"How Costly is External Financing? Evidence from a Structural Estimation"
Christopher A. Hennessy and Toni M. Whited (2007)
Journal of Finance

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Motivation

- Modigliani-Miller Irrelevance Theorem (1958, 1963)

  In frictionless world, financing decisions like capital structure (debt vs. equity), payout policy, cash holding, etc. do not matter.

- Why? No arbitrage

- MM assumes there are no financial friction:
  - Perfect and complete capital markets
  - No taxes
  - Bankruptcy is not costly
  - Capital structure does not affect investment policy or cash flows
  - Symmetric information

Hennessy and Whited (2007)

- HW (2007) formulate a dynamic structural model of optimal financial and investment policy for a firm facing
  - Corporate and personal taxes
  - Bankruptcy costs
  - Costs to issue external equity
- HW (2007) estimate parameters describing production technology and financial frictions using simulated method of moments (SMM)

Environment - Production and Debt

- Estimated parameters in red
- Firm produces with k capital
- Productivity follows discretized AR(1) process in logs:

$$\ln z' = \rho \ln z + \sigma_\varepsilon \varepsilon$$

where $\varepsilon \sim N(0,1)$. Tauchen discretization $\implies Q(z,z')$ transition probability and finite min/max

- Operating profits are zk^α where $\alpha \in (0,1)$
- Firm also has b net debt
  - $b > 0$ is one-period defaultable debt with interest rate $\tilde{r}$ that depends on k, b, and z (not contingent on z')
  - $b \leq 0$ is cash that returns risk-free rate r
- Firm defaults on debt if continuation value is negative

Environment - Taxes and Equity Issuance

- Personal tax rate $\tau_i \implies$ firms discounts using $\frac{1}{1+r(1-\tau_i)}$
- Corporate taxable income is operating profits net of depreciation and interest:

$$y \equiv zk^{\alpha} - \delta k - \tilde{r}(k, b, z^{-})b$$

- Corporate tax schedule has "kink" around zero

$$T^C(x) \equiv \begin{cases} \tau_c^+ x, & \text{if } x > 0 \\ \tau_c^- x, & \text{if } x \leq 0 \end{cases}$$

- Shareholder tax liability on dividend:

$$T^d(X) = \int_0^X \tau_d(x)dx \text{ where } \tau_d(x) \equiv \bar{\tau}_d * [1 - e^{-\phi x}]$$

- Firm pays fixed, linear, and quadratic costs for external equity issuance:

$$\Lambda(x) \equiv \begin{cases} \lambda_0 + \lambda_1 x + \lambda_2 x^2, & \text{if } x > 0 \\ 0, & \text{if } x \leq 0 \end{cases}$$

"Naive" Way to Write Firm Value Function

$$V(k,b,z,z^-) = \max_{(k',b')} \Bigg\{ \underbrace{w+b'-k'}_{\text{cash dividend } (+) \text{ or equity issuance } (-)} - \underbrace{T^d(w+b'-k')}_{\text{taxes on cash dividend}} - \underbrace{\Lambda(-(w+b'-k'))}_{\text{equity issuance cost}}$$
$$+ \frac{1}{1+r(1-\tau_i)} E\Big[\underbrace{\max\{V(k',b',z',z),0\}}_{\text{if } V(\cdot) \text{ is } (-) \implies \text{ default}}\Big]\Bigg\}$$

where

$$\underbrace{y}_{\text{taxable corporate income}} \equiv \underbrace{zk^\alpha}_{\text{operating profits}} - \underbrace{\delta k}_{\text{depreciation}} - \underbrace{\tilde{r}(k,b,z^-)b}_{\text{interest on debt}}$$

$$\underbrace{w}_{\text{realized net worth}} \equiv \underbrace{y - T^C(y)}_{\text{after-tax corporate income}} + \underbrace{k}_{\text{capital}} - \underbrace{b}_{\text{debt principal}}$$

$$\underbrace{T^C(x)}_{\text{corporate income tax bill}} \equiv \begin{cases} \tau_c^+ x, & \text{if } x > 0 \\ \tau_c^- x, & \text{if } x \leq 0 \end{cases}$$

$$\underbrace{T^d(x)}_{\text{taxes on cash dividend}} \equiv \begin{cases} \frac{\bar{\tau}_d}{\phi}(\phi x + e^{-\phi x} - 1), & \text{if } x > 0 \\ 0, & \text{if } x \leq 0 \end{cases}$$

$$\underbrace{\Lambda(x)}_{\text{equity issuance cost}} \equiv \begin{cases} \lambda_0 + \lambda_1 x + \lambda_2 x^2, & \text{if } x > 0 \\ 0, & \text{if } x \leq 0 \end{cases}$$

Smarter Way to Write Firm Value Function

$$V(w,z) = \max_{(k',b')} \Bigg\{ \underbrace{w + b' - k'}_{\text{cash dividend } (+) \text{ or equity issuance } (-)} - \underbrace{T^d(w + b' - k')}_{\text{taxes on cash dividend}} - \underbrace{\Lambda(-(w + b' - k'))}_{\text{equity issuance cost}}$$

$$+ \frac{1}{1 + r(1 - \tau_i)} E\Big[\underbrace{\max\{V(w', z'), 0\}}_{\text{if } V \text{ is } (-) \text{ can default}} \Big] \Bigg\}$$

where

$$\underbrace{y'}_{\text{taxable corporate income}} \equiv \underbrace{z'(k')^{\alpha}}_{\text{operating profits}} - \underbrace{\delta k'}_{\text{depreciation}} - \underbrace{\tilde{r}(k', b', z)b'}_{\text{interest on debt}}$$

$$\underbrace{w'}_{\text{realized net worth}} \equiv \underbrace{y' - T^C(y')}_{\text{after-tax corporate income}} + \underbrace{k'}_{\text{capital}} - \underbrace{b'}_{\text{debt principal}}$$

Default and Interest Rates

- Firm defaults on debt if w below z'-specific threshold:

$$\underline{w}(z') = V^{-1}(0, z') < 0 \implies z_d(k', b', z) \text{ threshold}$$

- If firm defaults, outside investor gets recovery value

$$R(k', z') = \underbrace{(1-\xi)(1-\delta)k'}_{\text{depreciated capital net of deadweight bankruptcy cost}} + \underbrace{z'(k')^\alpha}_{\text{operating profit}}$$
$$- \underbrace{T_c(z'(k')^\alpha - \delta k')}_{\text{corporate tax bill}} - \underbrace{\underline{w}(z')}_{\text{going-concern}}$$

- Interest rates on debt determined by zero-profit condition for outside investor

$$\underbrace{(1 + r(1-\tau_i))b'}_{\text{risk-free investment}} = \underbrace{(1 + (1-\tau_i)\tilde{r}(k', b', z))b' \int_{z_d(k',b',z)}^{\bar{z}} Q(z, dz')}_{\text{return on non-defaulted debt}}$$
$$+ \underbrace{\int_{\underline{z}}^{z_d(k',b',z)} R(k', z') Q(z, dz')}_{\text{return on defaulted debt}}$$

Computation

- No closed form solution $\implies$ solve numerically
- Computational strategy:
  - Guess $\tilde{r}(k', b', z) = r$
  - Solve V with value function iteration
  - Compute $z_d(k', b', z)$
  - Update $\tilde{r}(k', b', z)$ using zero-profit condition
  - Repeat until convergence

Computation Issues

1. Discount bond prices are bounded whereas interest rates are not:

$$V(w,z) = \max_{(k',b')} \Bigg\{ \underbrace{w + b'q(k',b',z) - k'}_{\text{dividend if } (+) \text{ or equity issuance if } (-)} - \underbrace{T^d(w + b'q(k',b',z) - k')}_{\text{taxes on dividend}}$$

$$- \underbrace{\Lambda(-(w + b'q(k',b',z) - k'))}_{\text{equity issuance cost}} + \frac{1}{1 + r(1-\tau_i)} E\Big[\underbrace{\max\{V(w',z'),0\}}_{\text{if } V \text{ is } (-)\text{, default}} |z \Big] \Bigg\}$$

$$\text{where} \quad \underbrace{y'}_{\text{taxable income}} \equiv \underbrace{z'(k')^\alpha}_{\text{operating profits}} - \underbrace{\delta k'}_{\text{depreciation}} - \underbrace{(1 - q(k',b',z))b'}_{\text{interest on debt}}$$

$$\underbrace{w'}_{\text{realized net worth}} \equiv \underbrace{y' - T^C(y')}_{\text{after-tax corporate income}} + \underbrace{k'}_{\text{capital}} - \underbrace{q(k',b',z)b'}_{\text{debt principal}}$$

2. What is the w grid?
   - HW (2007) are specific about z, b, k grids, but quiet about the w grid
   - My solution: Loop over z, b, k grids and solve w for $q = 0$ and $q = 1/(1+r)$, then linear interpolate between min and max

3. No contraction mapping for bond prices $\implies$ update q guess slowly

External Parameters from Related Literature

Parameter	Value
$\bar{\tau}_d$	0.12
τ_i	0.29
τ_c^+	0.40
τ_c^-	0.20
r	0.025
δ	0.15

Moments Selection

- Production function curvature α
  - Hello
- Fixed, linear, and quadratic external equity issuance costs $\lambda_0, \lambda_1, \lambda_2$
  - Hello
- Bankruptcy deadweight cost ξ
  - Hello
- Shareholder tax liability curvature ϕ
  - Hello
- Productivity shock variance and productivity persistence σ_ϵ, ρ
  - Hello

Moments and Estimated Parameters

Parameter	Estimates (HW)	SE (HW)
α	0.627	(0.219)
λ_0	0.598	(0.233)
λ_1	0.091	(0.026)
λ_2	0.0004	(0.0008)
ξ	0.104	(0.059)
ϕ	0.732	(0.844)
σ_ε	0.118	(0.042)
ρ	0.684	(0.349)

	Data (HW)	Simulated (HW)	Simulated (AHV)
Mean Equity Issuance/Assets	0.0892	0.0963	0.0406
Var of Equity Issuance/Assets	0.0911	0.0847	0.0005
Var of Investment/Assets	0.0068	0.0117	0.0047
Freq of Equity Issuance	0.1751	0.2305	1.0000
Payout Ratio	0.2226	0.2026	0.0000
Freq of Negative Debt	0.3189	0.3258	1.0000
Var of Dividends	0.0013	0.0037	0.0000
Mean Debt-Assets Ratio (Net of Cash)	0.1204	0.1104	-1.0333
Cov of Investment and Equity Issuance	0.0004	0.0005	0.0005
Cov of Investment and Leverage	-0.0018	-0.0025	0.0017
Serial Cor of Income/Assets	0.5121	0.5661	0.6666
SD of Shock to Income/Assets	0.1185	0.1057	0.0326