Financial Intermediary Capital

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Needed: A Theory of Financial Intermediary Capital

Question
- How does intermediary capital affect financing & macroeconomic activity?

Needed
- A dynamic theory of financial intermediary capital

Motivation
- Financial crisis and its aftermath
Our Theory of Financial Intermediary Capital

- **Financial intermediaries are collateralization specialists**
  - Intermediaries better able to collateralize claims than households

- **Financial intermediary capital**
  - ... required to finance additional collateralized amount
Our Theory of Financial Intermediary Capital: Implications

- **Two state variables**
  - Firm and intermediary net worth jointly determine dynamics of firm investment, financing, and loan spreads

- **Relatively slow accumulation of intermediary net worth**

- **Compelling dynamics**
  - When corporate sector is very constrained,
    - ... intermediaries “hold cash” at low interest rates
  - When intermediaries are very constrained,
    - ... firms’ investment stays low even as firms pay dividends
Literature: Models of Financial Intermediaries

- **Intermediary capital**
  - Holmström/Tirole (1997) – need capital at stake to commit to monitor
  - Diamond/Rajan (2000), Diamond (2007) – ability to enforce claims due to better monitoring

- **Other theories of financial intermediation - no role for capital**
  - Coalition based theories – Townsend (1978), Boyd/Prescott (1986)
Literature: Dynamic Models with Net Worth Effects

- **Firm net worth**
  - Bernanke/Gertler (1989), Kiyotaki/Moore (1997a)

- **Intermediary net worth**
  - Gertler/Kiyotaki (2010), Brunnermeier/Sannikov (2014)

- **Firm and intermediary net worth**
  - This paper
Model: Environment

- Discrete time
- Infinite horizon
- 3 types of agents
  - Households
  - Financial intermediaries
  - Firms
Model: Households

- Risk neutral, discount at $R^{-1} > \beta$ where firms’ discount rate is $\beta$

- Large endowment of funds (and collateral) in all dates and states
Model: Financing Subject to Collateral Constraints

- **Collateral constraints**
  - Complete markets in one period ahead Arrow securities
    - subject to collateral constraints
  - Firms can issue state-contingent promises
    - ... up to fraction $\theta$ of resale value of capital to households
    - ... up to fraction $\theta_i$ of resale value of capital to intermediaries
  - Related: Kiyotaki/Moore (1997a); but two types of lenders and allow risk management

- **Limited enforcement**
  - We derive such collateral constraints from limited enforcement without exclusion - different from Kehoe/Levine (1993)
  - Related: Rampini/Viswanathan (2010, 2013)
Model: Financial Intermediaries

- Risk neutral, discount at $\beta_i \in (\beta, R^{-1})$

- **Collateralization specialists**
  - Ability to seize up to fraction $\theta_i > \theta$ of (resale value of) collateral

- **Refinancing collateralized loans**
  - Idea: Intermediaries can borrow against their (collateralized) loans
    - ... but only to extent households can collateralize assets backing loans
  - Households can collateralize up to $\theta$ of collateral backing loans ("structures")
  - Intermediaries need to finance $\theta_i - \theta$ out of own net worth ("equipment")
Model: Collateral and Financing

- Capital, collateral value, and financing

![Diagram]

Working capital

Capital

Collateral value

(next period)

Financing

(this period)

\[
\begin{align*}
\text{Working capital} & \quad \{1, \theta, \theta(1 - \delta), \theta_i, \theta_i(1 - \delta), 1 - \delta, R^{-1}\theta(1 - \delta)\} \\
\text{Equipment} & \quad \{\theta_i, \theta_i(1 - \delta)\} \\
\text{Structures} & \quad \{0\} \\
\end{align*}
\]

\[
\begin{align*}
\text{Internal funds} & \quad \phi_i(R_i^t) \\
\text{Intermediaries} & \quad R_i^{t-1}(\theta_i - \theta)(1 - \delta) \\
\text{Households} & \\
\end{align*}
\]
Model: Representative Firm (or “Corporate Sector”)

■ Risk neutral, limited liability, discount at $\beta < 1$

■ Capital $k$
  ■ Depreciation rate $\delta$; no adjustment costs

■ Standard neoclassical production function
  ■ Cash flows $A' f(k)$ where $A' \equiv A(s')$ is (stochastic) Markov productivity with transition probability $\Pi(s, s')$
  ■ Strictly decreasing returns to scale ($f(\cdot)$ strictly concave)

■ Two sources of outside finance
  ■ Households
  ■ Financial intermediaries
Firm’s Problem

Firm solves following dynamic program

\[ v(w, Z) = \max_{\{d, k, b', b'_i, w'\} \in \mathbb{R}_+^2 \times \mathbb{R}^S \times \mathbb{R}_+^{2S}} d + \beta E [v(w', Z')] \]  

(1)

subject to budget constraints

\[ w + E [b' + b'_i] \geq d + k \]  

(2)

\[ A' f(k) + k(1 - \delta) \geq w' + Rb' + R'_i b'_i \]  

(3)

and collateral constraints

\[ \theta k(1 - \delta) \geq Rb' \]  

(4)

\[ (\theta_i - \theta) k(1 - \delta) \geq R'_i b'_i \]  

(5)

State-contingent interest rates \( R'_i \) determined in equilibrium
Firm’s Problem: Comments

- Two sets of state-contingent collateral constraints restricting
  - ... borrowing from households $b'$
  - ... borrowing from financial intermediaries $b'_i$

- **State variables**: net worth $w$ and state of economy $Z = \{s, w, w_i\}$
  - Net worth of representative firm $w$ and intermediary $w_i$
Intermediary’s Problem

- Representative intermediary solves

\[ v_i(w_i, Z) = \max_{\{d_i, l', l_i', w_i'\} \in \mathbb{R}_+^{1+3S}} d_i + \beta_i E[v_i(w_i', Z')] \]  \hspace{1cm} (6)

subject to budget constraints

\[ w_i \geq d_i + E[l'] + E[l_i'] \]  \hspace{1cm} (7)

\[ Rl' + R_i'l_i' \geq w_i' \]  \hspace{1cm} (8)

- State-contingent loans to households \( l' \) and to firms \( l_i' \)
Model with Limited Enforcement and Limited Participation

- **Timing**
  - Afternoon: repayments, investment, consumption
  - Morning: cash flows, repayments

- **Limited participation**
  - Afternoon: Firms, intermediaries, and households present
  - Morning: Firms and intermediaries present, not households

- **Limited enforcement**
  - Afternoon
    - Firms can abscond with cash flows and $1 - \theta$ of capital (not structures)
    - Intermediaries can abscond with funds paid in morning
  - Morning
    - Firms can abscond with cash flows and $1 - \theta_i$ of capital (not structures and equipment)
Equivalence: Limited Enforcement & Collateral Constraints

- Loans against $\theta_i - \theta$ ("equipment") only enforceable in morning
  - Intermediaries must extend such loans
  - Loans must be repaid each morning (no rollover) – new model of short term intermediated finance

- Loans up to $\theta$ ("structures") enforceable in afternoon
  - Households extend such loans w.l.o.g.
  - Rollover possible

- Two equivalent implementations with collateral constraints
  - Direct implementation
    - Households lend to firms directly
  - Indirect implementation
    - Households lend to intermediaries
    - Intermediaries lend to firms and borrow from households against collateralized corporate loans
Endogenous Minimum Down Payment Requirement

- **Minimum down payment requirement** \( \varphi \) (or margin)
  - Borrowing from households only
    \[
    \varphi = 1 - R^{-1} \theta (1 - \delta)
    \]
  - Borrowing from households and financial intermediaries
    \[
    \varphi_i(R'_i) = \varphi - E[(R'_i)^{-1}](\theta_i - \theta)(1 - \delta)
    \]

- **Firm’s investment Euler equation**
  \[
  1 \geq E \left[ \beta \frac{\mu'}{\mu} \frac{A' f_k(k) + (1 - \theta_i)(1 - \delta)}{\varphi_i(R'_i)} \right] \tag{9}
  \]
User Cost of Capital with Intermediated Finance

- **Extension of Jorgenson’s (1963) user cost of capital definition**

  \[ u \equiv r + \delta \]

- User cost would be rental cost in frictionless economy

- Premium on internal funds \( \rho \): \( \frac{1}{R + \rho} \equiv E[\beta \mu'/\mu] \)

- Premium on intermediated finance \( \rho_i \): \( \frac{1}{R + \rho_i} \equiv E[(R'_i)^{-1}] \)

- **Firm’s user cost of capital** \( u \) is

  \[ u \equiv r + \delta + \frac{\rho}{R + \rho} (1 - \theta_i)(1 - \delta) + \frac{\rho_i}{R + \rho_i} (\theta_i - \theta)(1 - \delta), \]

  where \( 1 + r \equiv R \)
Internal and intermediated funds are scarce

**Proposition 1 (Premia on internal and intermediated finance)**

- Premium on internal finance $\rho$ (weakly) exceeds premium on intermediated finance $\rho_i$
  \[ \rho \geq \rho_i \geq 0, \]

- Premia equal, $\rho = \rho_i$, iff $E[\lambda'_i] = 0$.

- Premium on internal finance strictly positive, $\rho > 0$, iff $E[\lambda'] > 0$. 
Definition 1 (Equilibrium) An equilibrium is

- allocation $x \equiv [d, k, b', b'_i, w']$ (for firm) and $x_i \equiv [d_i, l', l'_i, w'_i]$ (for intermediary)
- interest rate process $R'_i$ for intermediated finance

such that

- (i) $x$ solves firm’s problem in (1)-(5) and $x_i$ solves intermediary’s problem (6)-(8)
- (ii) market for intermediated finance clears in all dates and states

$$l'_i = b'_i.$$ (10)
Essentiality of Financial Intermediation

- **Definition 2 (Essentiality of intermediation)** *Intermediation is essential if an allocation can be supported with a financial intermediary but not without.*
  - Analogous: Hahn’s (1973) definition of essentiality of money

- **Intermediaries are essential**

- **Proposition 3 (Positive intermediary net worth)** *Financial intermediaries always have positive net worth in a deterministic or eventually deterministic economy.*

- **Proposition 4 (Essentiality of intermediaries)** *In any deterministic economy, financial intermediaries are always essential.*
  - Intuition: Without intermediaries, shadow spreads would be “high.”
Deterministic Steady State

- **Steady state spread and intermediary capitalization**

- **Definition 3 (Steady state)** A deterministic steady state equilibrium is an equilibrium with constant allocations, that is, \( x^* \equiv [d^*, k^*, b'^*, b'_i, w'^*] \) and \( x_i^* \equiv [d_i^*, l'^*, l'_i, w_i'^*] \).

- **Proposition 5 (Steady state)** In steady state
  - Intermediaries essential; positive net worth; pay positive dividends
  - Spread on intermediated finance \( R'_i^* - R = \beta_i^{-1} - R > 0 \)
  - (Ex dividend) intermediary net worth (relative to firm’s net worth)
    \[
    \frac{w_i^*}{w^*} = \frac{\beta_i(\theta_i - \theta)(1 - \delta)}{\varphi_i(\beta_i^{-1})}
    \]
    (ratio of intermediary’s financing to firm’s down payment requirement)
Deterministic Equilibrium Dynamics

- Two main phases: no dividend phase and dividend phase

Definition 6 (Deterministic dynamics) Given $w$ and $w_i$, there exists a unique deterministic dynamic equilibrium which converges to the steady state characterized by a no dividend region (ND) and a dividend region (D) (which is absorbing) as follows: [Region ND] $w_i \leq w_i^*$ (w.l.o.g.) and $w < \bar{w}(w_i)$, and (i) $d = 0$ ($\mu > 1$), (ii) the cost of intermediated finance is

$$R'_i = \max \left\{ R, \min \left\{ \frac{(\theta_i - \theta)(1 - \delta)}{\varphi} \left( \frac{w}{w_i} + 1 \right), \frac{A'f_k \left( \frac{w + w_i}{\varphi} \right)}{\varphi} + (1 - \theta)(1 - \delta) \right\} \right\},$$

(iii) investment $k = (w + w_i)/\varphi$ if $R'_i > R$ and $k = w/\varphi_i(R)$ if $R'_i = R$, and (iv) $w'/w'_i > w/w_i$, that is, firm net worth increases faster than intermediary net worth. [Region D] $w \geq \bar{w}(w_i)$ and (i) $d > 0$ ($\mu = 1$). For $w_i \in (0, \bar{w}_i)$, (ii) $R'_i = \beta^{-1}$, (iii) $k = \bar{k}$ which solves $1 = \beta[A'f_k(\bar{k}) + (1 - \theta)(1 - \delta)]/\varphi$, (iv) $w'_ex/w'_i < wex/w_i$, that is, firm net worth (ex dividend) increases more slowly than intermediary net worth, and (v) $\tilde{w}(w_i) = \varphi \bar{k} - w_i$. For $w_i \in [\bar{w}_i, w_i^*)$, (ii) $R'_i = (\theta_i - \theta)(1 - \delta)k/w_i$, (iii) $k$ solves

$$1 = \beta[A'f_k(k) + (1 - \theta)(1 - \delta)]/\varphi - w_i/k),$$

(iv) $w'_ex/w'_i < wex/w_i$, that is, firm net worth (ex dividend) increases more slowly than intermediary net worth, and (v) $\tilde{w}(w_i) = \varphi_i(R'_i)k$. For $w_i \geq w_i^*$, $\bar{w}(w_i) = w^*$ and the steady state of Proposition 5 is reached with $d = w - w^*$ and $d_i = w_i - w_i^*$. 

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Financial Intermediary Capital
Intermediary’s Net Worth Dynamics

- Law of motion (as long as no dividends)

\[ w_i' = R_i' w_i \]

- Intermediaries lend out all funds at interest rate \( R_i' (\geq R) \)

- Relatively slow accumulation of intermediary net worth
  - Intermediaries earn \( R_i' \) which is at most marginal return on capital (collateral constraint)
  - Firms earn average return (decreasing returns to scale)
Lemma 2 (Initial intermediary dividend) The representative intermediary pays at most an initial dividend and no further dividends until the steady state is reached. If $w_i > w_i^*$, the initial dividend is strictly positive.

Intuition: **Low firm net worth limits loan demand**

- Intermediaries save only part of net worth to meet future loan demand
Slow Intermediary Net Worth Accumulation

- Transition to steady state: Consider low initial firm net worth $w$
- Low firm net worth $\Rightarrow$ low investment $k = w/\phi_i(R)$ and low loan demand
  - **Intermediaries save at low interest rate** $R'_i = R$ (lend to households) to meet future loan demand

Firm net worth accumulates faster

- Investment $k = (w + w_i)/\phi$, loan demand, and interest rate $R'_i = (\theta_i - \theta)(1 - \delta)/\phi (w/w_i + 1)$ rise
- When collateral constraint stops binding, interest rate $R'_i = [A' f_k(k) + (1 - \theta)(1 - \delta)]/\phi$ falls

When interest rate reaches $\beta^{-1}$, firms pay dividends and stop growing, waiting for intermediary capital to catch up ("recovery stalls")

Once intermediaries catch up, interest rate falls and investment rises; **corporate sector relevers** until steady state $R'_i^* = \beta_i^{-1}$ reached
Dynamics of a Macroeconomic Downturn

- **Macroeconomic downturn**
  - Unanticipated drop in firm (and possibly intermediary) net worth from steady state (say due to surprise drop in productivity $A'$)

- Dynamics of net worth, spread, and investment

![Graph showing the dynamics of net worth, spread, and investment](image-url)
Dynamics of Net Worth, Spread, and Investment

Panel B1. Cost of intermediated finance

Panel B2. Firm and intermediary wealth

Panel B3. Intermediary lending

Panel B4. Investment
Dynamics of a Macroeconomic Downturn (Cont’d)

- **Persistent real effects**
  - Drop in real investment

- Spread on intermediated finance may fall (as loan demand falls)

- Intermediaries may pay initial dividend when downturn hits!
Dynamics of a Credit Crunch

- **Credit crunch**
  - Unanticipated drop in intermediary net worth $w_i$ from steady state

- Joint dynamics of firm and intermediary net worth
Dynamics of a Credit Crunch (Cont’d)

Dynamics of net worth, spread, and investment

Panel B1. Cost of intermediated finance

Panel B2. Firm and intermediary wealth

Panel B3. Intermediary lending

Panel B4. Investment

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Financial Intermediary Capital
Dynamics of a Credit Crunch (Cont’d)

- **Persistent real effects**

- Moderate drop: intermediaries cut dividends

- “Delayed recovery” (until intermediaries accumulate sufficient capital)
  - Suppose corporate sector still well capitalized
  - **Investment drops even as firms continue to pay dividends**
  - Why? – Higher interest rate $R'_i = \beta^{-1}$ increases cost of capital

- “Recovery stalls”
  - Suppose corporate sector no longer well capitalized
  - Investment drops more and interest rate $R'_i$ even higher
  - Partial recovery until $R'_i = \beta^{-1}$ then “waiting for intermediaries to catch up”
Comovement of Firm and Intermediary Net Worth

- **Sufficient conditions for comovement**

  - Is value of intermediary net worth high when value of firm net worth high?

- **Proposition 7 (Comovement of value of net worth)** *In economy which is deterministic from time 1 onward:*

  - **(i)** Representative firm collateral constrained for direct finance against at least one state at time 1.
  
  - **(ii)** If \( \lambda_i(s') = 0 \), \( \forall s' \in S \), marginal values comove: 
    \[ \frac{\mu(s')}{\mu(s'_+)} = \frac{\mu_i(s')}{\mu_i(s'_+)}, \forall s', s'_+ \in S. \]
  
  - **(iii)** If \( S = \{ \hat{s}', \tilde{s}' \} \) and \( \lambda(\hat{s}') > 0 = \lambda(\tilde{s}') \), then the marginal values must comove, \( \mu(\hat{s}') > \mu(\tilde{s}') \) and \( \mu_i(\hat{s}') \geq \mu_i(\tilde{s}') \).

- Interpretation: neither firms nor intermediaries hedge fully
Conclusions

- Theory of financial intermediaries as collateralization specialist
  - Better ability to enforce claims
    - ... implies role for financial intermediary capital
  - Tractable dynamic model
  - Intermediated finance is short term

- Dynamics of intermediary capital
  - Economic activity and spreads determined by firm and intermediary net worth jointly
  - Slow accumulation of intermediary net worth
  - Credit crunch has persistent real effects
Characterization of Firm’s Problem

■ Multipliers

■ ... on (2) through (5): \( \mu, \Pi(Z, Z')\beta\mu', \Pi(Z, Z')\beta\lambda', \) and \( \Pi(Z, Z')\beta\lambda' \)

■ ... on \( d' \geq 0 \) and \( b'_i \geq 0 \): \( \nu_d \) and \( \Pi(Z, Z')R'_i\beta\nu_i' \)

■ (Redundant: \( k \geq 0 \) and \( w' \geq 0 \) )

■ First order conditions

\[
\begin{align*}
\mu &= 1 + \nu_d \\
\mu &= E [\beta\mu' ([A'f_k (k) + (1 - \delta)] + [\lambda'\theta + \lambda'_i(\theta_i - \theta)] (1 - \delta))] \\
\mu &= R\beta\mu' + R\beta\lambda' \\
\mu &= R'_i\beta\mu' + R'_i\beta\lambda'_i - R'_i\beta\nu'_i \\
\mu' &= v'(w', Z') \\
\mu' &= v'(w', Z') = \mu
\end{align*}
\]

■ Envelope condition

\[ v'(w, Z) = \mu \]
Weighted Average User Cost of Capital

- User cost of capital with intermediated finance

\[ u \equiv \frac{R}{R + \rho}(r_w + \delta) \]

where **weighted average cost of capital** \( r_w \) is

\[ r_w \equiv (r + \rho)\phi_i(R'_i) + rR^{-1}\theta(1 - \delta) + (r + \rho_i)(R + \rho_i)^{-1}(\theta_i - \theta)(1 - \delta) \]
Characterization of Intermediary’s Problem

- Multipliers
  - ... on (7) through (8): \( \mu_i \) and \( \Pi(Z, Z')\beta_i\mu_i' \),
  - ... on \( d_i' \geq 0, l' \geq 0, \) and \( l_i' \geq 0: \eta_d, \Pi(Z, Z')R\beta_i\eta' \), and
  - \( \Pi(Z, Z')R_i'\beta_i\eta_i' \)
  - (Redundant: \( w_i' \geq 0 \))

- First order conditions

\[
\begin{align*}
\mu_i &= 1 + \eta_d, \quad (16) \\
\mu_i &= R\beta_i\mu_i' + R\beta_i\eta', \quad (17) \\
\mu_i &= R_i'\beta_i\mu_i' + R_i'\beta_i\eta_i', \quad (18) \\
\mu_i' &= v_i'(w_i', Z'), \quad (19)
\end{align*}
\]

- Envelope condition

\[
v_i'(w_i, Z) = \mu_i
\]
(Representative) **firm's static problem** given $R_i'$

$$
\max_{\{d,k,b',b_i',w_i'\}\in \mathbb{R}_+^2 \times \mathbb{R} \times \mathbb{R}_+^2} d + \beta w'
$$

subject to (2) through (5).

(Representative) **intermediary's static problem**

$$
\max_{\{d_i,l',l_i',w_i'\}\in \mathbb{R}_+^4} d_i + \beta_i w_i'
$$

subject to (7) through (8). $R_i'$ determined in equilibrium.
Poorly capitalized firms borrow from intermediaries

Suppose firms vary in their net worth $w$

Partial equilibrium: interest rate on intermediated finance $R_i'$ given

Proposition 8 (Intermediated vs. direct finance across firms)

Suppose $R_i' > \beta^{-1}$.

(i) Exist $0 < w_l < w_u$ such that firms with

... $w \leq w_l$ borrow as much as possible from intermediaries.

... $w \in (w_l, w_u)$ borrow positive amount from intermediaries.

... $w \geq w_u$ do not borrow from intermediaries.

(iii) Investment increasing in $w$.

Mirrors results of Holmström/Tirole (1997)
Effect of Intermediary Net Worth on Spreads

- Firm and intermediary net worth determine spreads jointly

Equilibrium in static economy with representative firm: $R'_i$ determined endogenously

Proposition 2 (Firm and intermediary net worth)

(i) For $w_i \geq w_i^*$, intermediaries well capitalized; minimal spread $\beta_i^{-1} - R > 0$.

(ii) Otherwise

- If $w \leq \underline{w}(w_i)$ intermediaries still well capitalized; spread $\beta_i^{-1} - R$.
- For $w > \underline{w}(w_i)$, intermediated finance scarce and spreads higher. For $w_i \in [\bar{w}_i, w_i^*)$, spreads increasing until $\hat{w}(w_i)$, then constant $\hat{R}'_i(w_i) - R \in (\beta_i^{-1} - R, \beta^{-1} - R]$. For $w_i \in (0, \bar{w}_i)$, spreads increasing until $\hat{w}(w_i)$, then decreasing until $\bar{w}(w_i)$, then constant $\beta^{-1} - R$. 
Role of Firm and Intermediary Net Worth

- Spreads high when firm and intermediary net worth low
  - ... and in particular when intermediary relative to firm net worth low
- Interest rate on intermediated finance $R_i' - 1$ (percent) as a function of firm ($w$) and intermediary net worth ($w_i$)

![Graph showing the relationship between firm net worth, intermediary net worth, and cost of intermediated funds.](Image)
Role of Firm and Intermediary Net Worth (Cont’d)

- Projection of interest rate on intermediated finance $R_i' - 1$ (percent) as a function of firm ($w$) for different levels of intermediary net worth ($w_i$)
Spreads determined by firm and intermediary net worth jointly

Contour of area where spread exceeds $\beta_i^{-1} - R$: $\bar{w}_i$ (solid) and $\hat{w}(w_i)$ (solid); $\hat{w}(w_i)$ (dashed); contour of area where spread equals $\beta_i^{-1} - \beta^{-1}$: $w_i$ (dash dotted) and $\bar{w}(w_i)$ (dash dotted).
Contours of regions describing deterministic dynamics of firm and financial intermediary net worth.