cdots$$

Equilibrium Conditions

1. Market clearing for capital goods and bonds

$$\int \zeta_t(\omega)d\omega + \int \xi_t(\omega)d\omega = 1$$

2. Market clearing for output:

$$\int (\zeta_t(\omega) + \xi(\omega))c^{\omega}(q_t)d\omega = \rho(q_t + p_t)$$

3. Valuation of capital ω -- return = Cov(risk, net worth risk)
   - Intermediaries

$$E[dr_t^{\omega} - dr_t^{M}] \leq Cov\left[d\varepsilon_t^{q} + d\varepsilon_t^{M}, d\varepsilon_t^{N}\right] \qquad (= if\ \zeta_t(\omega) > 0)$$

   - HH ω

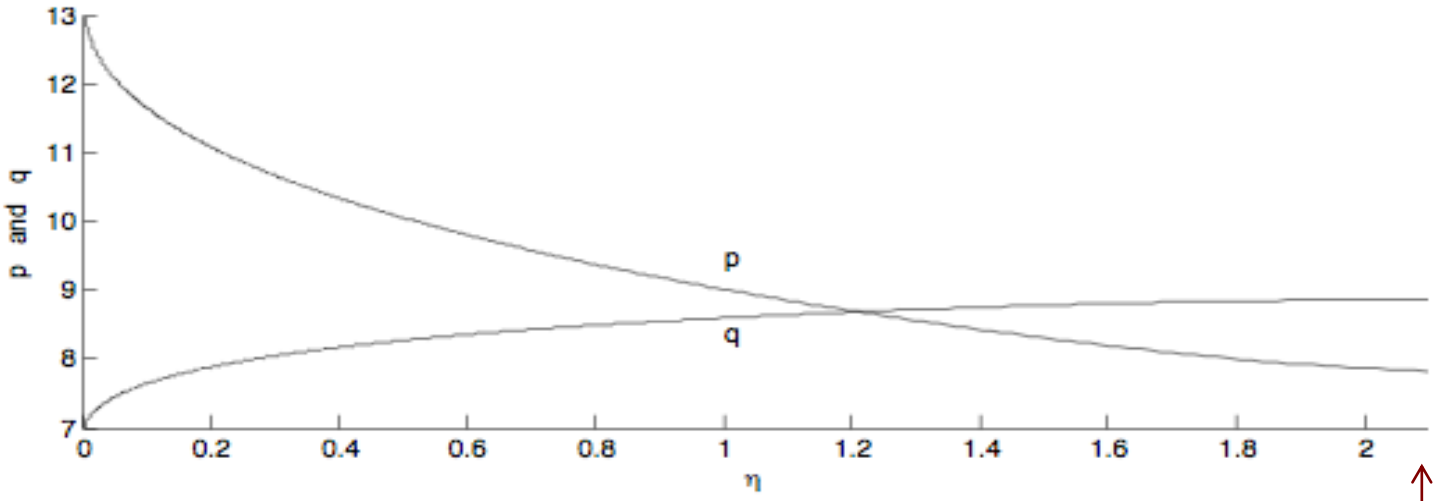
$$E[dr_t^{\omega} - dr_t^{M}] \leq Cov\left[d\varepsilon_t^{q} + d\varepsilon_t^{M}, d\varepsilon_t^{HH-N}\right] \ (= if\ \xi_t(\omega) > 0)$$

Simplified Example

- Three household types ω only
  - Low: very bad technology, hold money
  - Medium: risk-free technology, prefer to hold capital over money
  - High: risky production – low net worth

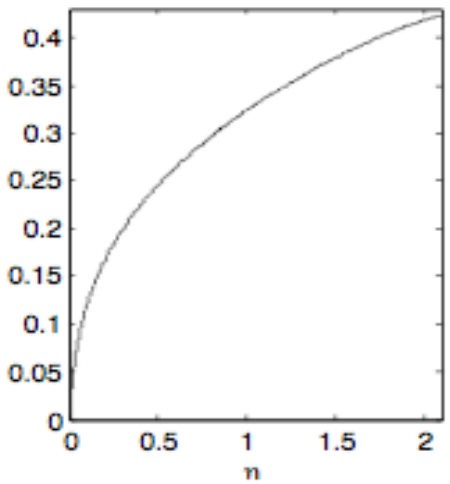
- Intermediaries choose to invest only in the most productive technology (due to high monitoring cost)

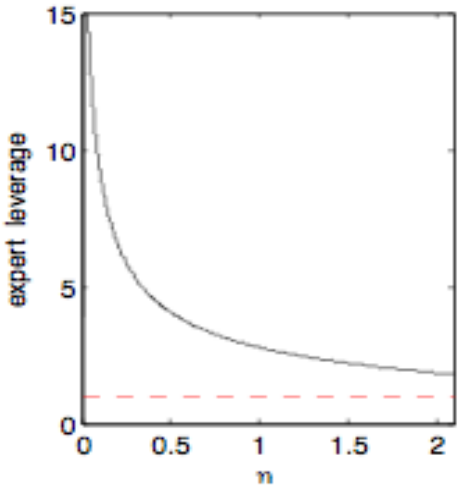
Example

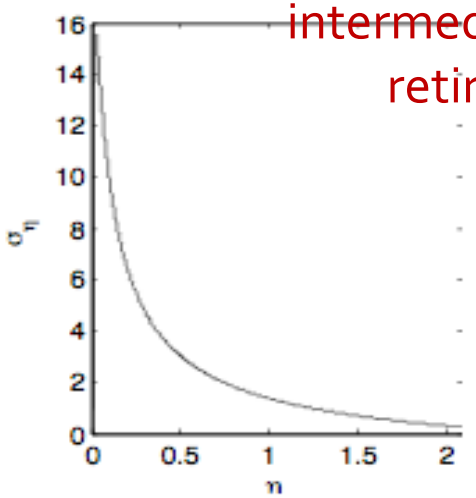


some intermediaries retire

- allocation to the most productive technology

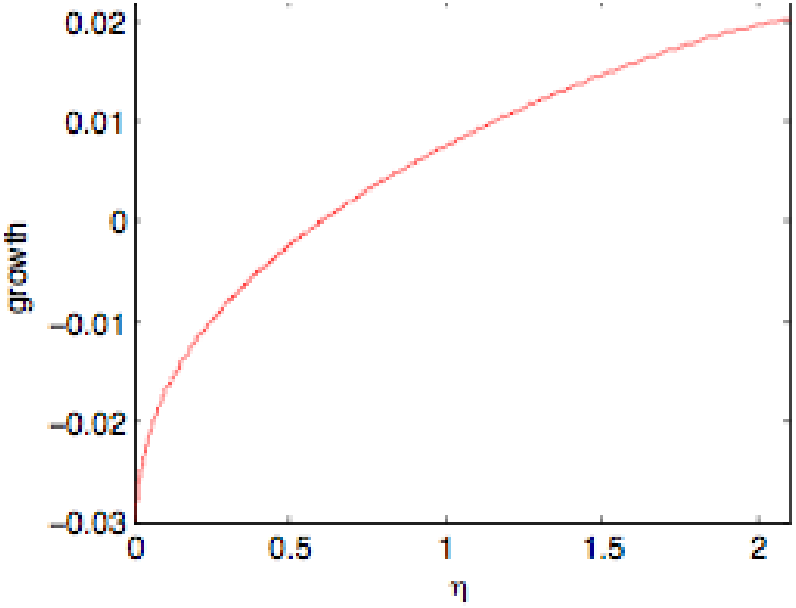


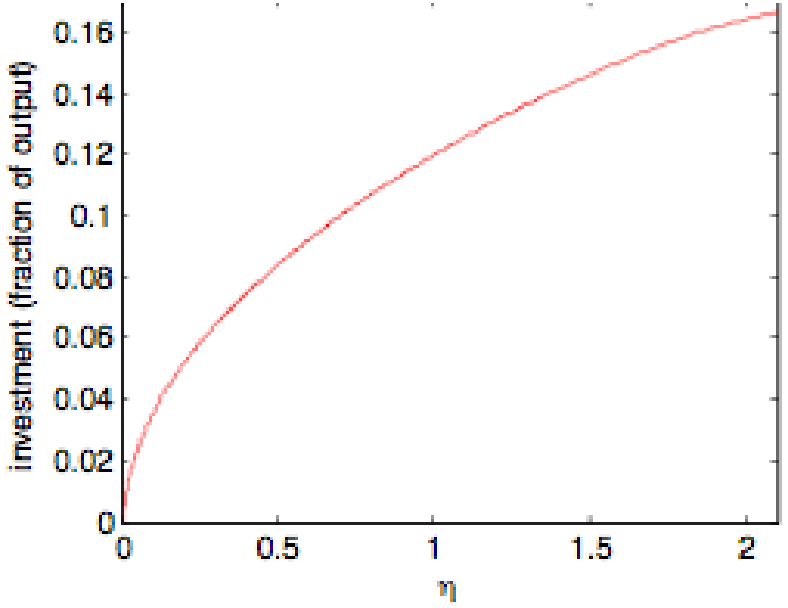


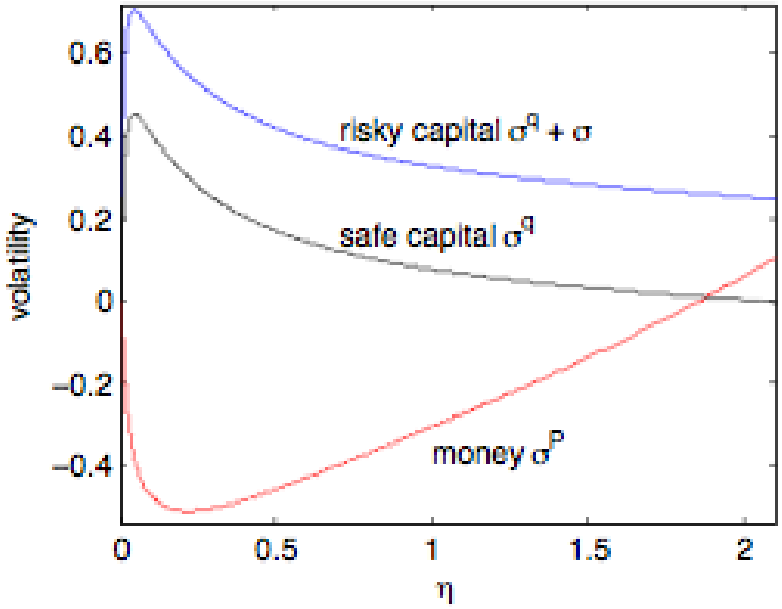


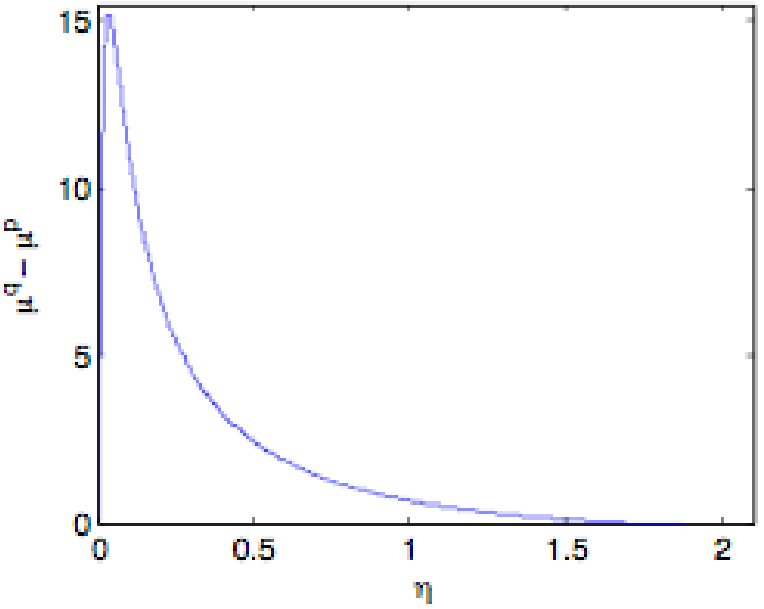
$\bar{a} = 1, r = 5\%, \delta^H = 0, \delta^M = 3\%, \sigma = 25\%, \theta^L = .65, \theta^M = 35\%, \theta^H = 0\%, \Phi(i) = (0.02i)^{1/2}$

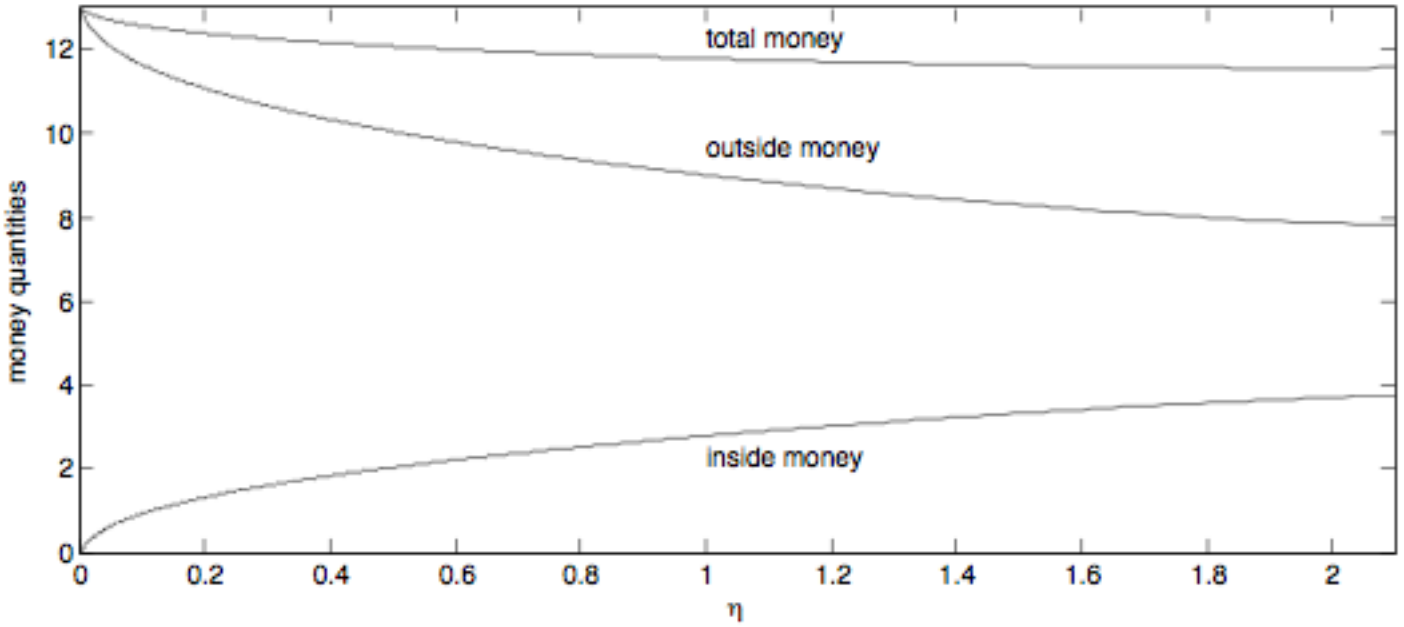
Brunnermeier & Sannikov 2011

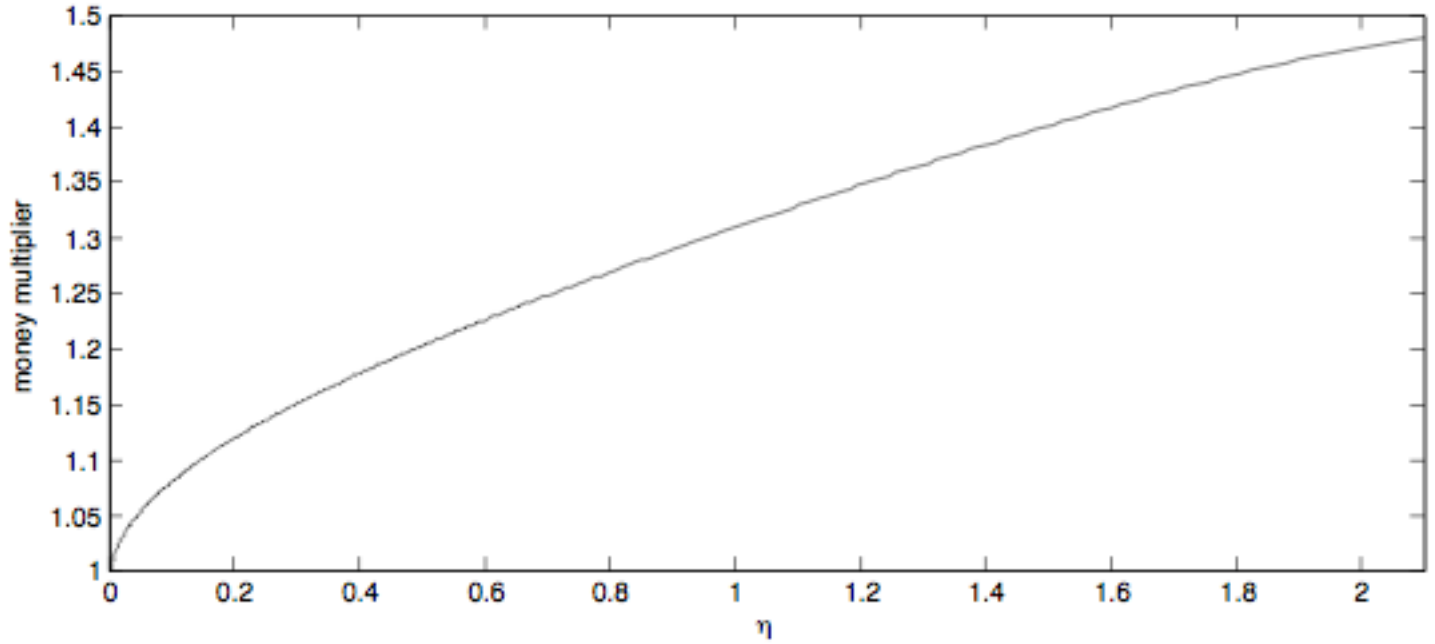

growth
η


investment (fraction of output)
η


volatility
risky capital $\sigma^q + \sigma$
safe capital σ^q
money σ^p
η


$\mu^q - \mu^p$
η


total money
outside money
inside money
money quantities
η
0
2
4
6
8
10
12
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2


money multiplier
η
1
1.05
1.1
1.15
1.2
1.25
1.3
1.35
1.4
1.45
1.5
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2

Observations

- As η goes down:
- Intermediaries take on less risk, competition decreases
- Price of capital q and investment, i(q), decrease
- Capital is allocated less efficiently
- Unproductive households hold less inside money (loans to intermediaries/entrepreneurs) and more outside fiat money
- Price of outside money goes up (deflation)
- Additional source of amplification in economy with money:
  - value of assets fall
  - value of liabilities increase (due to deflation)

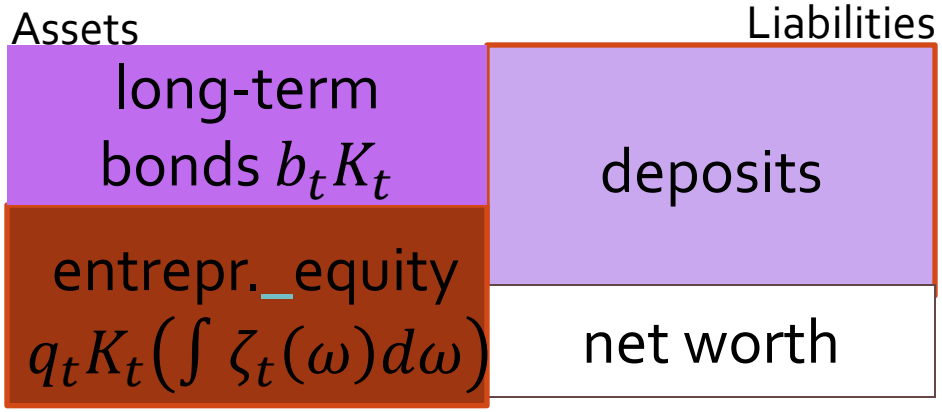
Monetary Policy

- So far, Gold Standard
  - outside money fixed,
  - pays no interest
  - no central bank

  - Introduce consul (perpetual) bond
    – pays interest rate in ST (outside) money
- Monetary Policies
  - Short-term interest rate policy
    - Central bank accepts deposits
      & pays interest rate (by printing money)
      - E.g. short-term interest rate is lowered when η becomes small
    - Budget neutral policies (at any point in time)
  - Asset purchase program
    - Bond – open market operations (OMO)

Money and Long-term Bond

- Policy instruments (functions of η_t)
  - Central bank pays interest $r_t \geq 0$ on money (by printing)
  - Sets total outstanding value $b_t K_t$ of perpetual bond (by transacting)
- Endogenous market reaction
  - Price of long-term bond (in money, per unit coupon rate)
  - $dB_t = \mu_t^B B_t dt + B_t d\varepsilon_t^B$
  - q_t = price of capital
  - $p_t K_t$ = value of money



Disentangling Money and Bonds

- Return on money: $dr_t^M = \mu_t^M dt + d\varepsilon_t^M$
- Price of bond: $\frac{dB_t}{B_t} = \mu_t^B dt + d\varepsilon_t^B$ ($\frac{1}{B_t}$ is current yield)
- Return on bonds:
  $dr_t^B = dr_t^M + (\frac{1}{B_t} - r_t + \mu_t^B + Cov[\varepsilon_t^B, \varepsilon_t^M])dt + d\varepsilon_t^B$
- All monetary instruments: $\frac{d(p_t+b_t)K_t}{(p_t+b_t)K_t} = dr_t^M + \frac{b_t}{p_t+b_t}(dr_t^B - dr_t^M)$
  $= \left(\mu_t^p + \mu_t^b + \mu_t^K + Cov\left[\varepsilon_t^p + \varepsilon_t^b, \varepsilon_t^K\right]\right)dt + d\varepsilon_t^p + d\varepsilon_t^b + \varepsilon_t^K$

- Collecting shocks: $d\varepsilon_t^M + \frac{b_t}{p_t+b_t} d\varepsilon_t^B = d\varepsilon_t^p + d\varepsilon_t^b + \varepsilon_t^K$

Equilibrium Conditions

1. Market clearing for capital goods and bonds

$$\int \zeta_t(\omega)d\omega + \int \xi_t(\omega)d\omega = 1, \qquad \zeta_t^B + \int \xi_t^B(\omega)d\omega = 1$$

2. Market clearing for output:

$$\int (\zeta_t(\omega) + \xi(\omega))c^{\omega}(q_t)d\omega = \rho(q_t + p_t + b_t)$$

3. Valuation of capital ω -- return = Cov(risk, net worth risk)

$$E[dr_t^{\omega} - dr_t^M] \leq Cov\left[d\varepsilon_t^q + d\varepsilon_t^M, d\varepsilon_t^N\right] \qquad (= if\ \zeta_t(\omega) > 0)$$

$$E[dr_t^{\omega} - dr_t^M] \leq Cov\left[d\varepsilon_t^q + d\varepsilon_t^M, d\varepsilon_t^{HH-N}\right] \quad (= if\ \xi_t(\omega) > 0)$$

4. Valuation of bonds

$$E[dr_t^B - dr_t^M] = Cov[d\varepsilon_t^B, d\varepsilon_t^N] \qquad \text{(assuming } \zeta_t^B > 0)$$

$$E[dr_t^B - dr_t^M] \leq Cov[d\varepsilon_t^B, d\varepsilon_t^{HH-N}] \quad (= \text{if } \xi_t^B(\omega) > 0)$$

Short-term interest rate

- Without long-maturity assets changes in short-term interest rate have no effect
  - Interest rate change equals instantaneous inflation change
- With bonds: of all monetary instruments, fraction $p_t/(p_t+b_t)$ is cash and $b_t/(p_t+b_t)$ are bonds
  - deflationary spiral is less pronounced because as η goes down, growing demand for money is absorbed by increase in value of long-term bonds
  - also, intermediaries hedge risks better by holding long-term bonds
  - however, intermediaries also have greater incentives to increase leverage/risk-taking ex-ante
- Effectiveness of monetary policy depend on maturity structure (duration) of government debt

	New Keynesian	I-Theory
Key friction	Price stickiness & ZLB	Financial friction
Driver	Demand driven as firms are obliged to meet demand at sticky price	Misallocation of funds increases incentive problems and restrains firms/banks from exploiting their potential
Monetary policy • First order effects	Affect HH's intertemporal trade-off Nominal interest rate impact real interest rate due to price stickiness	Ex-post: redistributional effects between financial and non-financial sector Ex-ante: insurance effect leading to moral hazard in risk taking (bubbles) - Greenspan put -
• Second order effects	Redistributional between firms which could (not) adjust price	
Time consistency	Wage stickiness Price stickiness + monopolistic competition	Moral hazard

	New Keynesian	I-Theory
Risk build-up phase		Endogenous due to accommodating monetary policy
Net worth dynamics	zero profit no dynamics	dynamic
State variables	Many exogenous shocks Intermediation/friction shock	Endogenous intermediation shock
Monetary policy rule	Taylor rule (is approximately optimal only if difference in u' is well proxied by output gap) • spreads • credit aggregates (?)	Depends on signal quality and timeliness of various observables
Policy instrument	Short-term interest rate + expectations	Short-term interest rate **+ long-term bond** + expectations
Role of money	In utility function (no deflation spiral)	Storage Precautionary savings

	Monetarism	I-Theory
Focus	Price stability	Price and Financial stability
Theory	Quantity theory of money P*Y = v*M Transaction role of money	Distribution of wealth (liquidity, balance sheet) endogenous money multiplier
Monetary aggregates	Mo (Brunner, Meltzer) M1-2(Friedman,Schwartz) Inside and outside money are *perfect substitutes*	Outside money is only *imperfect substitute* for inside money (intermediation) Bank underwriting (*credit lines*) is substitute to bank deposits (difficult to measure M1-3 in a meaningful way)
Monetary policy	Constant growth of M2 (Friedman)	Recapitalize banks through monetary policy Switch off deflationary pressure

Conclusion

- Unified macromodel to analyze both
  - Financial stability
  - Monetary stability
    - Liquidity spirals
    - Fisher deflation spiral
  - GDP drops are associated with deflation (not inflation) absent monetary policy
- Capitalization of banking sector is key state variable
  - Price stickiness plays no role (unlike in New Keynesian models)
- Monetary policy rule
  - Redistributional feature
  - Time inconsistency problem – "Greenspan put"

- Further research
  - "Minsky cycle"

Intermediaries and lending

- Monitoring technology
  Diamond (1984)
  Homstrom-Tirole (1997)