Dynamic Collateralized Finance

Adriano A. Rampini
Duke University, NBER, and CEPR

S. Viswanathan
Duke University

Elwell Research Visitor Ph.D. Lecture
Carlson School of Management, University of Minnesota

April 1, 2015
Aim: Tractable Dynamic Model of Collateralized Financing

- Key friction: **limited enforcement**
  - Enforcement of repayment by borrower limited to tangible assets
  - Implication: **collateral constraints**
    - Promises are not credible unless collateralized
  - Implementation: complete markets in one-period Arrow securities
    - Tractable!

- Key substantive implications
  1. **Capital structure**
     - Determinant: fraction tangible assets required for production
  2. **Risk management**
     - Involves state contingent promises and needs collateral
     - Opportunity cost: forgone investment
     - Severely constrained firms do not hedge
  3. **Leasing and rental markets**
     - Leasing has repossession advantage and permits greater borrowing
     - Severely constrained firms lease

- Useful laboratory to study dynamics of financial constraints
Papers on Dynamic Collateralized Finance

**Corporate risk management, capital structure, and leasing**


**Household insurance**


**Other applications**

(1) Capital Structure

- **Collateral key determinant of capital structure**
  - Enforcement of repayment by borrower limited to tangible assets
  - Nature of assets required for production determines financing

- Key papers: Rampini/Viswanathan (2010, 2013)
(Frictionless) Neoclassical Theory of Investment

- **Environment**
  - Discrete time, infinite horizon
  - Investor/owner

- **Preferences**
  - Investor is risk neutral and discounts at rate $R^{-1} < 1$

- **Endowments**
  - Investor net worth $w \gg 0$, i.e., deep pockets

- **Technology**
  - Capital $k$ invested in current period
  - Payoff ("cash flow") next period $Af(k)$ where parameter $A$ is "total factor productivity" (TFP)
  - Strict concavity $f_k(k) > 0$ and $f_{kk}(k) < 0$; also:
    - $\lim_{k \to 0} f_k(k) = +\infty$; $\lim_{k \to \infty} f_k(k) = 0$
  - Capital is durable and depreciates at rate $\delta$; capital $(1 - \delta)k$ remains next period
Neoclassical Investment: Investor’s Problem

- **Investor’s objective**
  - Maximize “value” – present discounted value of dividends

- **Investor’s problem - recursive formulation**
  - Choose current dividend $d$ and invest capital $k$ to solve

$$\max_{\{d, w', k\}} d + R^{-1}v(w')$$

subject to budget constraints (but no limited liability constraints)

$$w \geq d + k$$

$$Af(k) + k(1 - \delta) \geq w'$$
Neoclassical Investment and User Cost of Capital

- First-order conditions (FOC’s) (multipliers $\mu$ and $R^{-1}\mu'$)

\[
\begin{align*}
1 & = \mu \\
R^{-1} & = R^{-1}\mu' \\
\mu & = R^{-1}\mu'[Af_k(k) + (1 - \delta)]
\end{align*}
\]

- **Investment Euler Equation**
  - Optimal investment/capital $k^*$ solves (combining FOC’s)

\[
1 = R^{-1}[Af_k(k) + (1 - \delta)]
\]

or letting $R \equiv 1 + r$ and rewriting

\[
\underbrace{r + \delta}_{\text{user cost of capital}} = \underbrace{Af_k(k)}_{\text{marginal product of capital}}
\]

- Jorgenson’s (1963) **user cost of capital** (paid at end of period)

\[
u \equiv \underbrace{r}_{\text{interest rate}} + \underbrace{\delta}_{\text{depreciation rate}}
\]
Collateral Constraints as in Rampini/Viswanathan

- Environment with frictions (otherwise as before)

- Two types of agents
  - Owner/borrower
  - Investor/lender

- Borrower ("firm")
  - Preferences: risk neutral, impatient $\beta < R^{-1}$, and subject to limited liability
  - Endowment: borrower has limited funds $w > 0$

- Investor/lender has deep pockets (as before)

- Collateral constraints
  - Need to collateralize loan repayment with tangible assets
Collateral and Limited Enforcement

- **Question:** Why does borrower need to collateralize loans?
  - Enforcement is limited and it has to be incentive compatible for borrower to repay

- **Friction:** Limited enforcement without exclusion
  - Borrower can abscond with all cash flows and fraction $1 - \theta$ of (depreciated) capital
Limited Enforcement Implies Collateral Constraints

- **Enforcement constraint**
  - Ensure that borrower prefers to repay instead of absconding; heuristically,
  
  \[
  v(w') \geq v(Af(k) + (1 - \theta)k(1 - \delta))
  \]

  value when repaying \hspace{1cm} value when defaulting

  and since \( v(\cdot) \) is strictly increasing

  \[
  w' \geq Af(k) + (1 - \theta)k(1 - \delta)
  \]

  and using budget constraint to substitute for \( w' \) given borrowing \( b \)

  \[
  Af(k) + k(1 - \delta) - Rb = w' \geq Af(k) + (1 - \theta)k(1 - \delta)
  \]

  payoff when repaying \hspace{1cm} payoff when defaulting

- **Collateral constraint**
  - Canceling terms and rearranging enforcement constraint we obtain

  \[
  \theta k(1 - \delta) \geq Rb
  \]
Dynamic Financing Problem with Collateral Constraints

- **Firm’s problem**

\[ v(w) \equiv \max_{\{d,k,b,w'\}} d + \beta v(w') \]

subject to budget constraints and collateral constraint

\[ w + b \geq d + k \]
\[ Af(k) + k(1 - \delta) \geq w' + Rb \]
\[ \theta k(1 - \delta) \geq Rb \]

and limited liability \( d \geq 0 \)

- **Net worth next period** \( w' = Af(k) + k(1 - \delta) - Rb \)
First Order Conditions and Investment Euler Equation

- First-order conditions (multipliers $\mu$, $\beta \mu'$, and $\beta \lambda'$)

\[
1 \leq \mu,
\mu = \beta \mu' [Af_k(k) + (1 - \delta)] + \beta \lambda' \theta (1 - \delta),
\]

- Also: Envelope condition $v_w(w') = \mu$

- Investment Euler Equation

\[
1 = \beta \frac{\mu'}{\mu} \frac{Af_k(k) + (1 - \theta)(1 - \delta)}{1 - R^{-1} \theta (1 - \delta)}
\]
“Minimal downpayment” (per unit of capital)

\[ \varphi \equiv 1 - \frac{R^{-1} \theta (1 - \delta)}{\text{PV of } \theta \times \text{resale value of capital}} \]

Capital structure

- In deterministic case, collateral constraints always bind
- Debt per unit of capital
  \[ R^{-1} \theta (1 - \delta) \]
- Internal funds per unit of capital
  \[ \varphi = 1 - R^{-1} \theta (1 - \delta) \]
Collateralizability vs. Tangibility

- **Collateralizability** $\theta$
  - Structures more collateralizable than equipment (composition varies by industry)
  - Financial development may raise $\theta$ and hence leverage

- **Tangibility** $\phi$
  - Includes mainly structures (incl. land) and equipment
  - Suppose tangible assets are collateralizable (but not intangible assets)
  - Fraction tangible assets ($\phi$) needed for production key
    
    $$\phi(\varphi) = 1 - R^{-1} \varphi \theta (1 - \delta)$$

Investment Policy

- **Investment Euler Equation** for dividend paying firm

\[ 1 = \beta A f_k(k) + (1 - \theta)(1 - \delta) \]

- Dividend paying firm: Capital \( \bar{k} \) solves equation above
  - Comparing FOC’s can show \( \bar{k} < k^* \) (underinvestment)

- Non-dividend paying firm: \( k = \frac{1}{\varphi} \) \( w \) (invest all net worth and lever as much as possible)
Dividend Policy

- Threshold policy

- Pay out dividends today \( (d' > 0) \) if \( w \geq \bar{w} \)
  - Can we show threshold is optimal? Suppose pay dividends at \( w \) but not at \( w^+ > w \)
  - At \( w \), invest \( \bar{k} \); if not paying dividends at \( w^+ \), must invest more; can IEE hold?
Value of Internal Funds

- **Value of internal funds** $\mu$ (remember the envelope condition?)
  - Premium on internal funds (unless firm pays dividends) since $\mu \geq 1$

- **User cost** $u(w)$
  - User cost such that $u(w) = R\beta \frac{\mu'}{\mu} A f_k(k)$ where
    $$u(w) \equiv r + \delta + R\beta \frac{\lambda}{\mu} (1 - \theta)(1 - \delta) > u$$
    internal funds require premium
Net Worth Accumulation and Firm Growth

- **Dividend policy and net worth accumulation**
  - Dividend policy is threshold policy
  - For $w \geq \bar{w}$, pay dividends $d = w - \bar{w}$
  - For $w < \bar{w}$, pay no dividends and reinvest everything ("retain all earnings")

- **Investment policy and firm growth**
  - For $w \geq \bar{w}$, keep capital constant at $\bar{k}$ (no growth)
  - For $w < \bar{w}$, invest everything $k = \frac{1}{\varphi}w$ resulting in net worth $w' > w$ next period

- **Firm age**
  - Young firms ($w < \bar{w}$) do not pay dividends, reinvest everything, and grow
  - Mature firms ($w \geq \bar{w}$) pay dividends and do not grow
Conclusions for Capital Structure

- **Tangible assets as collateral**
  - If debt needs to be collateralized, type of assets required determines capital structure

- **Dynamics of financing**
  - Accumulate net worth over time
  - Young firms grow and retain all earnings
  - Mature firms pay dividends and grow less
(2) Corporate Risk Management

- Financial constraints give rationale for corporate risk management
  - If firms’ net worth matters, then firms are as if risk averse
  - Collateral constraints link financing and risk management
  - More constrained firms hedge less and often completely abstain

- Key papers: Rampini/Viswanathan (2010, 2013)
  - Rampini/Sufi/Viswanathan (2014) consider input price risk management
Collateral and Corporate Risk Management

- Why should firms hedge?
  - Firms are risk neutral, why hedge?
  - Financial constraints make firms risk averse
    - Firms’ value function concave in net worth

- Financing vs. risk management trade-off
  - Limited enforcement: Need to collateralize promises to financier and counterparties
  - Collateral constraints link financing and risk management
  - More constrained firms hedge less as financing needs dominate hedging concerns

- Relatedly for households: Financing vs. insurance trade-off
  - “The poor can’t afford insurance”
  - Rampini/Viswanathan (2015)
Environment as before but here with uncertainty

- Uncertainty: Markov chain state $s' \in S$ next period – transition probability $\Pi(s, s')$
- Two types of agents, owner/borrower and investor/lender

Preferences

- Borrower is risk neutral, impatient $\beta$, and subject to limited liability
- Lender is risk neutral and discounts at $R^{-1} \in (\beta, 1)$

Endowments

- Borrower has limited funds $w > 0$
- Lender has deep pockets
Risk Management à la Rampini/Viswanathan (Cont’d)

- **Technology**
  - Capital $k$ invested in current period yields stochastic payoff ("cash flow") in state $s'$ next period
    \[
    A(s')f(k)
    \]
    where $A' \equiv A(s')$ is realized “total factor productivity” (TFP)
  - Strict concavity $f_k(k) > 0$; $f_{kk}(k) < 0$; also: $\lim_{k \to 0} f_k(k) = +\infty$; $\lim_{k \to \infty} f_k(k) = 0$
  - Capital is durable and depreciates at rate $\delta$; capital $k(1 - \delta)$ remains next period

- **Collateral constraints**
  - Need to collateralize all promises to pay with tangible assets
  - Can pledge up to fraction $\theta < 1$ of value of depreciated capital
Firm’s Debt Capacity Use Problem

- **State contingent borrowing** $b' \equiv b(s')$

- Collateral constraint for state contingent borrowing $b'$
  \[
  \theta k(1 - \delta) \geq R b'
  \]

- **Firm’s debt capacity use problem**
  \[
  \max \{d, w', k, b'\} \quad \text{subject to budget constraints and collateral constraints, } \forall s' \in S,
  \]
  \[
  w + R^{-1} \sum_{s' \in S} \Pi(s, s') b' \geq d + k
  \]
  \[
  A' f(k) + k(1 - \delta) \geq R b' + w'
  \]
  \[
  \theta k(1 - \delta) \geq R b'
  \]
  and limited liability $d \geq 0$
Corporate Risk Management – Optimality Conditions

- First-order conditions (multipliers $\mu$, $\Pi(s, s') \beta \mu(s')$, and $\Pi(s, s') \beta \lambda(s')$)

\[ 1 \leq \mu, \quad v_w(w', s') = \mu' \]

\[ \varphi \mu = \sum_{s' \in S} \Pi(s, s') \beta \mu'[A' f_k(k) + (1 - \theta)(1 - \delta)], \quad \mu = \beta \mu' R + \beta \lambda R \]

- Investment Euler equation

\[ 1 = \sum_{s' \in S} \Pi(s, s') \beta \frac{\mu'}{\mu} A' f_k(k) + (1 - \theta)(1 - \delta) \]

- Firms are effectively risk averse about net worth
Corporate Risk Management Problem

- **Equivalent risk management formulation**
  - Collateral constraint for state contingent borrowing $b'$
    \[ \theta k(1 - \delta) \geq Rb' \]
  - Equivalently, borrow as much as possible and hedge
    \[ h' \equiv \theta k(1 - \delta) - Rb' \geq 0 \]

- **Firm’s risk management problem**

  \[
  \max_{\{d, w', k, h'\}} \quad d_0 + \beta \sum_{s' \in S} \Pi(s, s')v(w', s')
  \]

  subject to budget constraints and **short sale constraints**, $\forall s' \in S$,

  \[
  w \geq d + \varphi k + R^{-1} \sum_{s' \in S} \Pi(s, s')h' \]

  \[
  A'f(k) + (1 - \theta)k(1 - \delta) + h' \geq w'
  \]

  \[
  h' \geq 0
  \]

  and limited liability $d \geq 0$
Financing vs. Risk Management Trade-off

- **Investment Euler equation**

\[
1 = \sum_{s' \in S} \Pi(s, s') \beta \frac{\mu'}{\mu} \frac{A' f_k(k)}{\varphi} + (1 - \theta)(1 - \delta) \\
\geq \Pi(s, s') \beta \frac{\mu'}{\mu} \frac{A' f_k(k)}{\varphi} + (1 - \theta)(1 - \delta)
\]

- As \( w \to 0 \), capital \( k \to 0 \) and marginal product \( f_k(k) \to \infty \)
- Therefore, marginal value of net worth in state \( s' \) (relative to current period) \( \mu'/\mu \to 0 \)
- Using first order condition for hedging

\[
\lambda'/\mu = (\beta R)^{-1} - \mu'/\mu > 0
\]

so severely constrained firms do not hedge at all

- **Financing risk management trade-off**
  - Hedging uses up net worth which is better used to purchase additional capital
  - IID case: If firms hedge, they hedge states with low net worth due to low cash flows
Why Was This Not Previously Recognized?

  - 5 reasons provided (beyond “transactions costs”)
    - (i) market power; (ii) serial correlation of profits; (iii) aggregate risk;
      (iv) asymmetric information; (v) incentives
  - Fact that hedging uses up net worth is not listed
    - That said, Holmström/Tirole (2000) come close

- **No financing risk management trade-off in previous models**
  - Models consider risk management using frictionless markets
    - Without imposing same frictions on financing and hedging, no trade-off
  - Models have no financing in first period where firms hedge
    - Without investment which requires financing, no trade-off

- **Intuitive, but counterfactual, prediction: More constrained firms hedge more**
  - Froot/Scharfstein/Stein (1993)

- In practice, more constrained (and smaller) firms hedge less!
Conclusions for Corporate Risk Management

- Rationale for **corporate risk management**
  - Financial constraints make firms as if risk averse

- Trade-off between financing and risk management
  - Promises to financiers and hedging counterparties need to be collateralized
  - Severely constrained firms hedge less or not at all
    - ... both in theory and in practice
  - Such firms may be more susceptible to downturns
Leasing and Rental Markets

- Leasing has repossession advantage and permits greater borrowing
- Severely constrained firms (and households) lease
- Key papers: Rampini/Viswanathan (2013); Eisfeldt/Rampini (2009)
Financing Subject to Collateral Constraints

- Environment with collateral constraints but firms can lease
  - Three types of agents, owner/borrower, investor/lender, and lessor
  - Borrower is risk neutral, impatient $\beta < R^{-1}$, and subject to limited liability
  - Borrower has limited funds $w > 0$
  - Lender and lessor have deep pockets

- Borrowing subject to collateral constraints
  - Need to collateralize promises to pay with tangible assets (due to limited enforcement)
  - Promised repayment $\leq \theta \times$ resale value of tangible assets
Leasing as in Eisfeldt/Rampini and Rampini/Viswanathan

- **Leasing**: Borrower can rent capital

- **Repossession advantage**
  - Borrower cannot abscond with leased capital
  - In practice, repossession of rented capital easier than foreclosure on secured loan
  - Leasing allows borrower to borrow full resale value, not just fraction $\theta$

- **Monitoring cost** $m$ (per unit of capital)
  - Lessor needs to monitor to prevent abuse
  - Why? – Leasing separates ownership and control

- **User cost of leased capital** (assuming lessors, like lenders, discount at $R^{-1}$)
  \[ u_l \equiv r + \delta + m \]
  
  needs to be paid in advance, i.e., at time 0
Firm’s Problem with Leasing and Secured Lending

**Firm’s problem with leasing** \((k_o \text{ owned capital}; \ k_l \text{ leased capital})\)

\[
\max_{\{d,w',k_o,k_l,b\}} \quad d + \beta v(w')
\]

subject to budget constraints and collateral constraint

\[
\begin{align*}
w + b & \geq d + k_o + R^{-1} u_l k_l \\
Af(k_o + k_l) + k_o(1 - \delta) & \geq Rb + w'
\end{align*}
\]

\[
\theta k_o (1 - \delta) \geq Rb
\]

and non-negativity constraints \(k_o, k_l \geq 0\), as well as limited liability \(d \geq 0\)
Leasing and Secured Lending – Optimality Conditions

- First-order conditions (multipliers $\mu$, $\beta \mu'$, and $\beta \lambda$; let $k \equiv k_o + k_l$)

- As before,

$$1 \leq \mu, \quad v_w(w') = \mu', \quad \mu = \beta \mu' R + \beta \lambda R$$

and almost as before (except inequality as borrower might not own any assets)

$$\mu \geq \beta \mu' [Af_k(k) + (1-\delta)] + \beta \lambda \theta (1-\delta) \quad \Leftrightarrow \quad u(w) \geq R \beta \mu^{-1} Af_k(k)$$

and finally new

$$R^{-1} u_l \mu \geq \beta \mu' Af_k(k) \quad \Leftrightarrow \quad u_l \geq R \beta \mu^{-1} Af_k(k)$$
Lease or Buy?

- Lease if $u_l < u(w)$ and buy otherwise (“choose capital with lower user cost”)

- Recall:

$$u_l = r + \delta + m$$

monitoring cost

and

$$u(w) = r + \delta + \frac{\beta R \lambda}{\mu(1 - \theta)(1 - \delta)}$$

premium on internal funds required
Leasing as Costly, Highly Collateralized Financing

- **Incremental cash flows of buying vs. leasing**

  Time
  Buying (secured loan)  \[ 0 = 1 - R^{-1} \theta (1 - \delta) \]
  Leasing  \[ R^{-1} u_l \]
  Diff buying - leasing  \[ = \phi - R^{-1} u_l = (1 - \theta)(1 - \delta) \]
  extra funds required up front  extra amount recovered

- **Implicit interest rate on additional amount borrowed when leasing**

  \[ R_l \equiv \frac{(1 - \theta)(1 - \delta)}{\phi - R^{-1} u_l} = R \frac{1}{1 - \frac{m}{(1 - \theta)(1 - \delta)}} > R \]

- Leasing is costly financing since  \[ R_l > R \]
Lease or Buy?

- **Implicit “down payment” when leasing**

\[
R^{-1} u_l = 1 - R^{-1} \theta (1 - \delta) - R_l^{-1} (1 - \theta) (1 - \delta)
\]

- **Who leases?**
  - Severely constrained firms do!
  - As \( w \to 0, k \to 0 \) and \( f_k(k) \to +\infty \); hence, using FOCs, \( \mu' / \mu \to 0 \) and

\[
\frac{\beta R \lambda}{\mu} = 1 - \beta R \mu' / \mu \to 1 \quad \Rightarrow \quad u(w) \to r + \delta + (1 - \theta)(1 - \delta)
\]

- Assuming \( (1 - \theta)(1 - \delta) > m \), borrowers with sufficiently low \( w \) lease all their capital!
Conclusions for Leasing and Rental Markets

- Renting capital facilitates repossession

- Lessor is financier but retains ownership

- Leasing permits greater leverage which is beneficial for severely constrained firms