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

- Recent events

Theory of Financial Intermediary Capital

Our theory

- **Financial intermediaries are collateralization specialists**
  - Intermediaries better able to collateralize claims than households
- **Financial intermediary capital**
  - ... required to finance additional collateralized amount

Theory of Financial Intermediary Capital (Cont'd)

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: Financial Intermediary Capital

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**
  - Liquidity provision theories – Diamond/Dybvig (1983)
  - Diversified delegated monitoring theories – Diamond (1984), Ramakrishnan/Thakor (1984), Williamson (1986)
  - Coalition based theories – Townsend (1978), Boyd/Prescott (1986)

Literature: Financial Intermediary Capital (Cont'd)

Dynamic models with net worth effects

- **Firm net worth**
  - Bernanke/Gertler (1989), Kiyotaki/Moore (1997a)
- **Intermediary net worth**
  - Gertler/Kiyotaki (2010), Brunnermeier/Sannikov (2010)
- **Firm and intermediary net worth**
  - This paper

Model

Environment

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

Model: Households

Households

- Risk neutral, discount at $R^{-1} > \beta$ where firms' discount rate is β
- Large endowment of funds (and collateral) in all dates and states

Model: Collateral Constraints

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 θ of resale value of capital to households
    - ... up to fraction θ_i of resale value of capital to intermediaries
  - Related: Kiyotaki/Moore (1997a); but two types of lenders and allow risk management
- **Limited enforcement**
  - Rampini/Viswanathan (2010, 2012) derive such collateral constraints from limited enforcement without exclusion - different from Kehoe/Levine (1993)

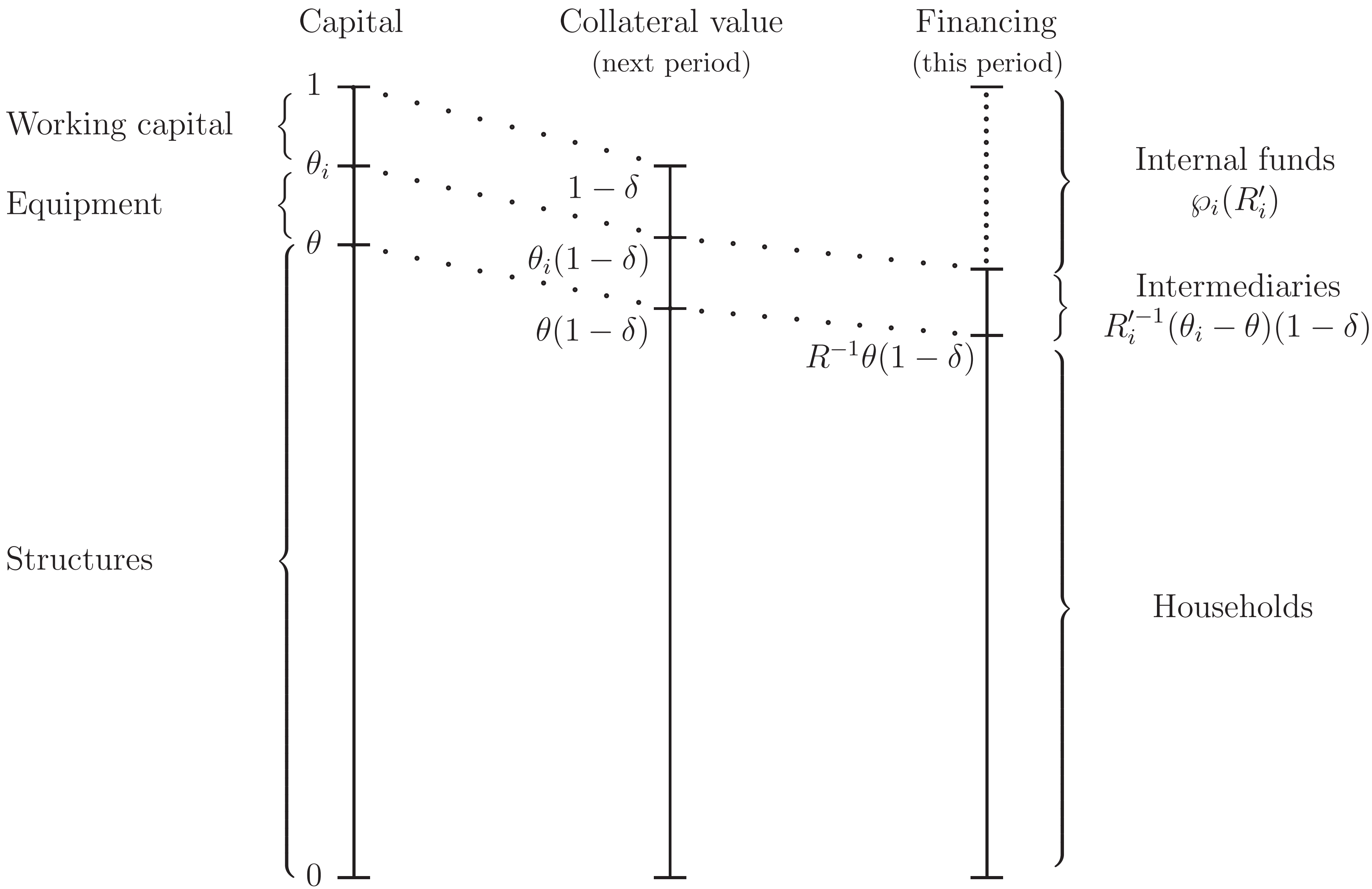
Model: Financial Intermediaries

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 θ 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



Model: Firms

Representative firm (or "corporate sector")

- Risk neutral, limited liability, discount at $\beta < 1$
- Capital k
  - Depreciation rate δ; 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

Dynamic program

- Firm solves

$$v(w, Z) = \max_{\{d,k,b',b'_i,w'\} \in \mathbb{R}_+^2 \times \mathbb{R}^S \times \mathbb{R}_+^{2S}} d + \beta E\left[v(w', Z')\right] \tag{1}$$

subject to budget constraints

$$w + E\left[b' + b'_i\right] \ \geq \ d + k \tag{2}$$

$$A' f(k) + k(1-\delta) \ \geq \ w' + Rb' + R'_i b'_i \tag{3}$$

and **collateral constraints**

$$\theta k(1-\delta) \ \geq \ Rb' \tag{4}$$

$$(\theta_i - \theta) k(1-\delta) \ \geq \ R'_i b'_i \tag{5}$$

Firm's Problem (Cont'd)

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

Endogenous Minimum Down Payment Requirement

Minimum down payment requirement $\wp$ (or margin)

- Borrowing from households only

$$\wp = 1 - R^{-1}\theta(1-\delta)$$

- Borrowing from households and financial intermediaries

$$\wp_i(R_i') = \wp - E[(R_i')^{-1}](\theta_i - \theta)(1-\delta)$$

Firm's investment Euler equation

$$1 \geq E\left[\beta \frac{\mu'}{\mu} \frac{A' f_k(k) + (1-\theta_i)(1-\delta)}{\wp_i(R_i')}\right] \tag{6}$$

User Cost of Capital with Intermediated Finance

Extension of Jorgenson's (1963) definition

- Jorgenson's (1963) user cost of capital: $u \equiv r + \delta$
- Premium on internal funds ρ: $1/(R+\rho) \equiv E[\beta\mu'/\mu]$
- Premium on intermediated finance ρ_i: $1/(R+\rho_i) \equiv E[(R_i')^{-1}]$
- **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 $1 + r \equiv R$

Premia on Internal and Intermediated Finance

Internal and intermediated funds are scarce

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

  - *Premium on internal finance* ρ *(weakly) exceeds premium on intermediated finance* ρ_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* $E[\lambda'] > 0$.

Intermediary's Problem

Representative intermediary's problem

- Intermediary solves

$$v_i(w_i, Z) = \max_{\{d_i, l', l_i', w_i'\} \in \mathbb{R}_+^{1+3S}} d_i + \beta_i E\left[v_i(w_i', Z')\right] \tag{7}$$

subject to budget constraints

$$w_i \geq d_i + E[l'] + E[l_i'] \tag{8}$$

$$Rl' + R_i' l_i' \geq w_i' \tag{9}$$

- State-contingent loans to direct lender l' and to firms l_i'

Equilibrium

Definition of an equilibrium

- **Definition 1 (Equilibrium)** *(Abridged) 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 (7)-(9)*

  - *(ii) market for intermediated finance clears in all dates and states*

$$l'_i = b'_i. \tag{10}$$

Essentiality of Financial Intermediation

Definition

- **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 spreads 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)** *(Abridged) 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)*

    $$\frac{w_i^*}{w^*} = \frac{\beta_i(\theta_i - \theta)(1-\delta)}{\wp_i(\beta_i^{-1})}$$

    (ratio of intermediary's financing to firm's down payment requirement)

Deterministic Dynamics

Equilibrium dynamics

- Two main phases: **no dividend phase and dividend phase**

Proposition 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*

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

(iii) investment $k = (w + w_i)/\wp$ if $R_i' > R$ and $k = w/\wp_i(R)$ 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 $1 = \beta[A' f_k(\bar{k}) + (1-\theta)(1-\delta)]/\wp$, (iv) $w_{ex}'/w_i' < w_{ex}/w_i$, that is, firm net worth (ex dividend) increases more slowly than intermediary net worth, and (v) $\bar{w}(w_i) = \wp\bar{k} - w_i$. For $w_i \in [\bar{w}_i, w_i^*)$, (ii) $R_i' = (\theta_i - \theta)(1-\delta)k/w_i$, (iii) k solves $1 = \beta[A' f_k(k) + (1-\theta)(1-\delta)]/(\wp - w_i/k)$, (iv) $w_{ex}'/w_i' < w_{ex}/w_i$, that is, firm net worth (ex dividend) increases more slowly than intermediary net worth, and (v) $\bar{w}(w_i) = \wp_i(R_i')k$. 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 $d_i = w_i - w_i^*$.*

Deterministic Dynamics (Cont'd)

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 (equilibrium) interest rate R_i' ($\geq R$)

- **Slow accumulation of intermediary net worth**
  - Intermediaries earn R_i'
    - At most marginal return on capital (**collateral constraint**)
    - Firms earn average return (**decreasing returns to scale**)

Deterministic Dynamics (Cont'd)

Initial dividend

- **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

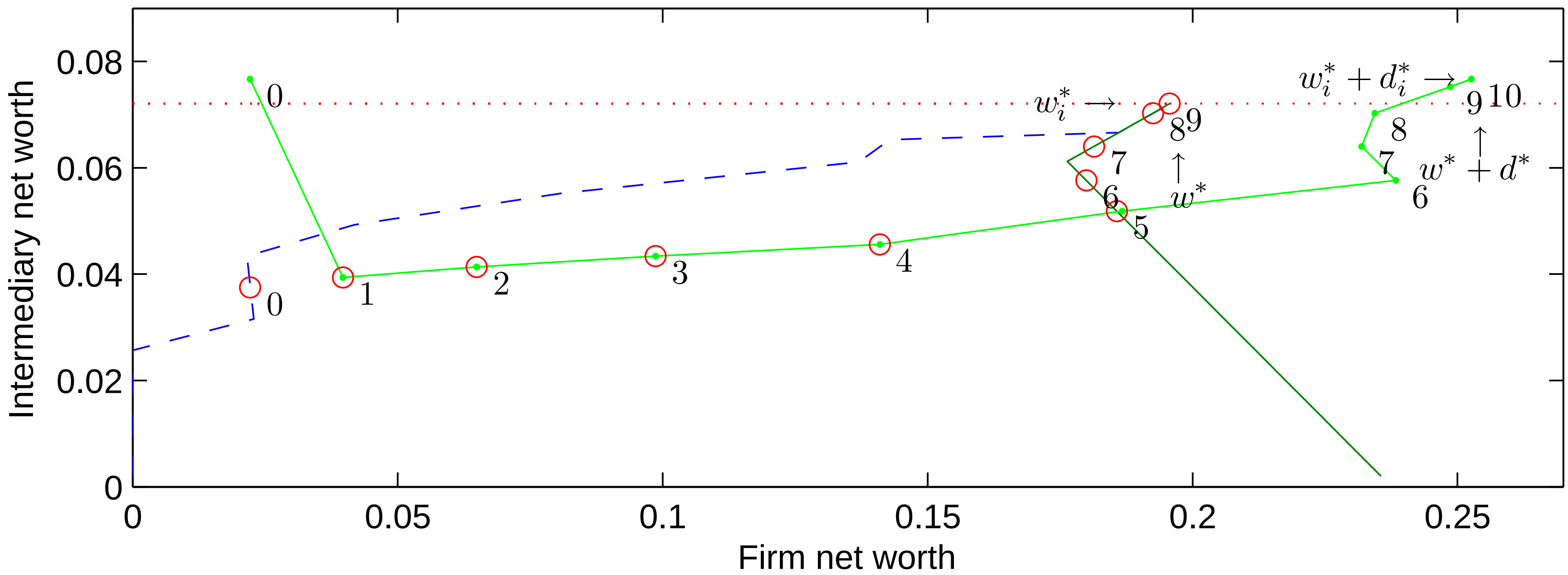
Slow Intermediary Net Worth Accumulation

Net worth dynamics

- Transition to steady state: Consider low initial firm net worth w
- Low firm net worth $\Rightarrow$ low investment $k = w/\wp_i(R)$ 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 $k = (w + w_i)/\wp$, loan demand, and interest rate $R'_i = (\theta_i - \theta)(1 - \delta)/\wp\,(w/w_i + 1)$ rise
  - When collateral constraint stops binding, interest rate $R'_i = [A' f_k(k) + (1 - \theta)(1 - \delta)]/\wp$ falls
- When interest rate reaches β^{-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

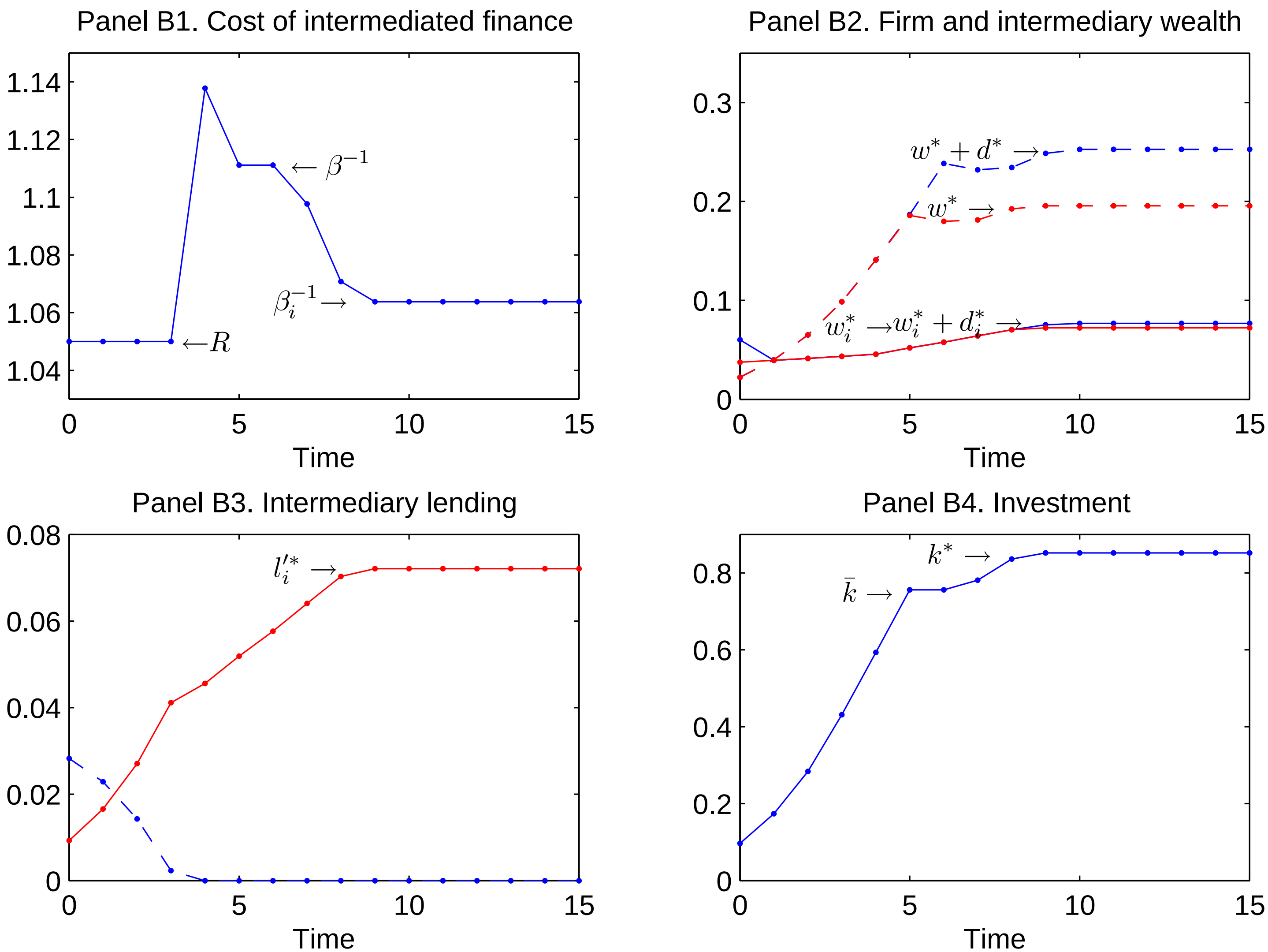
Deterministic Dynamics (Cont'd)

Joint dynamics of firm and intermediary net worth



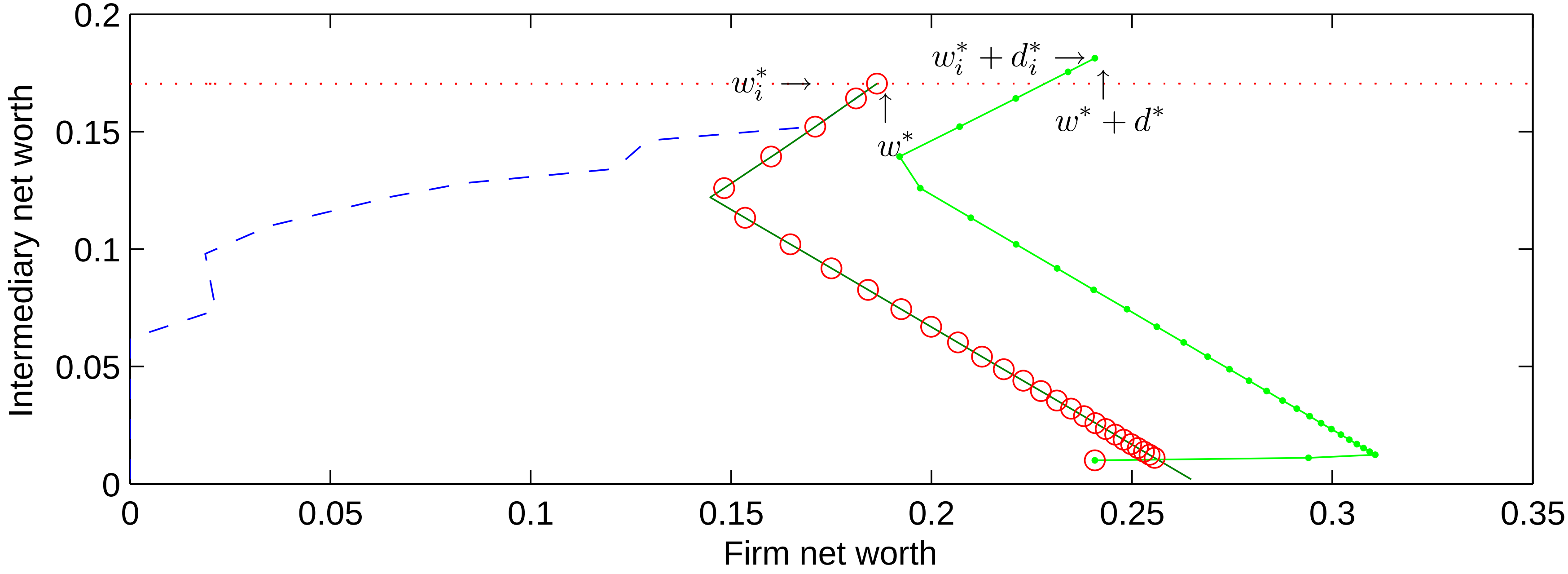
Deterministic Dynamics (Cont'd)

Dynamics of net worth, spread, and investment



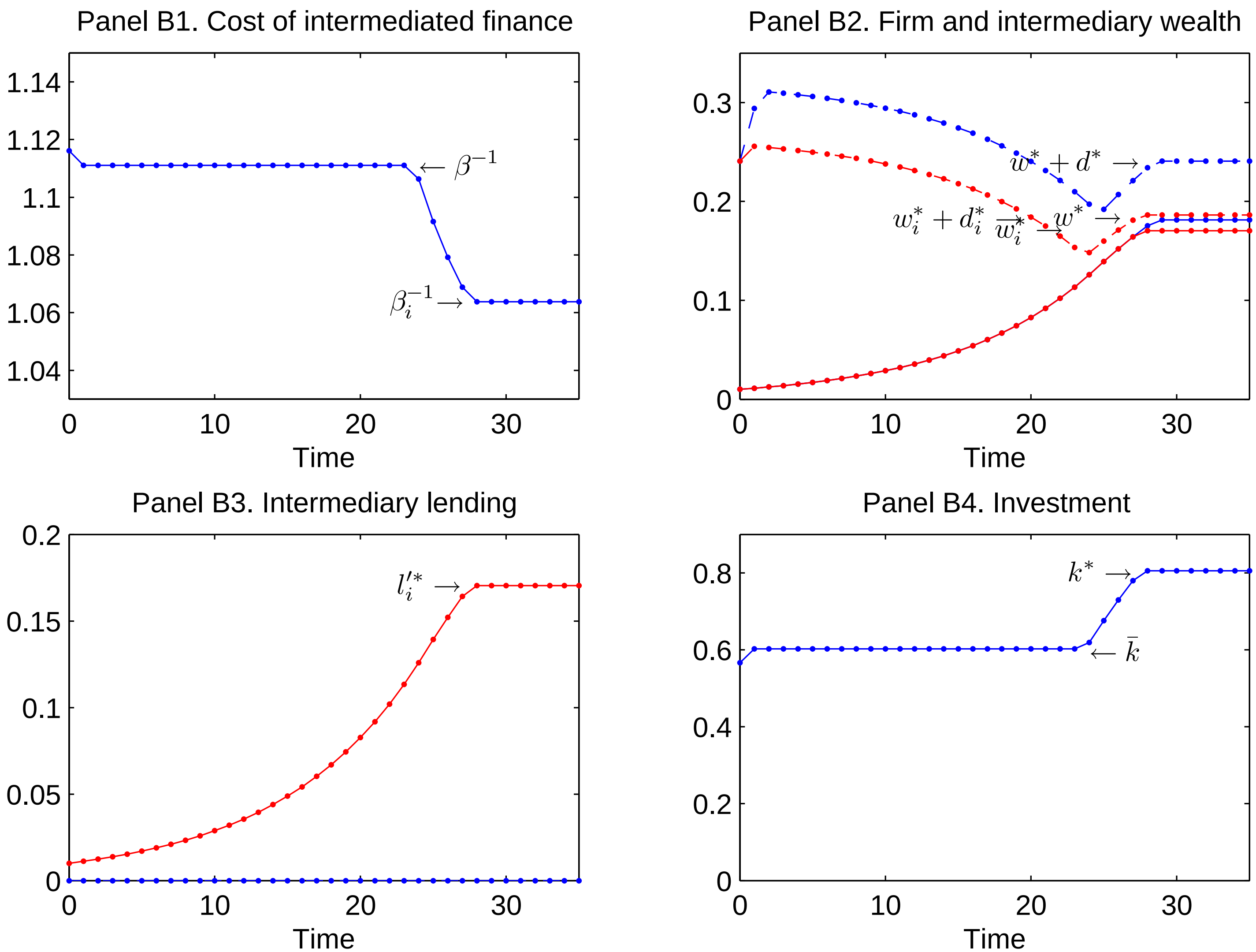
Dynamics of a Credit Crunch

Joint dynamics of firm and intermediary net worth



Dynamics of a Credit Crunch (Cont'd)

Dynamics of net worth, spread, and investment



Dynamics of a Credit Crunch

Credit crunch

- Unanticipated drop in intermediary net worth w_i from steady state

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"**

Dynamics of a General Downturn

General downturn

- Unanticipated drop in firm (and possibly intermediary) net worth from steady state
  - Say due to surprise increase in depreciation rate δ

Persistent real effects

- Drop in real investment
- Spread on intermediated finance may fall (as loan demand goes down)
- **Intermediaries may pay initial dividend when downturn hits!**

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)** *(Abridged) 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:* $\mu(s')/\mu(s'_+) = \mu_i(s')/\mu_i(s'_+), \forall s', s'_+ \in S$.
  - ***(iii)*** *If* $S = \{\hat{s}', \check{s}'\}$ *and* $\lambda(\check{s}') > 0 = \lambda(\hat{s}')$, *then the marginal values must comove,* $\mu(\hat{s}') > \mu(\check{s}')$ *and* $\mu_i(\hat{s}') \geq \mu_i(\check{s}')$.

- 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

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

First order conditions

- Multipliers
  - ... on (2) through (5): μ, $\Pi(Z, Z')\beta\mu'$, $\Pi(Z, Z')\beta\lambda'$, and $\Pi(Z, Z')\beta\lambda_i'$
  - ... on $d' \geq 0$ and $b_i' \geq 0$: ν_d and $\Pi(Z, Z')R_i'\beta\nu_i'$
  - (Redundant: $k \geq 0$ and $w' \geq 0$)

- First order conditions

$$\mu = 1 + \nu_d \tag{11}$$

$$\mu = E\left[\beta\mu'\left(\left[A' f_k(k) + (1-\delta)\right] + \left[\lambda'\theta + \lambda_i'(\theta_i - \theta)\right](1-\delta)\right)\right] \tag{12}$$

$$\mu = R\beta\mu' + R\beta\lambda' \tag{13}$$

$$\mu = R_i'\beta\mu' + R_i'\beta\lambda_i' - R_i'\beta\nu_i' \tag{14}$$

$$\mu' = v'(w', Z') \tag{15}$$

- Envelope condition

$$v'(w, Z) = \mu$$

Weighted Average User Cost of Capital

Weighted average cost of capital representation

- 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

$$r_w \equiv (r+\rho)\wp_i(R_i') + rR^{-1}\theta(1-\delta) + (r+\rho_i)(R+\rho_i)^{-1}(\theta_i - \theta)(1-\delta)$$

Characterization of Intermediary's Problem

First order conditions

- Multipliers
  - ... on (8) through (9): μ_i and $\Pi(Z, Z')\beta_i\mu_i'$,
  - ... on $d_i' \geq 0$, $l' \geq 0$, and $l_i' \geq 0$: η_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

$$\mu_i = 1 + \eta_d, \tag{16}$$

$$\mu_i = R\beta_i\mu_i' + R\beta_i\eta', \tag{17}$$

$$\mu_i = R_i'\beta_i\mu_i' + R_i'\beta_i\eta_i', \tag{18}$$

$$\mu_i' = v_i'(w_i', Z'), \tag{19}$$

- Envelope condition

$$v_i'(w_i, Z) = \mu_i$$

Financial Intermediation in a Static Economy

Firm's static problem

- Firm's problem given R_i'

$$\max_{\{d,k,b',b_i',w'\}\in\mathbb{R}_+^2\times\mathbb{R}\times\mathbb{R}_+^2} d+\beta w' \tag{20}$$

subject to (2) through (5).

Intermediary's static problem

- (Representative) intermediary solves

$$\max_{\{d_i,l',l_i',w_i'\}\in\mathbb{R}_+^4} d_i+\beta_i w_i' \tag{21}$$

subject to (8) through (9). R_i' determined in equilibrium.

Intermediated vs. Direct Finance in Cross Section

Poorly capitalized firms borrow from intermediaries

- Suppose firms vary in their net worth w
- Partial equilibrium: interest rate on intermediated finance R_i' given
- **Firms with low net worth borrow from intermediaries:**

  Proposition 8 (Intermediated vs. direct finance across firms) *(Abridged) Suppose* $R_i' > \beta^{-1}$.

  - ***(i)*** *Exist* $0 < \underline{w}_l < \underline{w}_u$ *such that firms with*
    - *...* $w \le \underline{w}_l$ *borrow as much as possible from intermediaries.*
    - *...* $w \in (\underline{w}_l, \underline{w}_u)$ *borrow positive amount from intermediaries.*
    - *...* $w \ge \underline{w}_u$ *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

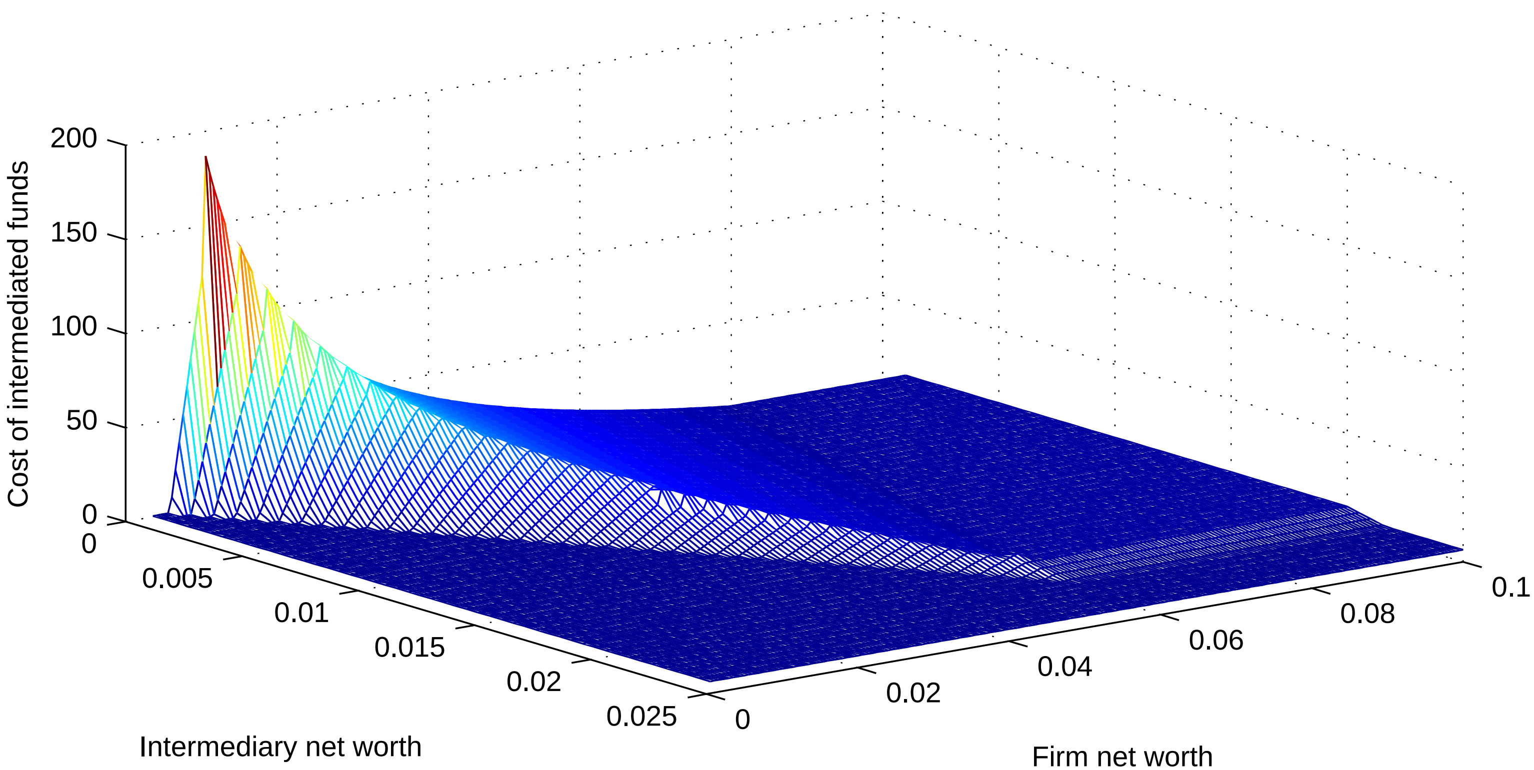
- **Proposition 2 (Firm and intermediary net worth)** *(Abridged)*
  - ***(i)*** *For $w_i \geq w_i^*$, intermediaries well capitalized; minimal spread $\beta_i^{-1} - R > 0$.*
  - ***(ii)*** *Otherwise*
    - *If $w \leq \underline{w}(w_i)$ intermediaries still well capitalized; spread $\beta_i^{-1} - R$.*
    - *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

Interest rate on intermediated finance $R_i' - 1$

- 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)

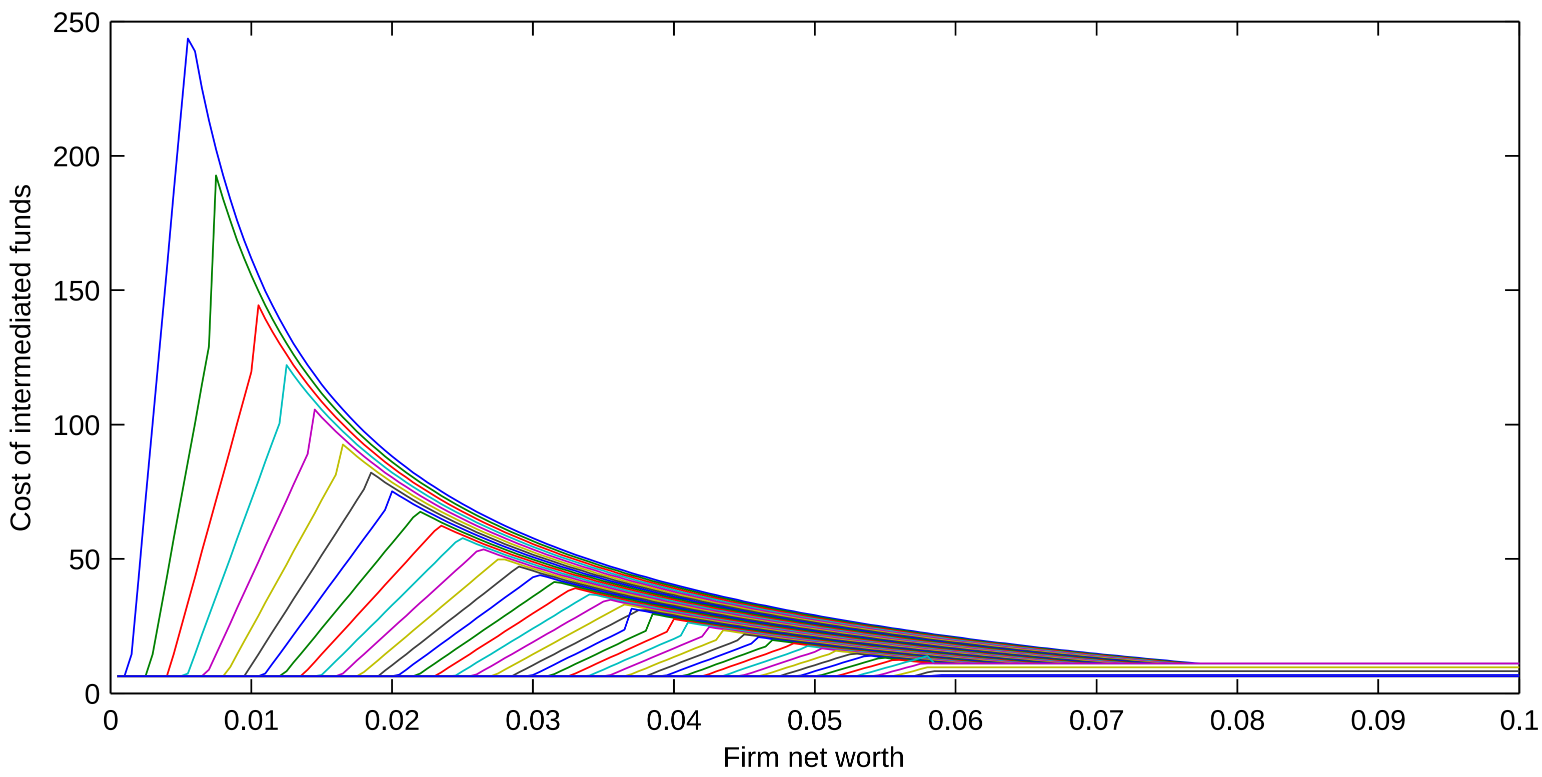


Role of Firm and Intermediary Net Worth

Interest rate on intermediated finance $R_i' - 1$

- Projection of spreads on intermediated finance

Interest rate on intermediated finance $R_i' - 1$ (percent) as a function of firm (w) for different levels of intermediary net worth (w_i)

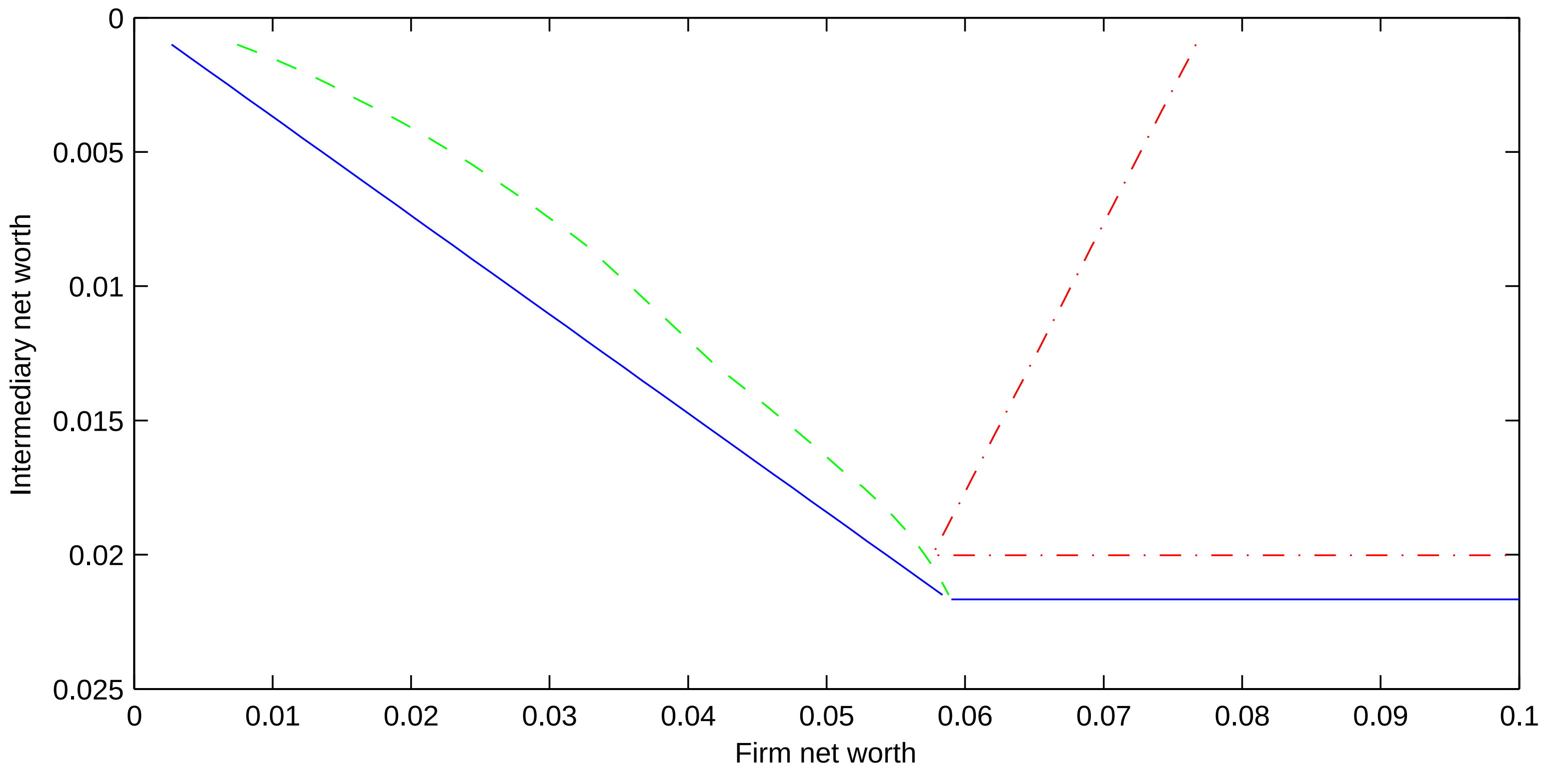


Role of Firm and Intermediary Net Worth

Interest rate on intermediated finance $R_i' - 1$

- Spreads determined by firm and intermediary net worth jointly

Contour of area where spread exceeds $\beta_i^{-1} - R$: $\bar{w}_i$ (solid) and $\underline{w}(w_i)$ (solid); $\hat{w}(w_i)$ (dashed); contour of area where spread equals $\beta_i^{-1} - \beta^{-1}$: $\underline{w}_i$ (dash dotted) and $\bar{w}(w_i)$ (dash dotted).



Dynamics of Firm and Intermediary Net Worth

Deterministic Dynamics

- Contours of regions describing deterministic dynamics of firm and financial intermediary net worth.