RECENT DEVELOPMENTS IN DYNAMIC CAPITAL STRUCTURE

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"Derivatives and Volatility 2017: The State of the Art"
Salomon Center at NYU Stern School of Business

April 27, 2017

* The authors thank Matt Olfat for excellent research assistance,
and colleagues at Berkeley, BU, and NYU for instructive discussions

Early "barrier" structural models of debt and capital structure

1. ***Debt maturity is exogenously given (or infinite):***
   - But choice of *optimal maturity is a key part of financial choice*: affects default, optimal leverage, and the extent of agency costs
2. ***Debt has perfect liquidity***
   - But Huang & Huang (2003, 2012) noted that *liquidity costs* needed to explain bond spreads (but didn't explicitly introduce; a residual)
   - Agency costs may also explain spreads; costs increase with maturity
3. ***Dynamics: assumed both***
   - Full roll-over of short term debt with constant maturity; *and* prior debt must be fully retired if additional debt issued. Relaxed by
     - Hackbarth & Mauer, "Optimal Priority, Capital Structure, and Investment (2012)
     - Admati et al on "The Leverage Ratchet Effect" (ADHP, 2013-16),
     - Dangl & Zechner "Debt Maturity and Dynamics of Leverage (DZ, 2016),
     - DeMarzo & He "Leverage Dynamics without Commitment" (DH, 2016)

OUR GOALS:

- Develop a model with (almost) closed form solutions that includes
  - A simple jump-diffusion process for firm value
  - Endogenous maturity choice as well as leverage
  - An illiquidity (or agency cost) premium for corporate debt
  - Extension of static model to dynamic (preliminary)

  Earlier models have introduced subsets of these aspects but not all, ***particularly illiquidity which affects optimal maturity***

  - *Extension of model I presented in Princeton Lectures in Finance (2006)* *https://www.princeton.edu/bcf/newsevents/events/lectures-in-finance/*

- Use this model to consider
  - **Optimal leverage *and* debt maturity choice**, and their joint sensitivity to exogenous parameters
  - **Debt dynamics** (particularly "Ratcheting" of Admati et al.) and interaction of original maturity choice and restructuring levels

1. A simple risk-neutral jump-diffusion process for firm value

Value of after-tax unlevered cash flows follows a simple Jump-Diffusion process *with "rare" disaster* (e.g. Barro (2006)):

$$dV_t = \quad \mu V_t dt + \sigma V_t dZ_t \quad \textit{if no jump at or prior to } t$$

$$= -kV_{t-} \qquad \textit{if jump at } t_- \textit{ and firm defaults}$$

- Diffusion is standard log diffusion process with constant mean, risk
- Jump occurs with constant intensity λ (≈ 0.60%; physical ≈ 0.24%)
- Later assume k = 1 ("total disaster") to simplify math
- Implies $\mu = (r - \delta + \lambda k)$, where payouts (interest + dividends) = δV_t
- Same as simplest case in Merton (1976)

We calibrate λ to match Moody's default statistics 1970-2010 and recovery rates on bonds; also calibrate to 1920-2011 default rates

➢ The jump process to default is similar to a "reduced form" approach
--but there's also diffusion to an endogenous default barrier

Main role of jump here: short term rates, defaults don't go to zero

2. Finite average maturity debt

We use the standard "exponentially declining" debt model (Leland (1994))

- Firm issues debt with principal P and a coupon rate C, infinite life
  - At initiation (t = 0), C set so debt sells at par: $D\big(V(0)\big) = P$

- A constant fraction m of outstanding debt principal is retired through time (e.g. through a sinking fund)
  - Debt extant at t = 0 receives cash flow $e^{-mt}(C + mP)dt$ at t
  - $\boxed{\text{Average life of debt } T = 1/m}$ (half-life = 0.69/m)
  - Retired debt is fully replaced continuously, but new debt sold at then-current market value $D(V(t))$ -- *Dangl-Zechner* modifies

- Default occurs when $V(t)$ falls to V_B, set by $\frac{dE(V)}{dV}|_{V=V_B} = 0$
  - In default, debt receives $(1-\alpha)V_B$
  - V_B depends both on leverage AND maturity

- *A Problem*: In virtually all studies, m = 0 optimizes firm value
  - Infinite life debt minimizes debt service, default

3. (Il)liquidity of debt: The "Credit Spread Puzzle"

- Huang & Huang (2003; 2012): Historical default rates and risk premia cannot account for the size of spreads
  - Confirmed by Longstaff, Mithal, & Neis (2005) who estimate a "Non-Default Component of spread" across ratings of 50-72 bps
  - Strongly related to illiquidity measures.
  - Strong maturity effect: increases 3 bps/yr of maturity
  - Spread could also reflect agency costs: increase with debt maturity (e.g. Myers (1977), Leland & Toft (1996), Hackbarth & Mauer (2012))

- We introduce a simple additional "*liquidity discount*" to corporate bonds: their payouts are discounted at $r_f + h$
  - $h = h_0 + h_1 * T$ (T = average debt maturity)
  - Higher discount rate disadvantages longer-term debt
  - Optimal maturity balances this disadvantage with lower debt service advantage (lower endogenous default barrier)

Calibration

r	**Riskfree Rate**	5.00%	(HH)	α	**Default Costs**	30.0%	(AK; Glover)
δ	**Payout Rate**	4.00%	(HH)	τ	**(Net) Tax Rate**	20.0%	
σ	**Asset Std Dev**	24.00%	(FS)		**Debt Issuance Costs**	1.00%	
λ	**Jump Risk**	0.60%	*		**Debt Rollover Costs**	0.25%	
	Q-Diffusion Return	1.60%			**Liquidity Discount (bps)**	40 + 3*T	(LMN)
	Risk Premium on Assets	4.00%	(based on 6% equity risk premium, 33% leverage)				
		*RN rate, calibrated to default. Physical = RN/2.5 (Driessen 2004) = 0.24%					

HH:Huang/Huang (2012); FS:Feldhutter/Schaefer (2016); AK:Andrade/Kaplan (1998);Glover (2016); LMN: Longstaff/Mithal/Neis (2005)

Model Outputs

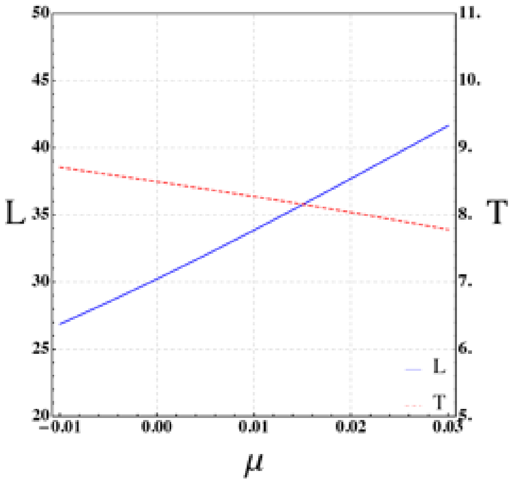
(Closed form solutions for debt and equity values, simple search for optimal leverage and maturity—easily implemented in Excel! Model on Conference site)

Optimal Leverage	**34%**		(vs. median SF 36%; HH = 43%)						
Average Maturity (T = 1/m)	**8.3**	yrs	Half life =	5.74 yrs	≈ 11.5 yr	regular debt maturity (Choi et al. 2016)			
Yield Spread	159	bps	(vs. median BBB spread SF= 148bps; HH = 158-194)						
Recovery Rate	51%		(vs. HH 51.3%; SF 37%)						
	Historical vs. Predicted Default Rates - Moody's 1970-2010								
Years after Issuance	**1**	**2**	**3**	**5**	**7**	**10**	**12**	**15**	**20**
Historical Default Probs	0.18%	0.51%	0.93%	1.95%	3.03%	4.90%	6.37%	8.85%	12.41%
Model Default Probs	0.24%	0.48%	0.76%	1.65%	2.97%	5.33%	6.93%	9.23%	12.63%

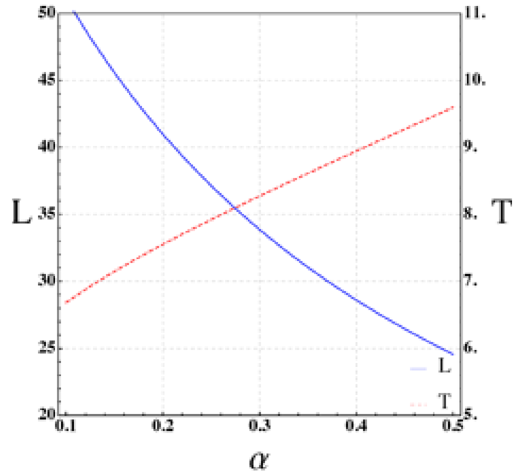
(See Appendix for calibration to Moody's 1920-2011 Default rates)

COMPARATIVE STATICS: Leverage L % in blue; Maturity T yrs. in red)

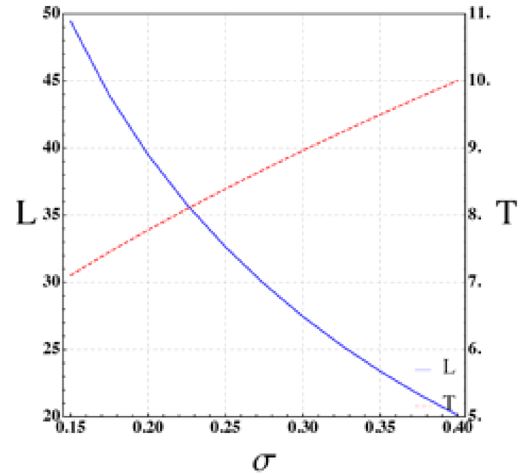
Growth Rate μ



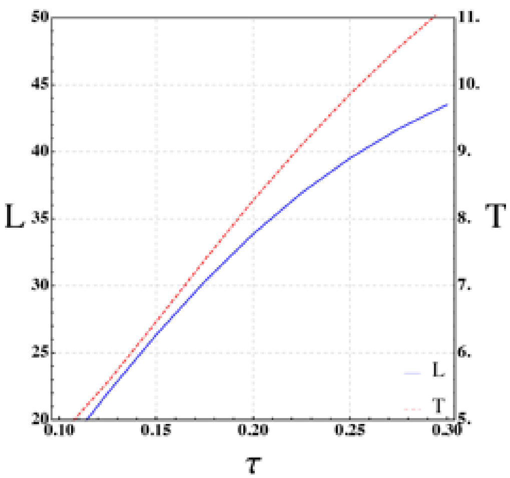
Default Costs α



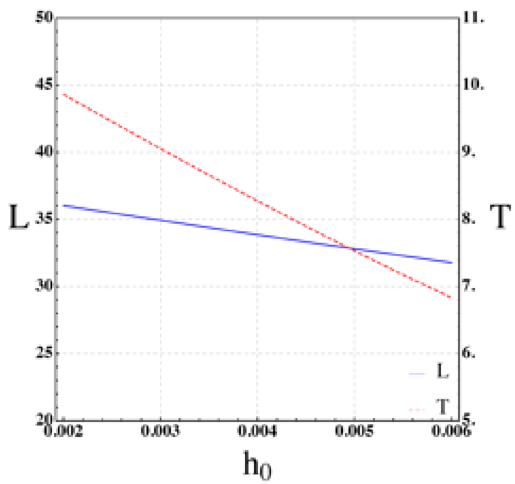
Asset Riskiness σ



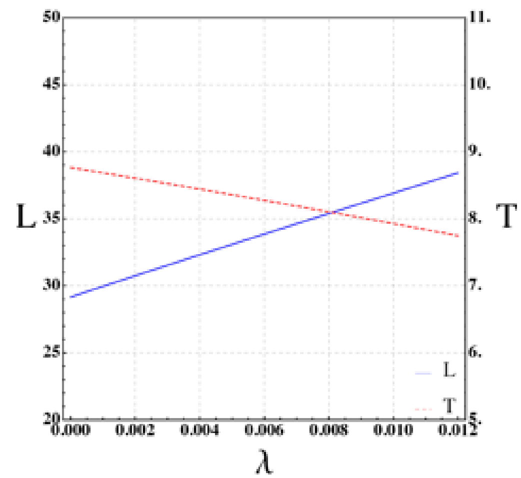
Tax Rate τ



Liquidity/Agency Cost h_0



Jump Intensity λ



Application 1: The Capital Structure of Growth Firms

Contention: ***Growth firms (high MB ratio) have less leverage, shorter maturity***

- Smith and Watts (SW, 1992): regress leverage on MB, negative relation
- Barclay & Smith (BS, 1995): regress maturity on MB, negative relation
  - But both studies consider M/B, which reflects endogenous leverage
  - Their independent variables don't include risk σ or default costs α

…MB is not a direct input in our model--it reflects endogenous firm value M

How do we describe a "growth firm"? Any or all of the below:

- ***High drift*** μ**:** more investment opportunities, less payouts
  - Shorter maturity but higher leverage
- ***High default costs ("alpha")***: lost growth opportunities (high MB)
  - Longer maturity but lower leverage
  - Could also be related to **(low) asset tangibility** (Rampini & Viswanawathan (2013)):
    --Leverage decreases with fewer tangible assets

- ***High risk ("sigma")***
  - Longer maturity but lower leverage
- ***Low effective tax rates ("tau")***
  - Shorter maturity and lower leverage
- ***Large Illiquidity or agency costs ("h")***
  - Shorter maturity and lower leverage

	Base		New	Optimal Leverage (%)	Average (1/m) Maturity (yrs)	Yield Spread	5-yr Default Probability
			BASE CASE:	33.9%	8.3	159	1.65%
Growth Rate (Mu)	1.00%	==>	4.00%	45.6%	7.5	165	2.80%
Default Costs (Alpha)	30.00%	==>	80.00%	16.6%	11.5	152	1.20%
Asset Risk (Sigma)	24.00%	==>	50.00%	15.3%	10.9	295	5.23%
Effective Tax Rate (tau)	20.00%	==>	5.00%	6.3%	3.5	111	1.19%
Total liquidity discount (h), bps	65.00	==>	100.00	29.5%	5.3	180	1.50%
			ALL OF THE ABOVE	0.00%	-	-	-

Application 2: The "Ratchet Effect" Admati et al. (2016)

CLAIM: After initial debt is issued to maximize total firm value,

- Equity holders will *never* find it advantageous to reduce leverage
  - Debt reduction decreases equity value—even when it increases firm value
  - Debt increases help equity by devaluing older debt—even with absolute priority
  - Agency problem similar to "asset substitution", where greater volatility helps equity at expense of debtholders and firm value *if no precommitment*

- Leverage will therefore increase monotonically--eventually to point where *tax benefits are entirely exhausted*
  - **Only taxes determine ultimate leverage, no default cost tradeoff**
  - Generalizes a local result in Leland (1994), who also suggests that ***debt can be reduced only by a re-negotiation of initial-debt terms***
  - Unlike Fischer, Heinkel, Zechner (1989) and Goldstein Ju Leland (2001), they do not require current debt must be fully retired before new issue

ADHP model quite simplistic:

- Jump-only process, no endogenous default, zero recovery in bankruptcy
- Nonetheless, we can examine their conclusions by using our model (v. 1) (assuming absolute priority of prior debt; no foresight)

ROUNDS	Optimal Leverage	% Equity Increase	Total Firm Value	Coupon	Principal	Average Maturity T	Total Debt Principal	Credit Spread (bps)
1	33.85	3.356	103.36	2.34	34.98	8.64	34.98	169
2	37.74	0.055	103.32	0.31	4.03	27.81	39.02	262
3	41.13	0.048	103.22	0.28	3.53	26.97	42.54	282
4	44.13	0.043	103.09	0.25	3.11	26.02	45.66	301
5	46.78	0.038	102.93	0.23	2.75	25.03	48.41	320
6	49.11	0.033	102.75	0.20	2.42	24.05	50.82	338
7	51.14	0.028	102.56	0.18	2.11	23.12	52.93	356
8	52.89	0.023	102.37	0.16	1.82	22.26	54.75	372
9	54.40	0.019	102.19	0.14	1.56	21.49	56.31	387
10	55.67	0.015	102.02	0.12	1.33	20.80	57.64	400

LOOKS CONCERNING! BUT NOTE AFTER INITIAL DEBT ISSUANCE:

- New rounds create tiny increases in equity value (5.5 down to 1.5 bps); and have increasing spreads (likely to be rated lower than original debt)
- Very long maturities: calibrated to half-life, bond maturities ≈ 30-40 yrs

- **More realistically, limit T max to 15** (regular bond maturity ≈ 20 yrs)

ROUNDS	Optimal Leverage	% Equity Increase	Total Firm Value	Coupon	Principal	Average Maturity T	Total Debt Principal	Credit Spread (bps)
1	33.85	3.356	103.36	2.34	34.98	8.64	34.98	169
2	36.80	0.038	103.32	0.23	3.07	15.00	38.05	245
3	38.56	0.014	103.27	0.14	1.82	15.00	39.87	256

- **Perhaps more realistically, limit T to original debt T** (maturity ≈ 12 yrs)

ROUNDS	Optimal Leverage	% Equity Increase	Total Firm Value	Coupon	Principal	Average Maturity T	Total Debt Principal	Credit Spread (bps)
1	33.85	3.356	103.36	2.34	34.98	8.64	34.98	169
2	34.94	0.006	103.33	0.08	1.13	8.86	36.11	217

- ***Even one subsequent issue yields less than 1 bp increase in equity value!***

  (Even less new debt if foresight of subsequent rounds)

CONCLUSIONS

Conclusions re Ratcheting: In the context of our model

- ADHP correct that firm will never want to reduce debt
  - But see Dangl-Zechner (2016), who argue **short term debt precommits to debt reduction** through repayment of principal
  - It may not be optimal for firm to fully roll over expiring debt
- Given miniscule equity gains (3.8 *bps or less*) and likely lower bond ratings, *the ADHP concern of* ***additional debt issuance seems very unlikely***

More Generally

- We have developed a model that allows the ***joint determination of leverage and maturity***
  - Leverage affects maturity, and vice-versa
  - Considering either in isolation can create misleading results

Appendix: Fitting the Model to 1920-2011 Default Data

Feldhutter & Schaefer (2016): When fitted to *long-term* default data, structural models don't need jumps, liquidity discounts to match spreads. No "Credit Puzzle"!

- But calibration with Black-Cox model ➔ T = ∞. No optimization
- Need jumps to explain short term default, spreads

Our model can match 1920-2011 data with minor Input Changes

(i) Increase jump frequency: λ = 0.006 ➔ 0.011 (still "rare")

(ii) Increase liquidity discount: $h = 40+3*T$ ➔ $h = 70+3*T$ bps

(iii) All other inputs remain same **(σ, δ, α)**

- **Optimal Leverage ≈ constant: 34%** (Graham et al. 2012 w/preferred stock)
- **Optimal Maturity falls from 8.3 years to 5.9 years** (Choi et al. 2016)

Default Frequencies now match 1920-2011 data quite well

	Historical vs. Predicted Default Rates - Moody's 1920-2011								
Years after Issuance	**1**	**2**	**3**	**5**	**7**	**10**	**12**	**15**	**20**
Historical Default Probs	0.29%	0.86%	1.55%	3.09%	4.63%	7.03%	8.62%	10.81%	13.63%
Model Default Probs	0.44%	0.88%	1.36%	2.63%	4.24%	6.88%	8.60%	11.03%	14.63%