The I Theory of Money

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Motivation

- Framework to study monetary and financial stability
- Interaction between monetary and macroprudential policy
- Connect theory of value and theory of money
- Intermediation (credit)
  - “Excessive” leverage and liquidity mismatch
- Inside money – as store of value
  - Demand for money rises with endogenous volatility
  - In downturns, intermediaries create less inside money
    - Endogenous money multiplier = f(capitalization of critical sector)
  - Value of money goes up – Disinflation spiral a la Fisher (1933)
  - Fire-sales of assets – Liquidity spiral
- Flight to safety
- Time-varying risk premium and endogenous volatility dynamics
Some literature

- Macro-friction models without money
  - Kiyotaki & Moore, BruSan2014, He & Krishnamurthy, DSS2015

- “Money models” without intermediaries
  - Money pays no dividend and is a bubble – store of value

- With intermediaries/inside money
  - “Money view” (Friedman & Schwartz) vs. “Credit view” (Tobin)

- New Keynesian Models:
  - BGG, Christian et al., … money in utility function
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### Friction OLG Incomplete Markets + idiosyncratic risk

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- New Keynesian Models: BGG, Christian et al., ... money in utility function
Roadmap

- Model absent monetary policy
  - Toy model: one sector with outside money
  - Two sector model
  - Adding intermediary sector and inside money

- Model with monetary policy

- Model with macro-prudential policy
One sector basic model

- Technologies $a$

- Each households can only operate one firm
  - Physical capital
    \[
    \frac{dk_t}{k_t} = \left(\Phi(t) - \delta\right)dt + \sigma^a dZ^a_t + \bar{\sigma} d\tilde{Z}^a_t
    \]
  - Output
    \[
    y_t = Ak_t
    \]

- Demand for money
Adding outside money

- $q_t K_t$ value of physical capital
  - Postulate constant $q_t$
- $p_t K_t$ value of outside money
  - Postulate value of money changes proportional to $K_t$

Each households can only operate one firm

- Physical capital
  \[
  \frac{dk_t}{k_t} = (\Phi(t_t) - \delta)dt + \sigma^a dZ^a_t + \bar{\sigma} d\tilde{Z}^a_t
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- Output
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  \]

Demand for money

Technologies $\alpha$
Adding outside money

- $qK_t$ value of physical capital
  - $dr^a = \frac{A^{-t}}{q}dt + (\Phi(t) - \delta)\ dt + \sigma^a dZ_t^a + \tilde{\sigma}d\tilde{Z}_t^a$

- $pK_t$ value of outside money
  - $dr^M = (\Phi(t) - \delta)\ dt + \sigma^a dZ_t^a$

- Each households can only operate one firm
  - Physical capital
    - $\frac{dk_t}{k_t} = (\Phi(t_t) - \delta)dt + \sigma^a dZ_t^a + \tilde{\sigma}d\tilde{Z}_t^a$
  - Output
    - $y_t = Ak_t$
Demand with $E\left[\int_{0}^{\infty} e^{-\rho t} \log c_t \, dt\right]$
Demand with log-utility

- **qK_t** value of physical capital
  - \( dr^a = \frac{A-\ell}{q}dt + (\Phi(\ell) - \delta) dt + \sigma^a dZ_t^a + \tilde{\sigma} d\tilde{Z}_t^a \)

- **pK_t** value of outside money
  - \( dr^M = (\Phi(\ell) - \delta) dt + \sigma^a dZ_t^a \)

- Consumption demand: \( \rho(p + q)K_t \)

- Asset (share) demand \( x^a \):

  \[
  E[dr^a - dr^M]/dt = Cov[dr^a - dr^M, \frac{dn_t^a}{n_t^a}] = x^a \tilde{\sigma}^2
  \]

  \[
  x^a = \frac{E[dr^a - dr^M]/dt}{\tilde{\sigma}^2} = \frac{(A-\ell)/q}{\tilde{\sigma}^2}
  \]

- Investment rate: (Tobin's q)

  \[
  \Phi'(\ell) = 1/q
  \]
Demand with log-utility

- **$qK_t$** value of physical capital
  - $dr^a = \frac{A-\iota}{q}dt + (\Phi(\iota) - \delta) \ dt + \sigma^a dZ_t^a + \bar{\sigma} d\tilde{Z}_t^a$

- **$pK_t$** value of outside money
  - $dr^M = \Phi(\iota) \ dt + \sigma^a dZ_t^a$

- Consumption demand: $\rho(p + q)K_t$

- Asset (share) demand $x^a$:
  $$E[dr^a - dr^M]/dt = Cov[dr^a - dr^M, \frac{dn^a_t}{n_t^a}] = x^a \bar{\sigma}^2$$

- Investment rate: (Tobin’s q)
  - For $\Phi(\iota) = \frac{1}{\kappa} \log(\kappa \iota + 1) \Rightarrow \iota = \frac{q-1}{\kappa}$
Market clearing

- $qK_t$ value of physical capital
  - $dr^a = \frac{A-\iota}{q}dt + (\Phi(\iota) - \delta) dt + \sigma^a dZ^a_t + \tilde{\sigma} d\tilde{Z}^a_t$

- $pK_t$ value of outside money
  - $dr^M = (\Phi(\iota) - \delta) dt + \sigma^a dZ^a_t$

- Consumption demand:
  - $\rho(p + q)K_t = (A - \iota)K_t$

- Asset (share) demand $x^a$:
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- Investment rate: (Tobin’s q)
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### Equilibrium

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![Graph](image.png)
## Welfare analysis

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welfare\(_0\) < welfare

### What ratio nominal to total wealth \( \frac{p}{q+p} \) maximizes welfare?

- Force agents to hold less \( k \) & more money
- Raise \( \frac{p}{q+p} \) if and only if \( \bar{\sigma}(1 - \kappa \rho) \leq 2\sqrt{\rho} \)
- Lowers \( q \Rightarrow \) higher \( E[dr^a - dr^M] = \frac{A-\mu}{q} dt \)
- Create \( q \)-risk to make precautionary money savings more attractive

pecuniary externality
Roadmap

- Model absent monetary policy
  - Toy model: one sector with outside money
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- Model with monetary policy

- Model with macro-prudential policy
Outline of two sector model

- Technologies $b$

- Technologies $a$

Households have to
- Specialize in one subsector for one period
  \[
  \frac{dk_t}{k_t} = \cdots dt + \sigma^b dZ^b_t + \tilde{\sigma} d\tilde{Z}^b_t
  \]
- Demand for money

\[
\frac{dk_t}{k_t} = \cdots dt + \sigma^a dZ^a_t + \tilde{\sigma} d\tilde{Z}^a_t
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Add outside money

- Technologies \( b \)

- Technologies \( a \)

Households have to
- Specialize in one subsector for one period
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Roadmap

- Model absent monetary policy
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Add intermediaries

- Technologies $b$
  - Risk can be partially sold off to intermediaries

- Technologies $a$
  - Risk is not contractable (Plagued with moral hazard problems)
Add intermediaries

- Technologies $b$

  - Intermediaries
    - Can hold outside equity & diversify within sector $b$
    - Monitoring

- Technologies $a$

  - Outside Money
Add intermediaries

- Technologies $b$
- Technologies $a$

- Intermediaries
  - Can hold outside equity & diversify within sector $b$
  - Monitoring
Add intermediaries

- Technologies $b$

  - Intermediaries
    - Can hold outside equity & diversify within sector $b$
    - Monitoring
    - Create inside money
    - Maturity/liquidity transformation
Shock impairs assets: 1st of 4 steps

- Technologies $b$

- Technologies $a$
Shrink balance sheet: 2nd of 4 steps

- Technologies \( b \)
- Technologies \( a \)
Liquidity spiral: asset price drop: 3\textsuperscript{rd} of 4

- Technologies $b$

- Technologies $a$

Switch
Disinflationary spiral: 4\textsuperscript{th} of 4 steps

- Technologies \( b \)

- Technologies \( a \)
Formal model: capital & output

Technologies

Physical capital $K_t$
- Capital share

$$\psi_t \quad 1 - \psi_t$$

Output goods

Aggregate good (CES)
- Consumed or invested
- Numeraire

$$Y_t^b = Ak_t^b \quad \text{Imperfect substitutes} \quad Y_t^a = Ak_t^a$$

$$Y_t = \left( \frac{1}{2} (Y_t^b)^{(s-1)/s} + \frac{1}{2} (Y_t^a)^{(s-1)/s} \right)^{s/(s-1)}$$

Price of goods

$$P_t^b = \frac{1}{2} \left( \frac{Y_t}{Y_t^b} \right)^{1/s} \quad P_t^a = \frac{1}{2} \left( \frac{Y_t}{Y_t^a} \right)^{1/s}$$

- Model setup in paper is more general: $Y_t = A(\psi_t)K_t$
Formal model: risk

- When $k_t$ is employed in sector $a$ by agent $j$

\[ dk_t = (\Phi(\iota_t) - \delta)k_t dt + \sigma^a k_t dZ^a_t + \sigma^j k_t d\tilde{Z}^a_t \]

- $\Phi(\iota_t)$ is increasing and concave, e.g. $\log[(\kappa \iota_t + 1)/\kappa]$
- All $dZ$ are independent of each other

- Intermediaries can diversify within sector $b$
  - Face no idiosyncratic risk

- Households cannot become intermediaries or vice versa
Asset returns on money

- **Money**: fixed supply in baseline model, total value $p_t K_t$
  - Return = capital gains (no dividend/interest in baseline model)
  - If $d p_t / p_t = \mu_t p_t dt + \sigma_t p_t dZ_t$, 
  - $d K_t / K_t = (\Phi(\eta_t) - \delta) dt + (1 - \psi_t) \sigma^K a dZ^a_t + \psi_t \sigma^K b dZ^b_t$
  - $d r^M_t = (\Phi(\eta_t) - \delta + \mu_t p_t + (\sigma^K_t)^T \sigma^K_t) dt + (\sigma^K_t + \sigma^K_t) dZ_t$

- $\pi_t = \frac{p_t}{q_t + p_t}$ fraction of wealth in form of money
Capital/risk shares

Technologies \( b \)

- Money
- Inside equity
- Risky Claim
- \( \psi_t q_t K_t \)
- \( 1 - \chi_t \)
- \( (1 - \chi_t) \psi_t q_t K_t \)

Technologies \( a \)

Fraction \( \alpha_t \) of HH

- Money
- Inside Money (deposits)
- Net worth \( N_t \)
- HH Net worth

\[ HH Net worth = (1 - \psi_t) q_t K_t \]
**Capital/risk shares**

- **Technologies $b$**
  - Inside equity: $\chi_t$
  - Risky Claim: $\psi_t q_t K_t$
  - Inside equity: $1 - \chi_t$

- **Technologies $a$**
  - Fraction $\alpha_t$ of HH

If $\chi_t > \chi$, inside and outside equity earn same returns (as portfolio of $b$-technology and money).

If the equity constraint $\chi_t = \chi$ binds, inside equity earns a premium $\lambda$. 
Allocation

- Equilibrium is a map

  Histories of shocks $\{Z_\tau, 0 \leq \tau \leq t\}$ \rightarrow prices $q_t, p_t, \lambda_t$, allocation $\alpha_t, \chi_t$ & portfolio weights $(x_t, x^a_t, x^b_t)$

  wealth distribution

  $\eta_t = \frac{N_t}{(p_t+q_t)K_t} \in (0,1)$

  intermediaries’ wealth share

- All agents maximize utility
  - Choose: portfolio, consumption, technology

- All markets clear
  - Consumption, capital, money, outside equity of $b$
Numerical example: capital shares

$$\rho = 5\%, A = .5, \sigma^a = \sigma^b = .4, \sigma^j = .9, \tilde{\sigma}^a = .6, \tilde{\sigma}^a = 1.2, s = .8, \Phi(t) = \frac{\log[k\iota + 1]}{\kappa}, \kappa = 2, \chi = .001$$
Numerical example: prices

Disinflation spiral

Liquidity spiral

$q, p$

$q$ under perfect sharing of aggregate risk

$p$ under perfect sharing of aggregate risk
Numerical example: prices

\[ \pi = \frac{p}{p+q} \]

Disinflation spiral

Liquidity spiral

\( p \) under perfect sharing of aggregate risk

\( q \) under perfect sharing of aggregate risk
Numerical example: dynamics of $\eta$

\[
\sigma_{\eta}^{t} = \frac{x_{t}(\sigma^{b}1^{b} - \sigma_{t}^{K})}{1 - \left(\frac{\psi_{t}(1-x_{t})-\eta}{\eta}\right)\frac{-\pi'(\eta)}{\pi/\eta}}
\]

- **volatility in equilibrium**
- **fundamental portion of equilibrium volatility**
- **drift in equilibrium**
- **drift under perfect sharing of aggregate risk**
- **steady state**

**fundamental volatility**
Overview

- No monetary economics
  - Fixed outside money supply
  - Amplification/endogenous risk through
    - Liquidity spiral  asset side of intermediaries’ balance sheet
    - Disinflationary spiral  liability side

- Monetary policy
  - Aside: Money vs. Credit view (via helicopter drop)
  - Wealth shifts by affecting relative price between
    - Long-term bond
    - Short-term money
  - Risk transfers – reduce endogenous aggregate risk

- Macroprudential policy
- Adverse shock → value of risky claims drops
- Monetary policy response: cut short-term interest rate
  - Value of long-term bonds rises - “stealth recapitalization”
- Liquidity & Deflationary Spirals are mitigated
Effects of policy

- Effect on the value of money (liquid assets) – helps agents hedge idiosyncratic risks, but distorts investment
  - We saw this in the toy model with one sector

- Redistribution of aggregate risk, mitigates risk that an essential sector can become undercapitalized

- Affects earnings distribution, rents that different sectors get in equilibrium
Monetary policy and endogenous risk

- Intermediaries’ risk (borrow to scale up)

$$\sigma_t^\eta = \frac{x_t(\sigma^b 1^b - \sigma^K_t)}{1 - \left(\frac{\psi - \eta - \pi'(\eta)}{\pi/\eta}\right) + \left(\frac{\psi(1 - \chi - \eta - \pi(1 - \psi)}{\eta} + \frac{\pi(1 - \psi)}{\eta}\right) \frac{b_t - B'(\eta)}{p_t B(\eta)/\eta}}$$

- Example:

$$\frac{b_t B'(\eta)}{p_t B(\eta)} = \alpha_t \frac{\pi'(\eta)}{\pi(1 - \pi)}$$

- Intuition:
  with right monetary policy bond price $B(\eta)$ rises as $\eta$ drops “stealth recapitalization”
  - Can reduce liquidity and disinflationary spiral
Numerical example with monetary policy

- Allocations

- Prices

Higher intermediaries' capital share \((1 - \chi)\psi\)

Less production of good \(a\)

\(p\) less disinflation

\(q\) is more stable
Numerical example with monetary policy

\[
\sigma_t^\eta = \frac{x_t (\sigma^b 1^b - \sigma^K)}{1 - \left( \frac{\psi - \eta}{\eta} \right) - \pi' (\eta) + \left( \frac{\psi - \eta}{\eta} + \frac{\pi}{\eta} (1 - \psi) \right) \frac{b_t - B'(\eta)}{p_t B(\eta) / \eta}}
\]

Recall
\[
\frac{b_t B'(\eta)}{p_t B(\eta)} = \alpha_t \frac{\pi'(\eta)}{\pi (1 - \pi)}
\]
Numerical example with monetary policy

- Welfare:
  HH and Intermediaries

Sum
Monetary policy ... in the limit

- Full risk sharing of all aggregate risk

\[ \sigma_t^\eta = \frac{x_t}{1 - \left(\frac{\psi - \eta}{\eta}\right) - \frac{\pi'}{\pi} + \left(\frac{\psi(1 - \chi)}{\eta} + \frac{\pi(1 - \psi)}{\eta}\right) \frac{b_t - B'(\eta)}{p_t B(\eta)/\eta}} \quad \lim_{t \to -\infty} \left(\sigma^b 1^b - \sigma^K_t\right) \]

- \( \eta \) is deterministic and converges over time towards 0
Monetary policy ... in the limit

- full risk sharing of all aggregate risk

- Aggregate risk sharing makes $q$ deterministic

- Like in benchmark toy model
  - Excessive $k$-investment
  - Too high $q$ (pecuniary externality)
    - Lower capital return

- Endogenous risk corrects pecuniary externality
Overview

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  - Amplification/endogenous risk through
    - Liquidity spiral asset side of intermediaries’ balance sheet
    - Disinflationary spiral liability side

- Monetary policy
  - Wealth shifts by affecting relative price between
    - Long-term bond
    - Short-term money
  - Risk transfers – reduce endogenous aggregate risk

- Macroprudential policy
  - Directly affect portfolio positions
MacroPru policy

- Regulator can control
  - Portfolio choice $\psi_s, x_s$
  - Investment decision $\iota(q)$
  - Consumption decision $c$

- Regulator cannot control
  - Investment decision $\iota(q)$
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of intermediaries and households
MacroPru policy

- Regulator can control
  - Portfolio choice $\psi_s, x_s$
  - De-facto controls $q$ and $p$ within some range
  - De-factor controls wealth share $\eta$
    - Force agents to hold certain assets and generate capital gains

- cannot control
  - Investment decision $\iota(q)$
  - Consumption decision $c$
  - Of intermediaries and households

- In sum, regulator maximizes sum of agents value function
  - Choosing $\psi^b, q, \eta$
MacroPru policy: Welfare frontier

- Stabilize intermediaries net worth and earnings
- Control the value of money to allow HH insure idiosyncratic risk (investment distortions still exists, otherwise can get 1st best)
Conclusion

- Unified macro model to analyze
  - Financial stability - Liquidity spiral
  - Monetary stability - Fisher disinflation spiral

- Exogenous risk &
  - Sector specific
  - Idiosyncratic

- Endogenous risk
  - Time varying risk premia – flight to safety
  - Capitalization of intermediaries is key state variable

- Monetary policy rule
  - Risk transfer to undercapitalized critical sectors
  - Income/wealth effects are crucial instead of substitution effect
  - Reduces endogenous risk – better aggregate risk sharing
    - Self-defeating in equilibrium – excessive idiosyncratic risk taking

- Macro-prudential policies
  - MacroPru + MoPo to achieve superior welfare optimum