**FTG Working Paper Series**

Intermediation via Credit Chains

by

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Finance Theory Group

www.financetheory.com

# Intermediation via Credit Chai

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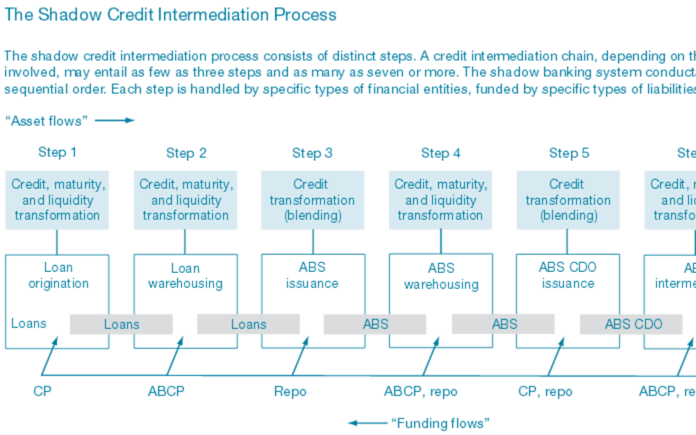
# Motivation: Long Credit Chains (1)

Shadow banking system features long credit chains

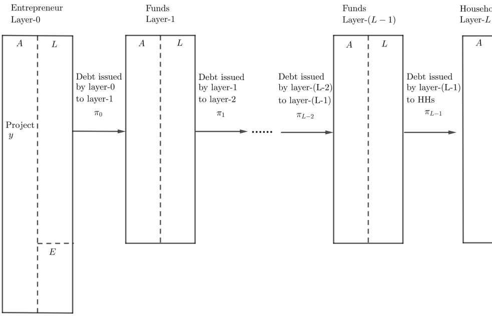


# Motivation: Long Credit Chains (2)

- Credit chain: **One institution's asset is another i liability** ⇒ Interconnected balance sheets
- During 2007-09 financial crisis, households invest MMMFs hold ABCPs issued by special purpose v ⇒ SPVs hold medium term bank notes ⇒ banks mortgages
- Nowadays, Mutual funds hold parts of collaterali obligations (CLOs)

# This Paper (1)

- Our model delivers intermediation via credit chai




- What is the benefit of intermediating via credit ch
- Is the equilibrium credit chain length socially effi

# This Paper (2)

- Fundamental economic issue:
  - With market frictions, short-term debts facilitate r
    transformation between households with short-te
    needs and long-term asset
  - But, short-term debt leads to excessive liquidatio
- A fully dynamic model of endogenous credit cha
  following trade-off of layers
  - Benefit: insulate real project from liquidation giv
    cash-flow
  - Cost: (exogenous) layer cost
- Today, mainly go through a three-period example
- Social planner can improve welfare by limiting cre

# Literature

- **Credit chains**: Adrian and Shin (2010), Di Maggio ar (2017), Donaldson and Micheler (2018), Glode and Op
- **Debt runs**: Diamond and Dybvig (1983), Calomiris a Goldstein and Pauzner (2005), He and Xiong (2012), G Metrick (2012), Copeland, Martin and Walker (2014), K Nagel and Orlov (2014), He and Manela (2016), Schmi and Wermers (2016)
- **Network and contagion**: Allen and Gale (2000), All Carletti (2012), Elliott, Golub and Jackson (2014)
- **Asset trading chains**: Atkeson, Eisfeldt and Weill (2 Opp (2016), Glode, Opp and Zhang (2019), Hugonnier (2019), Shen, Wei and Yan (2021)

# Outline

# Example Setup

- $t = 0, 1, 2, 3$
- Households:
  - Two-period OLG born at $t = 0, 1, 2$, each endowe
    consumption good when born; no discount $U_t =$
  - Can save in securities offered in the market

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  - Issue debt to maximize $t = 0$ value $P_0$ paid by O
- Zero-coupon debt securities, focus on different de
  - (Optimal) principal payment $F = 1$ upon mature

# Setup Cont.

- When debt matures: refinance from new cohort t
  - If rollover fails, asset **liquidated** at discount $\alpha$ (re intermediation) of the equilibrium market price
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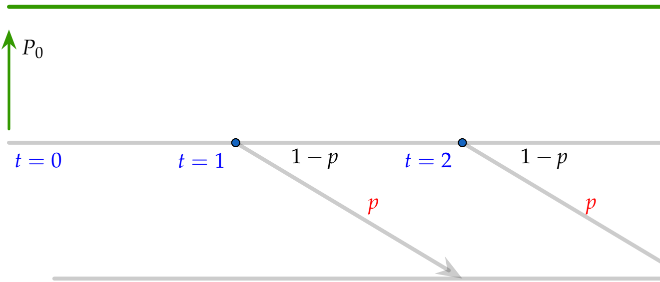
- Both "discounts" apply to equilibrium market pri
  - Micro-foundation: intermediaries buy the securit
    (liquidation or resell), put on their book for one n
    households next morning

- In the example (as well as the model) we set $\alpha =$
  - Liquidation $\alpha_l$ could differ from secondary-mark just need both to be less than 1
- **Rollover, if successful,** is the best way to transfer households (than **liquidation** or **secondary-mark**
  - Liquidation cost is prohibitive
  - Corporate bonds transaction cost 53 bps, but ABC underwriting/issuance fee 5-15 bps

# Case 0: Long-Term Three-Period Debt

- Entrepreneur issues three-period debt to househo

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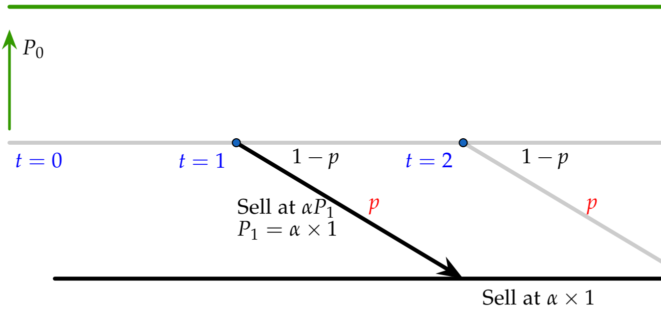


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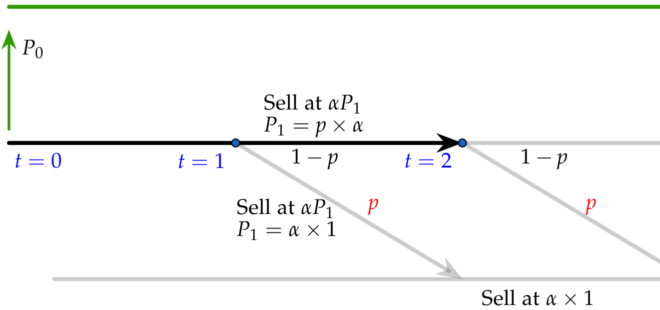


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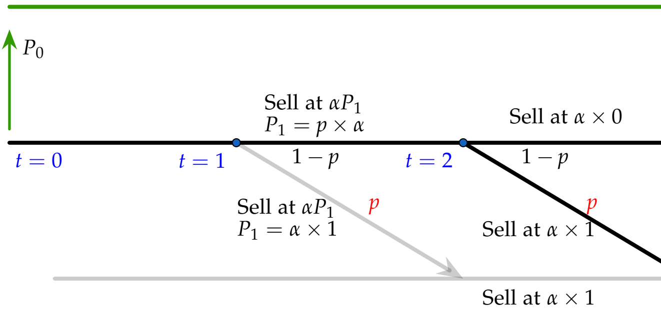


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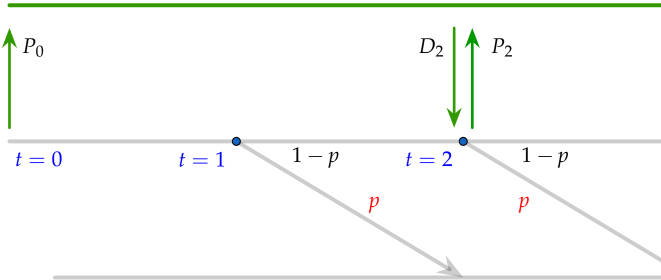


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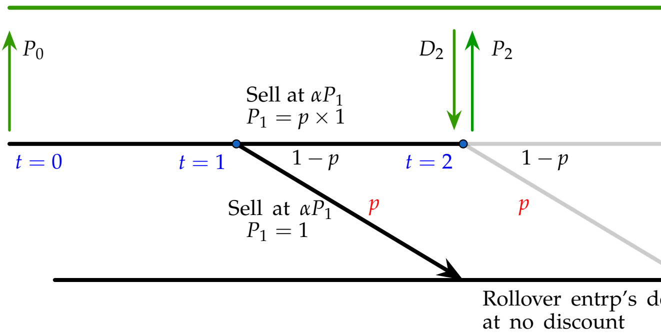


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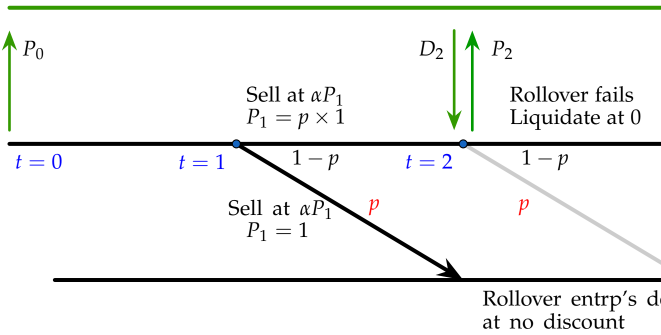


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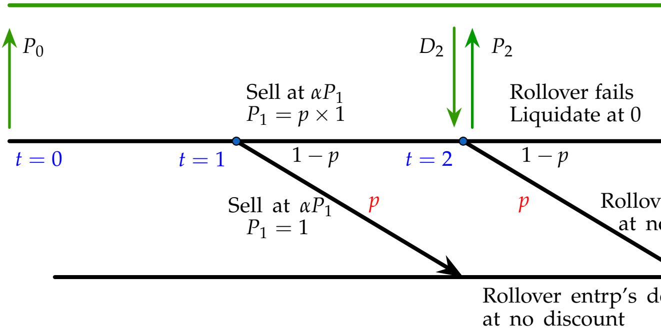


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# Case 2: Short-Term One-Period Debt

- One-period debt to households; the project liquid
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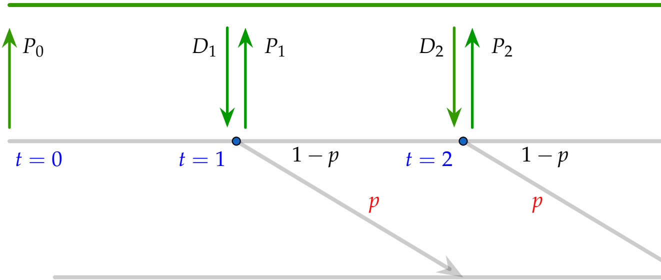


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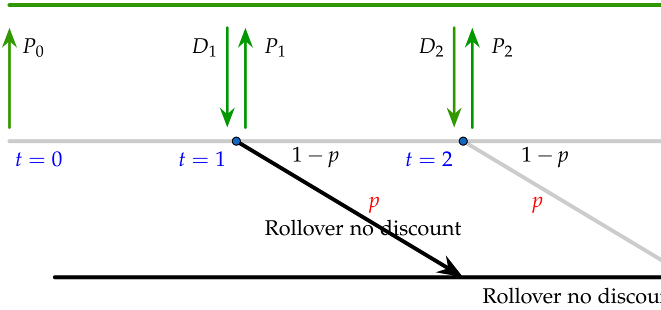


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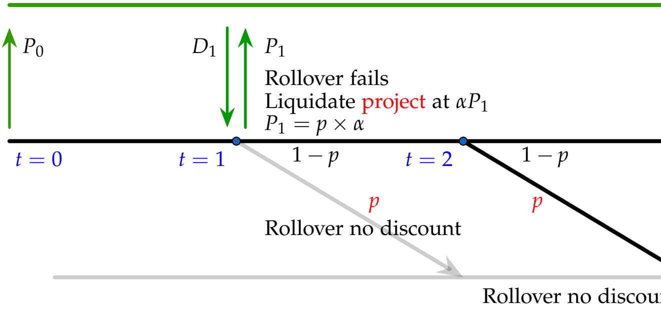


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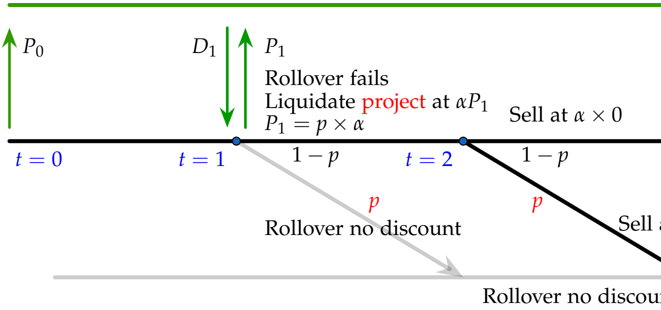


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# Special Case: State-Contingent Maturity

- Short-term debt, but matures at $t = 1$ iff good new
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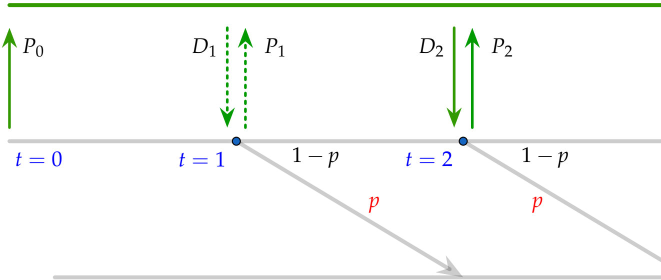


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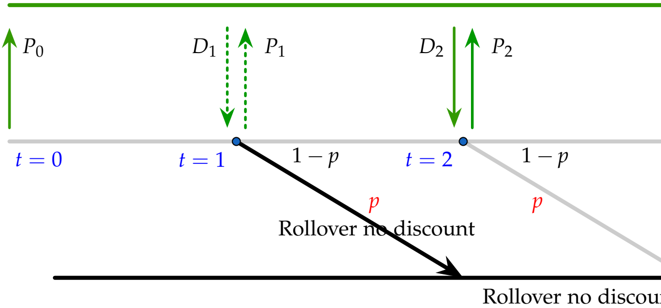


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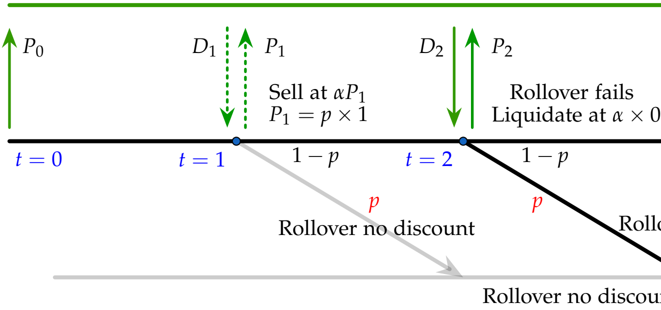


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# Case 3: Two-Layer Credit Chain

- Entrepreneur issues a two-period debt to fund, w
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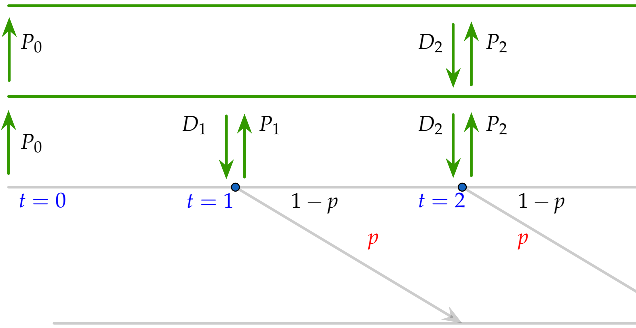
- Fund's asset: debt claims over project's cash flow

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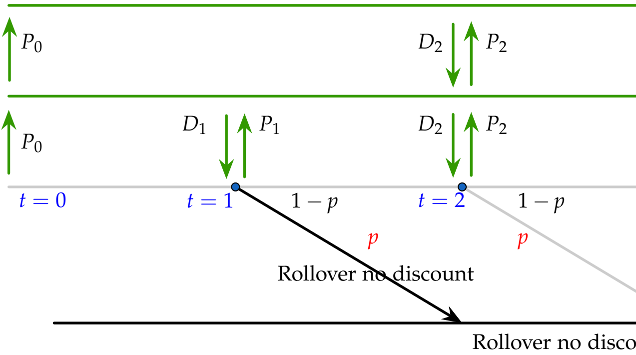


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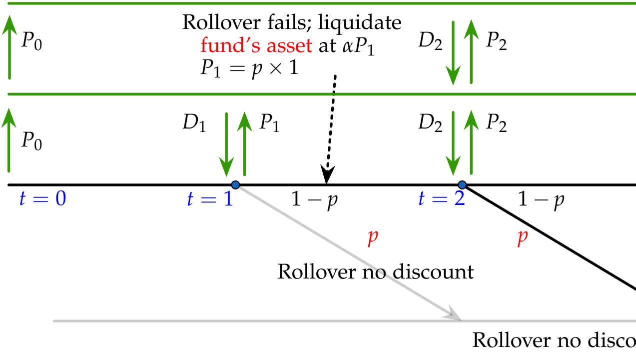


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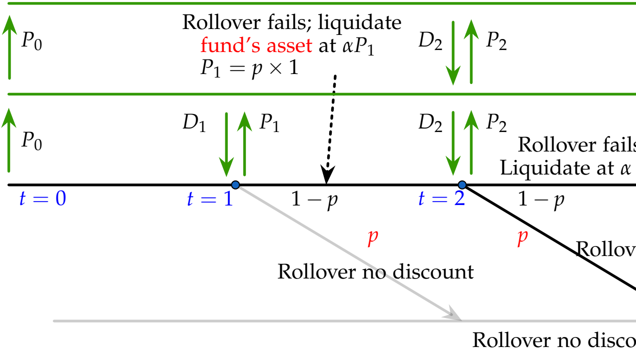


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# Intuition

- Short-term debt gets around secondary market tr
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- Two-layer structure "replicates" the state-continge
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    subsequent short-term debt claims over cash-flow
  - In contrast, single-layer short-term debt: long-ter
    over cash-flow gets traded repeatedly
- Conceptual connection to Diamond and Rajan (20
  - There, intermediaries increase recovery value onc
    the **continuation game** after asset liquidation (du
    human capital)
  - Here, credit chain matters for **continuation game**
    project's future cash flows from heavy discount

# Extending to Multiple Layers

- The intuition extends to $L$ layers
  - Suppose project matures in $L$ periods
  - Entrepreneur (layer 0) issues debt with $m = L - 1$
  - Fund in layer 1 holds debt with $m = L - 1$ and is
    $m = L - 2$

    ...
  - Fund in layer $l$ holds debt with $m = L - l$ and iss
    $m = L - l - 1$, for any $l$
- In the model, for tractability we assume debt con
  random maturity
  - Each layer's debt contract has random maturity $\lambda$
    matures if above-layers' debts mature
  - Fund in layer $l$ is holding debt with maturity rate
    is issuing debt with maturity rate $1 - (1 - \lambda_d)^{l+1}$

# Outline

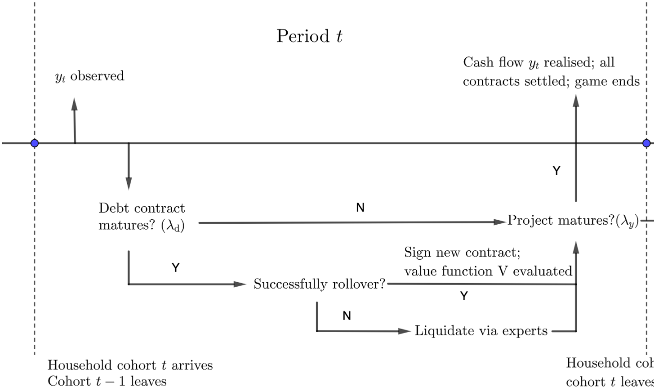
# Households and the Firm

- Time is discrete and infinite
- OLG Households: measure 1
  - Live for two periods: no discount

$$U_t = c_t^t + c_{t+1}^t$$

  - Endowed with $e$ units of consumption good whe
- Entrepreneur: infinitely lived with time discount
- Project: matures with probability $\lambda_y$ each period
  - Produces $y_t$ if matures in period $t$; produces noth
  - $y_t \sim H(\cdot)$ and is i.i.d. across periods
- Intermediaries: infinitely lived with time discoun

# Timing


Period $t$
$y_t$ observed
Cash flow $y_t$ realised; all contracts settled; game ends
Y
N
Debt contract matures? $(\lambda_d)$
Project matures?$(\lambda_y)$
Sign new contract; value function V evaluated
Y
Successfully rollover?
Y
N
Liquidate via experts
Household cohort $t$ arrives
Cohort $t-1$ leaves
Household coh
cohort $t$ leaves

# Contracts

- Debt-like contract: $\pi_t = \{\tilde{F}_{y,s}, F_{d,s+1}\}_{s=t}^{T}$ matures w
  $\lambda_d$ in each period, $\mathcal{F}_s$-measurable for any $s \geq t$

  $\tilde{F}_{y,s} \cdot \mathbf{1}_{\text{project matures at period } s \text{, w.p. } \lambda_y} + F_{d,s+1} \cdot \mathbf{1}_{\text{debt matures}}$

  - $\tilde{F}_{y,s}(y_s) = \min(F_{y,s}, y_s)$
  - $y_s$ is known (and occurs if project matures) when
    contract at $t = s$ which affects the rollover

- Creditors can renegotiate by "prepaying" the deb
  matures
  - Effectively, creditors can unilaterally trigger the d
  - Focus on renegotiation-proof contracts; ensures s

- Price $P(\pi, y)$. This is the endogenous proceeds th
  from offering $\pi$ given $y$

# Credit Chain

- Consider credit chain of length $L$: entrepreneur is
  households are at layer $L$
- A fund in layer $l$ borrow from $l+1$ with contract
- Resource constraint:

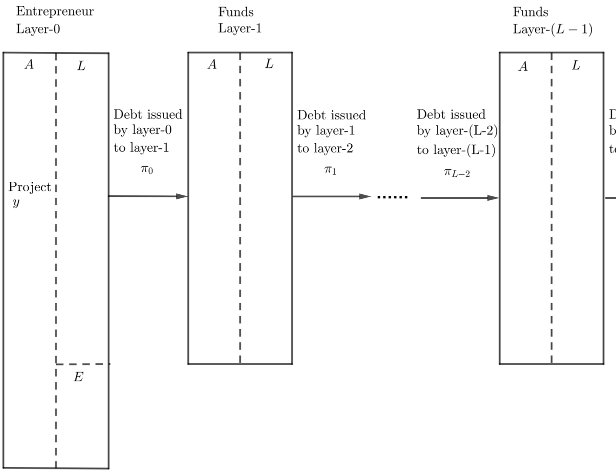
$$F_{y,l} \leq F_{y,l-1} \leq y \quad \text{for } 0 < l < L$$

- No-bubble constraint:

$$F_{d,l} \leq F_{d,l-1} \leq e \quad \text{for } 0 < l < L$$

- "Event-triggered prepayment" among contracts i
  - When the project matures, $y$ trickles down
  - When $l$-layer debt matures and successful rollove
    down for $l' > l$ (or just restore at $l$)

# Illustration of the Layer Structure



# Debt Rollover and Secondary Market

- When $y_t \geq \hat{y}_l$, layer $l$ can rollover successfully
  - Nothing changes in the chain structure
- Otherwise, rollover fails
  - Layer $l$'s asset is worth $B_l(y, L)$ to cohort $t$ househ
    $B_l(y, L)$ endogenously determined
  - Liquidation will be intermediated by a distressed
    discount $\alpha \Rightarrow$ distress funds pay only $\alpha B_l(y, L)$
  - Restructuring/legal cost $c \geq 0$ per layer
- Cohort $t-1$ households recover

$$\min(\alpha B_l(y, L), F_{d,l}) - c(L - l)$$

# Credit Chain Restoration when Default O

- To determine $B_l(y, L)$, we assume
  - With probability $\beta \in [0, 1]$, the chain is restored i
  - With probability $1 - \beta$,
    - Cohort $t$ households hold debt issued by layer $l$ – period
    - The chain is restored with probability 1 in the fol absent another run
  - $\beta < 1$ makes the ex-ante chain formation matters
- The entrepreneur is always rehired after rollover project-specific human capital

# Value Functions

- In the event of successful rollover $y > \hat{y}$, $l$-fund ta
given, choose $\pi_l$ to maximize proceeds and contin

$$\mathbf{1}^{l}_{rollover}(P_l(\pi_l, y; \pi_{l-1}, L) - F_{d,l} + V_l(y, \pi_l; \pi$$

▸ Funds' Value Function ▸ Entrepreneur's Value Function

- Households' payoff

$$e - P_{L-1}(y) + V_L(y; \pi_{L-1}, L)$$

▸ Households' Value Function

# Outline

# Equilibrium Definition

- Contracts $\pi_{l,t}$ are chosen to maximize the respecti
  payoff
- Equilibrium credit chain length $L^*$ is such that fir
  managers $(L^* - 1)$ prefers to borrow directly from
  - For all other funds $0 < l < L^* - 1$, they prefer to
    funds than to borrow directly from households
- Intermediary funds are competitive to earn zero p

# Optimal Contract

- Under Assumption 1 which says $e$ is relatively sm
  are **stationary** over time
  - $y_t$ is i.i.d. and $F_{d,l,t} \leq e$ binds in all periods
- Contracts are **layer independent**:

$$F_{d,0} = F_{d,1} = ... = F_{d,L-1} \qquad F_{y,0} = F_{y,1} = ..$$

  - Lower layers (larger $l$) are less concerned about r
    - Why? Any layer $l$ only cares about the rollover ri
      households ($L$) $\Rightarrow$ larger $l$ set higher $F_{d,l}$
    - Hence $F_{d,l} \leq F_{d,l-1}$ (no-Ponzi condition) binds fo
  - $F_{d,l} = F_{d,l-1} \Rightarrow F_{y,l} = F_{y,l-1}$ because of zero profit
- $F_y$ equals the run threshold (stationary, layer inde
- $\pi^*$ is characterized in closed form

# Equilibrium Chain Length

- The equilibrium chain length $L^*$ minimizes the ro

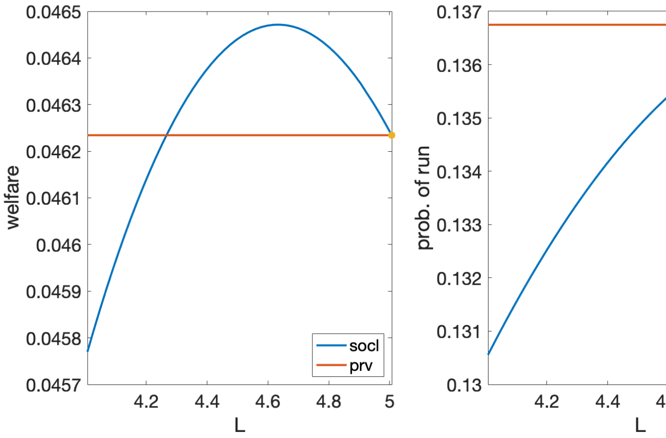
$$L^* = \arg\min_{L} F_y(e, L)$$

▸ Details

- Social v.s. private: endogenize $e$ and analyze whe credit chain length improves welfare ▸ Model Details
- Key friction: layer $L-1$ decides the chain length, takes as given when designing contract
  - Shorter chain $\Rightarrow$ smaller maturity mismatch $\Rightarrow$ sı risks $\Rightarrow$ larger borrowing amount $F_d$
  - Decentralised $F_d$ is too low; entrepreneur/funds by period and cannot commit to future contract v
  - Though $F_d$ up, the overall stability increases

# Numerical Example

Social v.s. Private Welfare and Probability of



# Conclusion

- Provide a model of credit chains with endogenou
  chain length
- Highlight the asset insulation effect of the layer st
- Despite the benefit of intermediating via layers, th
  equilibrium features too long chains

# Appendix: Value Functions—Funds

$$V_l(y, \pi_l; \pi_{l-1}, L) = \lambda_y \underbrace{(\tilde{F}_{y,l-1} - \tilde{F}_{y,l})}_{\text{Project matures}}$$

$$+ (1-\lambda_y)\alpha \Bigg\{ (1-\lambda_d)^{l+1}\mathbb{E}\Big[ \qquad \underbrace{V_l(y', \pi_l; \pi_{l-1}, L)}_{\text{Neither debt issued by nor held by layer } l \text{ mature}}$$

$$+ \sum_{i=0}^{l-1} (1-\lambda_d)^i \lambda_d \mathbb{E}\Big[ \underbrace{\mathbf{1}^i_{rollover}(-F_{d,l} + F_{d,l-1} - P'_{l-1} + \max_{\pi'_l}(P'_l + V_l(y',}_{\text{Debt held by layer } l \text{ matures}}$$

$$+ (1-\lambda_d)^l \lambda_d \mathbb{E}\Big[ \qquad \underbrace{\mathbf{1}^l_{rollover}(-F_{d,l} + \max_{\pi'_l}(P'_l + V_l(y', \pi'_l; \pi_{l-1}, L)))}_{\text{Debt held by layer } l \text{ does not mature but debt issued by layer } l \text{ m}}$$

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# Appendix: Value Functions— Entreprene

$$V_0(y,\pi_0;L) = \underbrace{\lambda_y(y-\tilde{F}_{y,l})}_{\text{Project matures}} + (1-\lambda_y)\alpha\Big\{(1-\lambda_d)\mathbb{E}\big[\qquad \underbrace{V_0(y',\pi_0;}_{\text{Debt issued by layer-0 do}}$$

$$+\lambda_d\mathbb{E}\big[\underbrace{\mathbf{1}^0_{rollover}(-F_{d,0}+\max_{\pi_0'}(P_0'+V_0(y',\pi_0';L)))}_{\text{Debt issued by layer-0 matures and rollover succeeds}} +$$

$$\underbrace{(1-\mathbf{1}^0_{rollover})[(\beta+(1-\beta)(1-\lambda_y)\alpha)(-P'_{-1}+\max_{\pi_0'}(P_0'+}_{\text{Debt issued by layer-0 matures and rollover fails}}$$

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# Appendix: Value Functions—Households

$$V_L(y;\pi_{L-1},L) = \lambda_y \underbrace{\tilde{F}_{y,L-1}}_{\text{Project matures}}$$

$$+ (1-\lambda_y)\Big\{(1-\lambda_d)^L \mathbb{E}[\underbrace{\alpha V_L(y';\pi_{L-1},L,L)}_{\text{Debt does not mature}}]$$

$$+ \sum_{l=0}^{L-1}(1-\lambda_d)^l \lambda_d \mathbb{E}[\underbrace{\mathbf{1}^l_{rollover} F_{d,l-1} + (1-\mathbf{1}^l_{rollover})(\alpha B_l(y}_{\text{Debt matures}}$$

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# Appendix: Equilibrium Credit Chain Len

Rollover: $F_y(e, L)$ is the solution to the following equa

$$\underbrace{V_L(F_y; \{e, F_y\}, L)}_{\text{Demand of debt}} = \underbrace{e}_{\text{Supply}}$$

## Proposition

*The equilibrium chain length $L^*$ minimizes the rollover risk*

$$L^* = \arg\min_L F_y(e, L),$$

*which is characterized by the following equation uniquely:*

$$0 = \underbrace{\lambda_d (1 - \lambda_d)^{L^*} (1 - H(F_y))(1 - \alpha) e}_{\textit{Marginal benefit of increasing } L} - \underbrace{cH(F_y)(1 -}_{\textit{Marginal cost}}$$

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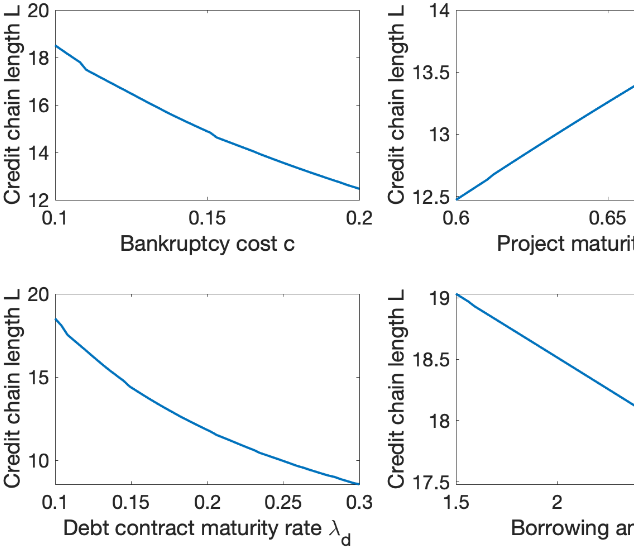
# Special Case: $c = 0$

- When $c = 0$, equilibrium chain length is $\infty$
- Hypothetical structure: $L$ layers, but debt maturit households (layer $L$) and layer $L - 1$) is $1 - (1 - \lambda$
  - Effective debt maturity rate is the same as having
  - Denote its value by $\tilde{V}_L(L)$
- Consider the change in value for households whe

$$V_{L+1}(L+1) - V_L(L)$$

$$= \underbrace{\tilde{V}_L(L) - V_L(L)}_{\text{Benefit of shorter maturity}} + \underbrace{\frac{(1-\lambda_y)\lambda_d m_L H(F_y)(B_L(L}{1-(1-\lambda_y)\alpha(m_{L+1}+H}}_{>0 \text{ net benefit of more layers; illust}}$$

# Comparative Statics of Credit Chain Leng



# Appendix: Model Modification

- Richer setting to endogenize $e$ while maintaining
of the contracts
- Modified timing at period $t$:
  - Before $y_t$ is realised, each household chooses $c_t^D$ t
  - After $y_t$ realises, households can choose to consu
addition, but only receive a utility of $1 - \epsilon$ per ur
  - Minimum departure from baseline yet endogeniz

$$e - c_t^D \to F_d, \quad c_t^N \begin{cases} \to 0 & \text{If debt matures and rol} \\ > 0 & \text{Otherwise} \end{cases}$$

  - In period $t + 1$, households collect money, consur
economy
- No households observe the contracts, due to the c
credit chain

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# Appendix: Optimal Condition of $F_d$

- Consider one shot deviation in $F_{d,t}$ and take as gi $F_{d,t+s} \leq e - c^D_{t+s}$
- There are a continuum of equilibria, we focus on yields the highest welfare

$$(1-\alpha)\,(1-m_L)(1-H(F_y)) - \frac{h(F_y)}{\lambda_y}\sum_{l=0}^{L-1}\lambda_d m_l\left(F_d - \alpha B_l(F_y\right.$$

- Higher $F_d$
  - Benefit: larger value created from differences in i
  - Cost: higher probability of rollover failures

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# Appendix: Welfare Analysis

- Does limiting credit chain length improve welfare increasing borrowing amount $F_d$

$$\underbrace{\frac{dW}{dF_d}}_{>0}\underbrace{\frac{dF_d}{dL}}_{<0}+\frac{dW}{dF_y}\underbrace{\frac{dF_y}{dL}}_{=0}+\underbrace{\frac{dW}{dL}}_{=0}<0$$

- Key friction: layer $L-1$ decides the chain length, takes as given when designing contract;
  - Shorter chain $\Rightarrow$ smaller maturity mismatch $\Rightarrow$ s risks $\Rightarrow$ larger borrowing amount $F_d$
  - Decentralised $F_d$ is too low; entrepreneur/funds by period and cannot commit to future contract
  - Though $F_d$ up, the overall stability increases
- Samuelson (1958)

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# References

**Diamond, Douglas W. and Raghuram G. Rajan**, "Liq
Liquidity Creation, and Financial Fragility: A Theor
*Journal of Political Economy*, 2001, *109* (2), 287–327.