Princeton Initiative 2011
Macro, Money and Finance

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Macro-literature on Frictions

1. Persistence, amplification and instability
   a. Persistence: Carlstrom, Fuerst
   b. Amplification: Bernanke, Gertler, Gilchrist
   c. Instability: Brunnermeier, Sannikov
2. Credit quantity constraints through margins
   a. Credit rationing: Stiglitz, Weiss
   b. Margin spirals : Brunnermeier, Pederson
   c. Endogenous constraints: Geanakoplos
3. Demand for liquid assets & Bubbles – "self insurance"
   a. OLG, Aiyagari, Bewley, Krusell-Smith, Holmstroem Tirole,…
4. Financial intermediaries & Theory of Money

Demand for Liquid Assets, Bubbles, …

M. Brunnermeier, T. Eisenbach, and Y. Sannikov

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Demand for Liquid Assets

- *Technological and market illiquidity* create time amplification and instability
  - Fire-sales lead to time varying price of capital
  - Liquidity spirals emerge when price volatility interacts with debt constraints
- Focus on demand for liquid instruments
  - No amplification effects, i.e. reversible investment and constant price of capital q
    - Borrowing constraint = collateral constraint
  - Introduce idiosyncratic risk, aggregate risk, and finally amplification

Outline – Demand for Liquid Assets

- Deterministic Fluctuations
  - Overlapping generations
  - Completing markets with liquid asset
- Idiosyncratic Risk
  - Precautionary savings
  - Constrained efficiency
- Aggregate Risk
  - Bounded rationality
- Amplification Revisited

Overlapping Generations

- Samuelson (1958) considers an infinite-horizon economy with two-period lived overlapping agents
  - Population growth rate n
- Preferences given by $u(c_t^t, c_{t+1}^t)$
  - Pareto optimal allocation satisfies $\frac{u_1}{u_2} = 1 + n$
- OLG economies have multiple equilibria that can be Pareto ranked

OLG: Multiple Equilibria

- Assume $u(c_t^t, c_{t+1}^t) = \log c_t^t + \beta \log c_{t+1}^t$
  - Endowment $y_t^t = e, y_{t+1}^t = 1 - e$
- Assume complete markets and interest rate r
- Agent's FOC implies that $\frac{c_{t+1}^t}{\beta c_t^t} = 1 + r$
  - For $r = n$, this corresponds to the *Pareto solution*
  - For $r = \frac{1-e}{\beta e} - 1$, agents will consume their endowment
- Autarky solution is clearly *Pareto inferior*

OLG: Completion with Durable Asset

- Autarky solution is the **unique** equilibrium implemented in a sequential exchange economy
  - Young agents cannot transfer wealth to next period
  - *… more from Chris Sims on this issue on Sunday*
- A durable asset provides a <u>store of value</u>
  - Effective store of value reflects *market liquidity*
  - Pareto solution can be attained as a competitive equilibrium in which the price level grows at same rate as the population, i.e. $b_{t+1} = (1+n)b_t$
  - Old agents trade durable asset for young agents' consumption goods

OLG: Production

- Diamond (1965) introduces a capital good and production
  - Constant-returns-to-scale production $Y_t = F(K_t, L_t)$
- Optimal level of capital is given by the *golden rule*, i.e. $f'(k^*) = n$
  - Here, lowercase letters signify **per capita** values
- Individual (and firm) optimization implies that
  - $\frac{u_1}{u_2} = 1 + r = 1 + f'(k)$
  - It is possible that $r < n \Rightarrow k > k^* \Rightarrow$ Pareto inefficient

OLG: Production & Efficiency

- Diamond recommends issuing government debt at interest rate r
- Tirole (1985) introduces a rational bubble asset trading at price b_t
  - $b_{t+1} = \frac{1+r_{t+1}}{1+n} b_t$
- Both solutions *crowd out* investment and increase r
  - If baseline economy is inefficient, then an appropriately chosen debt issuance or bubble size can achieve Pareto optimum with $r = n$

OLG: Crowding Out vs. Crowding In

- Depending on the framework, government debt and presence of bubbles can have two opposite effects
  - Crowding out refers to the decreased investment to increase in supply of capital
  - Crowding in refers to increased investment due to improved risk transfer
- Woodford (1990) explores both of these effects

OLG: Woodford 1

- Consider a model with two types of agents
  - Per capita production $f(k)$
  - Alternating endowments $\bar{e} > \underline{e} > 0$
  - No borrowing
- Stationary solution
  - High endowment agents are *unconstrained*, consuming $\bar{c}$ and saving part of endowment
  - Low endowment agents are *constrained*, consuming $\underline{c} \leq \bar{c}$ and depleting savings

OLG: Crowding Out

- Euler equations
  - Unconstrained: $u'(\bar{c}) = \beta(1+r)u'(\underline{c})$
  - Constrained: $u'(\underline{c}) \geq \beta(1+r)u'(\bar{c})$
- Interest rate is lower than discount rate
  - $f'(k) - 1 = r \leq \beta^{-1} - 1 \equiv \rho \Rightarrow$ Pareto inefficient
- Increasing debt provides *market liquidity*
  - This increases interest rate and reduces capital stock
  - With $r = \rho \Rightarrow \underline{c} = \bar{c}$ (full insurance)

OLG: Woodford 2

- Assume agents now have alternating *opportunities* (instead of endowments)
  - Unproductive agents can only hold government debt
  - Productive agents can hold debt *and* capital
- Stationary solution
  - Unproductive agents are *unconstrained*, consuming $\bar{c}$ and saving part of endowment (as debt)
  - Productive agents are *constrained*, consuming $\underline{c} \leq \bar{c}$ and investing savings and part of endowment in capital

OLG: Crowding In

- Euler equations
  - Unconstrained: $u'(\bar{c}) = \beta(1+r)u'(\underline{c})$
  - Constrained: $u'(\underline{c}) = \beta f'(k)u'(\bar{c})$
  - Interest rate satisfies $1 + r \leq f'(k)$
- Increasing debt provides *market liquidity*
  - This increases r and k since $\beta(1+r) = \frac{1}{\beta f'(k)}$
  - Transfer from unproductive periods to productive periods
  - Increase debt until both agents are unconstrained

Outline – Demand for Liquid Assets

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Precautionary Savings

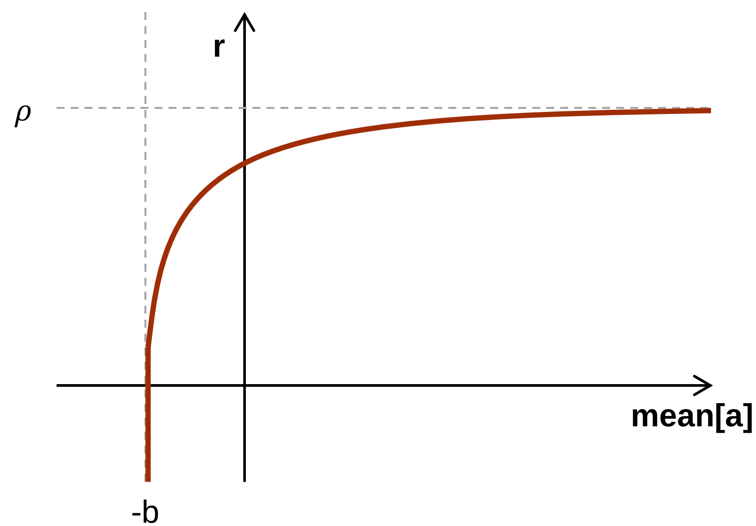
- Consumption smoothing implies that agents will save in high income states and borrow in low income states
  - If markets are incomplete, agents may not be able to efficiently transfer consumption between these outcomes
- Additional precautionary savings motive arises when agents cannot insure against uncertainty
  - Shape of utility function u'''
  - Borrowing constraint $a_t \geq -b$

PCS: Prudence

- Utility maximization $E_0[\sum_{t=0}^{\infty} \beta^t u(c_t)]$
  - Budget constraint: $c_t + a_{t+1} = e_t + (1+r)a_t$
  - Standard Euler equation: $u'(c_t) = \beta(1+r)E_t[u'(c_{t+1})]$
- If $u''' > 0$, then Jensen's inequality implies:
  - $\frac{1}{\beta(1+r)} = \frac{E_t[u'(c_{t+1})]}{u'(c_t)} > \frac{u'(E_t[c_{t+1}])}{u'(c_t)}$
  - Marginal value is greater due to uncertainty in c_{t+1}
  - Difference is attributed to *precautionary savings*
- Prudence refers to curvature of u', i.e. $P = -\frac{u'''}{u''}$

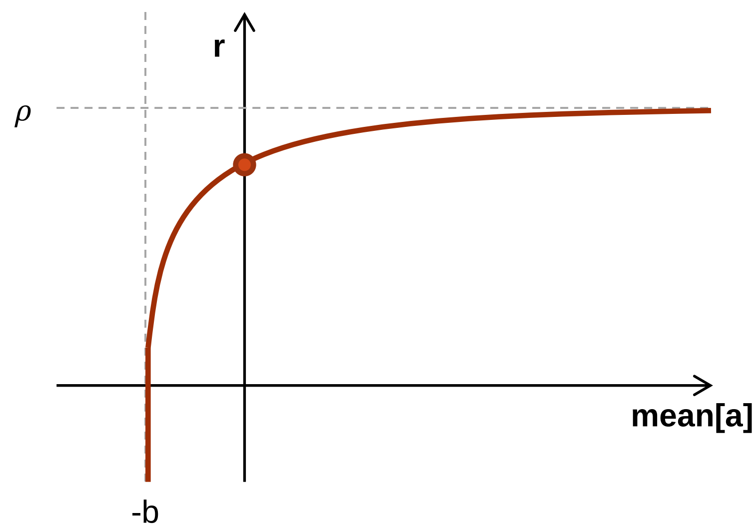
PCS: Borrowing constraint + Idiosync. Risk

- With *incomplete markets* and *borrowing constraints*, agents engage in precautionary savings in the presence of idiosyncratic income shocks
- Following Bewley (1977), mean asset holdings $E[a]$ result from individual optimization



BC: Exchange Economy

- In an exchange economy, aggregate supply of assets must be zero
  - Huggett (1993)
- Equilibrium interest rate always satisfies $r < \rho$



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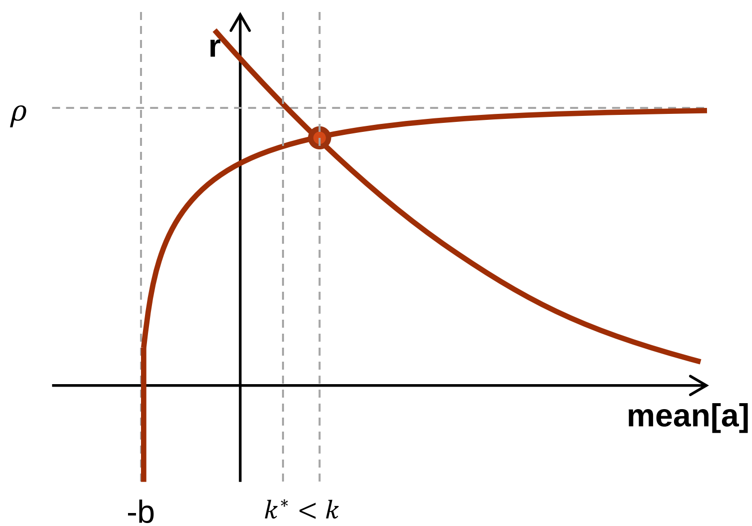
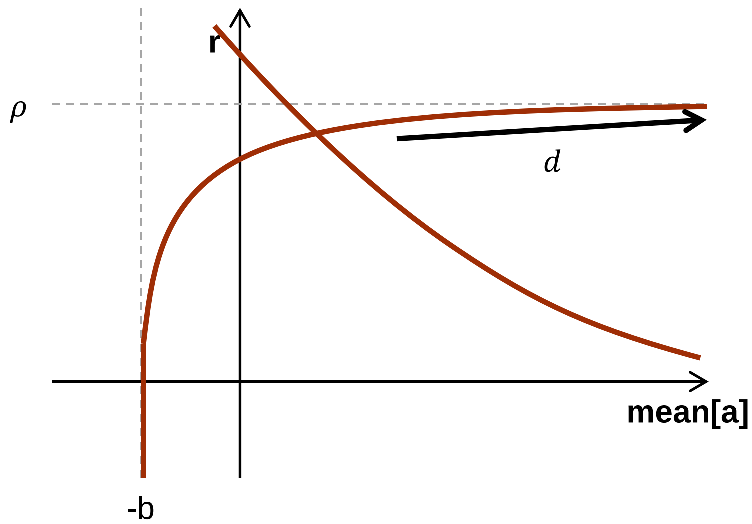
BC: Production Economy

- Aiyagari (1994) combines the previous setup with standard production function $F(K, L)$
  - Constant aggregate labor L
- Demand for capital is given by $f'(k) - \delta = r$
  - Efficient level of capital $f'(k^*) - \delta = \rho \Rightarrow k^* < k$



BC: Production Economy

- Aiyagari (1995) shows that a tax on capital earnings can address this efficiency problem
  - This decreases the net interest rate received by agents
- Government debt does not work “perfectly”
  - No finite amount of government debt will achieve $r = \rho$



Constrained Inefficiency

- Bewley-Aiyagari economies result in competitive allocations that are not only Pareto inefficient, but are also *constrained* Pareto inefficient
  - Social planner can achieve a Pareto superior outcome even facing same market incompleteness
- This result can be attributed to *pecuniary externalities*
  - In competitive equilibrium, agents take prices as given whereas a social planner can induce wealth transfers by affecting relative prices
  - Stiglitz (1982), Geanakoplos-Polemarcharkis (1986)

CI: Aiyagari Economy

- Davila, Hong, Krusell, Rios-Rull (2005) consider welfare increasing changes in Aiyagari setting
- Higher level capital leads to higher wages and lower interest rates
  - Higher wage amplifies contemporaneous effect of labor endowment shock
  - Lower interest rate dampens impact of endowment shock in following periods

CI: Amplification

- Two period setting with $t \in \{0,1\}$
  - Initial wealth y
  - Labor endowment $e \in \{e_1, e_2\}$ (i.i.d)
  - Aggregate labor: $L = \pi e_1 + (1-\pi)e_2$
  - Production function $f(K, L)$
- Agent consumption plan given by $\{c_0, c_1, c_2\}$
  - $c_i \leq e_i w + K(1+r)$
  - $\frac{dU}{dK} = \{-u'(c_0) + \beta(1+r)[\pi u'(c_1) + (1-\pi)u'(c_2)]\} +$
    $\beta[\pi u'(c_1)K + (1-\pi)u'(c_2)K]\frac{dr}{dK} +$
    $\beta[\pi u'(c_1)e_1 + (1-\pi)u'(c_2)e_2]\frac{dw}{dK}$

CI: Amplification

- The first expression is zero from agent's FOC
  - Agents take prices as given, i.e. assume $\frac{dw}{dK} = \frac{dr}{dK} = 0$
- In a competitive equilibrium $\frac{dr}{dK} = f_{KK}$ and $\frac{dw}{dK} = f_{KL}$
  - f linearly homogeneous implies $K f_{KK} + L f_{KL} = 0$
- This provides:
  - $\frac{dU}{dK} = \beta\pi(1-\pi)\frac{K f_{KK}}{L}(u'(c_1) - u'(c_2))(e_2 - e_1) < 0$
  - Reducing level of capital improves ex-ante utility

CI: Dampening

- Consider addition of third period $t = 2$
  - Same labor endowment $e \in \{e_1, e_2\}$
- Effect of change in capital level at $t = 1$ depends on realization of labor endowment
  - $\Delta = \beta\pi(1-\pi)\frac{Kf_{KK}}{L}(u'(c_1) - u'(c_2))(e_2 - e_1) < 0$
  - $\frac{dU_i}{dK} = \beta\left[\Delta + \beta\left(\pi u'(c_{i1})\right) + (1-\pi)u'(c_{i2})\right)(K_i - K)f_{KK}]$
- Second term is positive if and only if $K_i < K$
  - Increasing capital more desirable for low endowment agents and less desirable for high endowment agents

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Aggregate Risk

- Krusell, Smith (1998) introduce aggregate risk into the Aiyagari framework
  - Aggregate productivity shock that follows a Markov process z_t and $Y_t = z_t F(K_t, L_t)$
- Aggregate capital stock determines equilibrium prices r_t, w_t
  - However, the evolution of aggregate stock is affected by the **distribution** of wealth since poor agents may have a much higher propensity to save
  - Tracking whole distribution is practically impossible

AR: Bounded Rationality

- Krusell, Smith assume agents are boundedly rational and approximate the distribution of capital by a finite set of moments M
  - Regression R^2 is relatively high even if $\#M = 1$
- This result is strongly dependent on low risk aversion and low persistence of labor shocks
  - Weak precautionary savings motive except for poorest agents
  - Since wealth-weighted averages are relevant, this has a negligible effect on aggregate quantities

AR: Persistence

- Constantinides & Duffie (1996) highlight importance of persistent income shocks
  - Any price process can be replicated (in a non-trading environment)
- With non-stationary and heteroskedastic individual income processes, self-insurance through precautionary saving is far less effective
  - Any shock to agent's income permanently affects expected share of future aggregate income
  - Wealth heterogeneity is significant

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Amplification Revisited

- Investment possibility shocks
  - Production possibilities: Scheinkman & Weiss (1986)
  - Investment possibilities: Kiyotaki & Moore (2008)
- Interim liquidity shocks
  - Exogenous shock: Holmstrom & Tirole (1998)
  - Endogenous shock: Shleifer & Vishny (1997)
- Preference shocks
  - No aggregate risk: Diamond & Dybvig (1983)
  - Aggregate risk: Allen & Gale (1994)

Scheinkman & Weiss

- Two types of agents with perfectly negatively correlated idiosyncratic shocks
  - No aggregate risk, but key difference is that labor supply is now elastic
- Productivity reflects *technological liquidity*
  - Productivity switches according to a Poisson process
  - Productive agents can produce consumption goods
- No capital in the economy
  - Can only save by holding money (fixed supply)
  - Productive agents exchange consumption goods for money from unproductive agents

SW: Aggregate Dynamics

- Aggregate fluctuations due to elastic labor supply
- Price level is determined in equilibrium
  - As productive agents accumulate money, wealth effect induces lower labor supply
  - Aggregate output declines and price level increases
- Effect of changes in money supply depends on distribution of money between agent types
  - Increase in money supply will reduce (increase) aggregate output when productive agents hold less (more) than half the money supply, i.e. when output is high (low)

Kiyotaki & Moore 08

- Two types of agents, entrepreneurs and households
  - Entrepreneurs can invest,
    but only when they have an investment opportunity
  - Opportunities correspond to *technological liquidity*
- Investment opportunities arrive i.i.d. and cannot be insured against
  - Entrepreneur can invest with probability π
- Agents can hold equity or fiat money

KM: Financing

- Entrepreneurs have access to 3 sources of capital
  - New equity claims, but a fraction $1-\theta$ must be held by entrepreneur for at least one period
  - Existing equity claims, but only a fraction ϕ_t of these can be sold right away
  - Money holdings, with no frictions
- Capital frictions represent *illiquidity*

KM: Entrepreneurs

- Budget constraint:
  - $c_t + i_t + q_t(n_{t+1} - i_t) + p_t(m_{t+1} - m_t) = r_t n_t + q_t(1-\delta)n_t$
  - Equity holdings net of investment $n_{t+1} - i_t$
  - Price of equity/capital q_t can be greater than 1 due to limited investment opportunities
- Liquidity constraint:
  - $n_{t+1} \geq (1-\theta)i_t + (1-\phi_t)(1-\delta)n_t$
  - Limits on selling new and existing equity place lower bound on future equity holdings

KM: Investment Opportunity

- For low θ, ϕ_t, liquidity constraints are binding and money has value
- An entrepreneur with an investment opportunity will spend all of his money holding
  - Budget constraint can be rewritten as $c_t^i + q_t^R n_{t+1}^i = r_t n_t + (\phi_t q_t + (1-\phi_t) q_t^R)(1-\delta) n_t + p_t m_t$
  - Replacement cost of capital: $q_t^R \equiv \frac{1-\theta q_t}{1-\theta}$
  - Can create new equity holdings at cost $q_t^R < q_t$, but this reduces value of remaining unsold holdings

KM: No Investment Opportunity

- Entrepreneur without investment opportunity decides on allocation between equity (depends on opportunity at $t+1$) and money
  - Return to money: $R^m_{t+1} \equiv \frac{p_{t+1}}{p_t}$
  - No opportunity: $R^s_{t+1} \equiv \frac{r_{t+1}+q_{t+1}(1-\delta)}{q_t}$
  - Opportunity: $R^i_{t+1} \equiv \frac{r_{t+1}+\left(\phi_{t+1}q_{t+1}+(1-\phi_{t+1})q^R_{t+1}(1-\delta)\right)}{q_t}$

KM: Logarithmic Utility

- Under logarithmic utility, entrepreneurs will consume $1 - \beta$ fraction of wealth
- Around steady-state, aggregate level of capital is smaller than in first-best economy, i.e. $K_{t+1} < K^*$
  - Expected return on capital $E_t[f'(K_{t+1}) - \delta] > \rho$
- Conditional liquidity premium arises since $E_t[R_{t+1}^m] < E_t[R_{t+1}^s] < 1 + \rho$
  - Unconditional liquidity premium may also arise (but is smaller) since $E_t\left[R_{t+1}^i\right] < E_t[R_{t+1}^m]$

KM: Real Effects

- Negative shocks to *market liquidity* ϕ_t of equity have aggregate effects
  - Shift away from equity into money
  - Drop in price q_t and increase in p_t
  - Decrease in investment and capital
- Shock to financing conditions feeds back to real economy as a reduction in output
  - KM find that government can counteract effects by buying equity and issuing new money (upward pressure on q_t and downward pressure on p_t)

Holmstrom & Tirole 98

- Three period model with $t \in \{0,1,2\}$
- Entrepreneurs with initial wealth A
  - Investment of I returns RI in $t = 2$ with probability p
  - Interim funding requirement ρI at $t = 1$ with $\rho \sim G$
  - Extreme *technological illiquidity*, as investment is worthless if interim funding is not provided
- Moral hazard problem
  - Efficiency requires $\rho \leq \rho_1 \equiv pR \Rightarrow$ continuation
  - Only $\rho \leq \rho_0 < \rho_1$ of funding can be raised due to manager's private benefit, i.e. principal-agent conflict

HT: Optimal Contracting

- Optimal contract specifies:
  - Investment size I
  - Continuation cutoff $\hat{\rho}$
  - Division of returns contingent on realized ρ
- Entrepreneurs maximize expected surplus, i.e.
  - $\max_{I,\hat{\rho}} \left\{ I \int_0^{\hat{\rho}} (\rho_1 - \rho) dG(\rho) - I \right\}$
- Households can only be promised ρ_0 at $t = 1$
  - Breakeven condition: $I \int_0^{\hat{\rho}} (\rho_0 - \rho) dG(\rho) = I - A$
- Solution provides cutoff $\hat{\rho} \in [\rho_0, \rho_1]$

HT: General Equilibrium

- Without a storage technology, liquidity must come from financial claims on real assets
  - *Market liquidity* of claims becomes crucial
- If there is no aggregate uncertainty, the optimal contract can be implemented:
  - Sell equity
  - Hold part of market portfolio
  - Any surplus is paid to shareholders as dividends

HT: Aggregate Risk

- With aggregate risk, optimal contract may not be implementable
  - Market liquidity of equity is affected by aggregate state
- Consider perfectly correlated projects
  - Liquidity is low when it is needed (bad aggregate state)
  - Liquidity is high when it is not needed (good state)
- This introduces a role for government to provide a store of wealth

Shleifer & Vishny 97

- Fund managers choose how aggressively to exploit an arbitrage opportunity
- Mispricing can widen in interim period
  - Investors question investment and withdraw funds
  - Managers must unwind position when mispricing is largest, i.e. most profitable
  - Low *market liquidity* due to limited knowledge of opportunity
- Fund managers predict this effect, and thus limit arbitrage activity
  - Keep buffer of liquid assets to fund withdrawals

Diamond & Dybvig 83

- Three period model with $t \in \{0,1,2\}$
- Continuum of ex-ante identical agents
  - Endowment of 1 in $t = 0$
  - Idiosyncratic preference shock, i.e. probability λ that agent consumes in $t = 1$ and probability $1 - \lambda$ that agent consumes in $t = 2$
- Preference shock is not observable to outsiders
  - Not insurable, i.e. incomplete markets

DD: Investment

- Good can be stored without cost
  - Payoff of 1 in any period
- Long term investment project
  - Payoff of $R > 1$ in $t = 2$
  - Salvage value of $r \leq 1$ if liquidated early in $t = 1$
  - Market for claims to long-term project at price p
- Trade-off between return and *liquidity*
  - Investment is subject to *technological illiquidity*, i.e. $r \leq 1$
  - Market liquidity is represented by interim price p

DD: Consumption

- Investing x induces contingent consumption plan:
  - $c_1 = px + (1-x)$
  - $c_2 = Rx + \frac{R(1-x)}{p}$
- In equilibrium, we require $p = 1$
  - If $p < 1$, then agents would store the asset and purchase project at $t = 1$
  - If $p > 1$, then agents would invest and sell project at $t = 1$

DD: Optimality

- With interim markets, any investment plan leads to $c_1 = 1, c_2 = R$
  - If $r < 1$, fraction $1 - \lambda$ of aggregate wealth must be invested in project (market clearing)
  - Since $p > r$, then asset's *market liquidity* is greater than its *technological liquidity*
- This outcome is clearly superior to autarky, with $c_1' = r, c_2' = R$ or $c_1'' = c_2'' = 1$

Allen & Gale

- AG extend DD framework by adding aggregate risk
  - Here, $\lambda = \lambda_H$ with probability π and $\lambda = \lambda_L < \lambda_H$ with probability $1 - \pi$
- Agents observe realization of aggregate state and idiosyncratic preference shock at $t = 1$
  - After resolution of uncertainty, agents can trade claims to long-term project at $p_s \in \{p_H, p_L\}$
  - Asset's *market liquidity* will vary across states
- For simplicity, assume $r = 0$

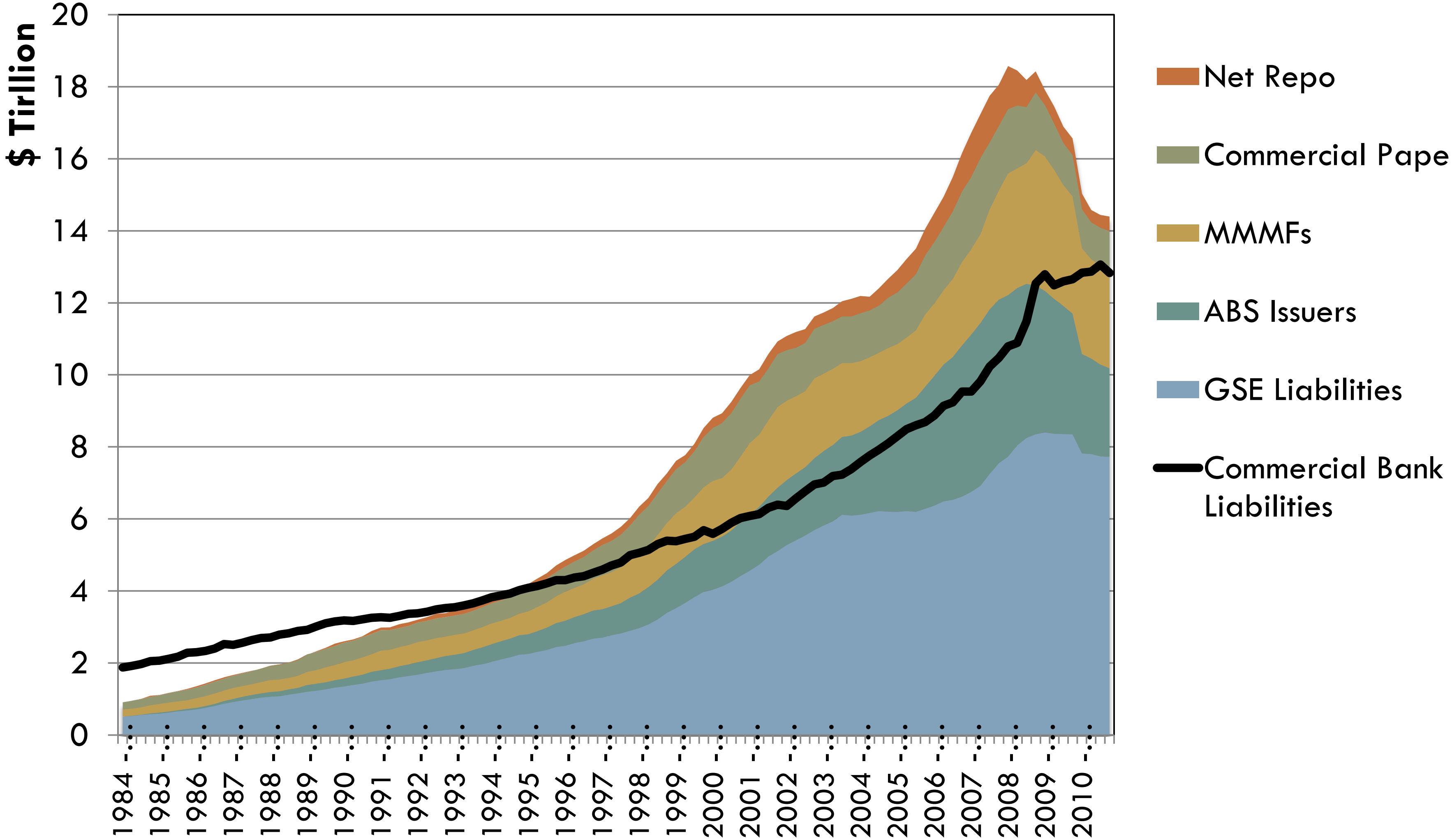
AG: Prices

- Market clearing requires $p_s \leq R$
  - Late consumers stored goods: $(1-\lambda_s)(1-x)$
  - Early consumers invested goods: $\lambda_s x$
- Cash-in-the-market pricing
  - $p_s = \min\left\{R, \frac{(1-\lambda_s)(1-x)}{\lambda_s x}\right\}$
  - This implies that $p_H \leq p_L$, i.e. *market liquidity* is weaker when there are a large proportion of early consumers
- Despite deterministic project payoffs, there is volatility in prices

Overview

- Persistence
- Dynamic Amplification
  - Technological illiquidity BGG
  - Market illiquidity KM97
- Instability, Volatility Dynamics, Volatility Paradox
- Volatility and Credit Rationing/Margins/Leverage
- Demand for Liquid Assets
- Financial Intermediation

Gross Shadow Banking and Commercial Banking Liabilities



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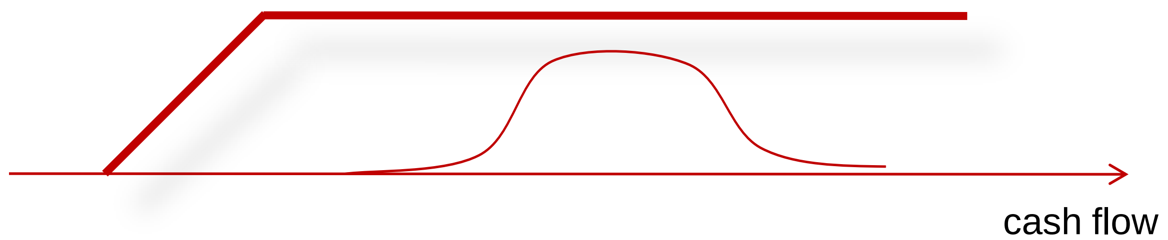
Creating Info-Insensitive Securities

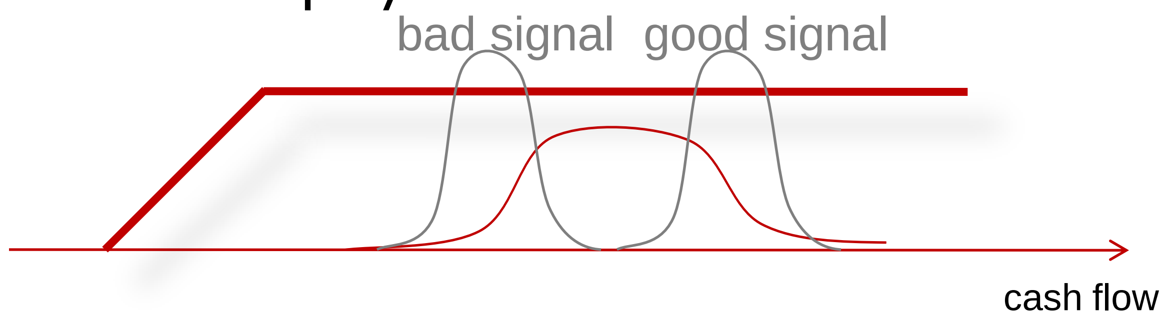
- Debt contract payoff – prior distribution of cash flow



- Asymmetric info (lemons') problem kicks in
  - No more rollover
- Maturity choice:
  - Short-term debt: distribution shrinks (less info-sensitity)

Creating Info-Insensitive Securities

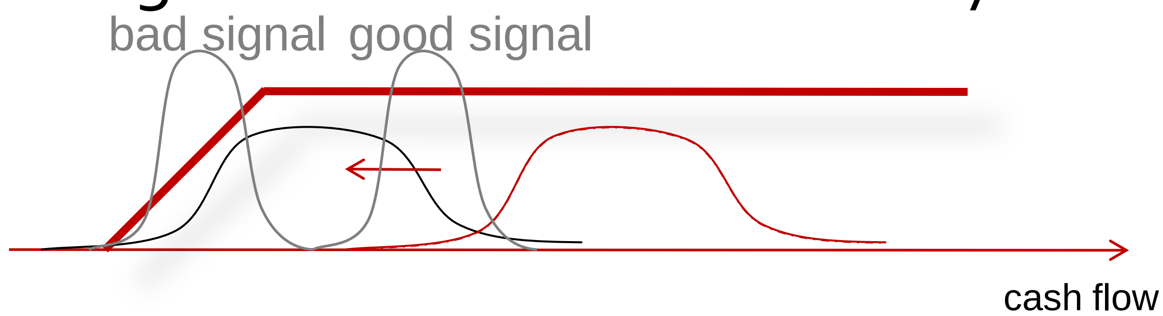
- Debt contract payoff



- Informational value of signal is extremely low (in flat part of contract payoff

Creating Info-Insensitive Securities

- Increasing the information sensitivity of debt



- Now signal is very valuable
- Asymmetric info (lemons') problem kicks in
  - No more rollover
- Maturity choice:
  - Short-term debt: distribution shrinks (less info-sensitity)

Repo market

- Repurchase agreement
  - Borrow: sell assets with a agreement to repurchase it in one day/months
  - Repo types:
    - General collateral (GC) repos
      collateral are treasuries, agency papers
    - MBS repos
      collateral are mortgage backed securities
  - Outside of bankruptcy protection(in US not in UK)

- Repo haircuts widened sharply