Structural Models of the Firm: An Underview

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The Prize Jury

Those whose work inspired mine

Steve Ross and …Black, Merton, Brennan, and Schwartz

I'm calling this an **"underview."** The number of publications in the field since 1994, and the time available, prevents any attempt at an "overview".

I apologize in advance for omitting mention of many excellent papers!

What motivates this literature?

- Using valuation tools from continuous-time asset pricing to study basic questions of corporate finance (not just capital structure)!

  - Much of corporate finance theory centers on firms ***maximizing (equity) value*** to make decisions

  - Contingent claim pricing offers potential for more precise answers, analyzing ***dynamics*** and ***closed form solutions***

    - Beyond 2 periods, 2 states of nature!

  - Merton's speech at 1st Moody's conference (2004?)

Fundamental Debt Valuation Framework :

Black and Scholes (1973), Merton (1974), Black and Cox (1976)

- But BS/M framework considers *zero-coupon debt only*
  - Default only at given time horizon; never prior to maturity
  - B & C considers infinite life debt with endogenous default
  - Papers didn't examine optimal leverage

Other very important pre-1994 papers:

- Brennan and Schwartz (*JB* 1978, *JF* 1984)
- Cox, Ingersoll, & Ross (*Emet* 1985)
- Fischer, Heinkel, and Zechner (*JF*, 1989)
- Mello and Parsons (*JF* 1992)
- Kim, Ramaswamy, and Sundaresan (*Fin. Management*, 1993)

My 1994 Paper

- Completed at just the right time to be considered for Ross Prize!
- Introduced taxes, default costs, and endogenous default
- Derived ***closed-form solutions*** to debt and equity values,
  the default boundary, and *optimal leverage*.

Comprehensive comparative statics, largely intuitive, but with ***a few surprises***:

- Credit spreads *fall* as the riskless rate rose
- For bonds near default ("junk"), prices could *rise* (and credit spreads fall)
  as asset value volatility increases
- Optimal debt for firms with higher default costs may have a *lower*
  credit spread. (Lower leverage)

This Talk

- **Organized around how subsequent *theoretical* papers generalize my results (by relaxing key assumptions)**

- **Nonetheless, much of this subsequent work is motivated by important *empirical results:***

  - The **credit spread puzzle**: structural predictions of spreads are too low, particularly for *low-risk* and *short maturity* debt.
    - Jones, Mason, and Rosenfeld (*JF*, 1983)
  - Structural model explanatory variables don't seem to predict **changes in spreads** well through time
    - Collin-Dufresne, Goldstein, & Martin (*JF* 2001)
  - Structural **predictions of optimal leverage seem high,** and predicted changes in leverage seem inconsistent with the data
    - Lemmon, Roberts, & Zender (*JF* 2008) and references therein

Key 1994 assumptions: Like the original Black/Scholes / Merton models:

1) Underlying asset value follows an *exogenous process*

   Underlying asset is the value of operational cash flows and coincides with the *value of an unlevered firm*

2) Process is a diffusion with constant volatility and total payout rates

3) The riskless rate is constant

4) Debt and equity are contingent claims on underlying asset value

5) Firms cannot sell assets to meet debt servicing payments

6) Debt and equity have no issuance costs or (il)liquidity premia

Notes:

7) Implicit assumption that underlying value is a *traded asset*

8) No info. asymmetry: the *value process is perfectly observed*

Further assumptions re. debt:

9) Default endogenously determined (given fixed coupon)

10) Static capital structure (*constant amount of debt* or coupon)

11) Default costs a constant fraction of value at default

12) Infinite-life debt (can't examine *term structure of yield spreads*)

13) Single type/priority of debt

14) Managers make decisions in shareholders' interests
(but possible agency costs between stock and bond holders)

15) No personal taxes

Clearly the 1994 model is barebones and makes *heroic assumptions*!

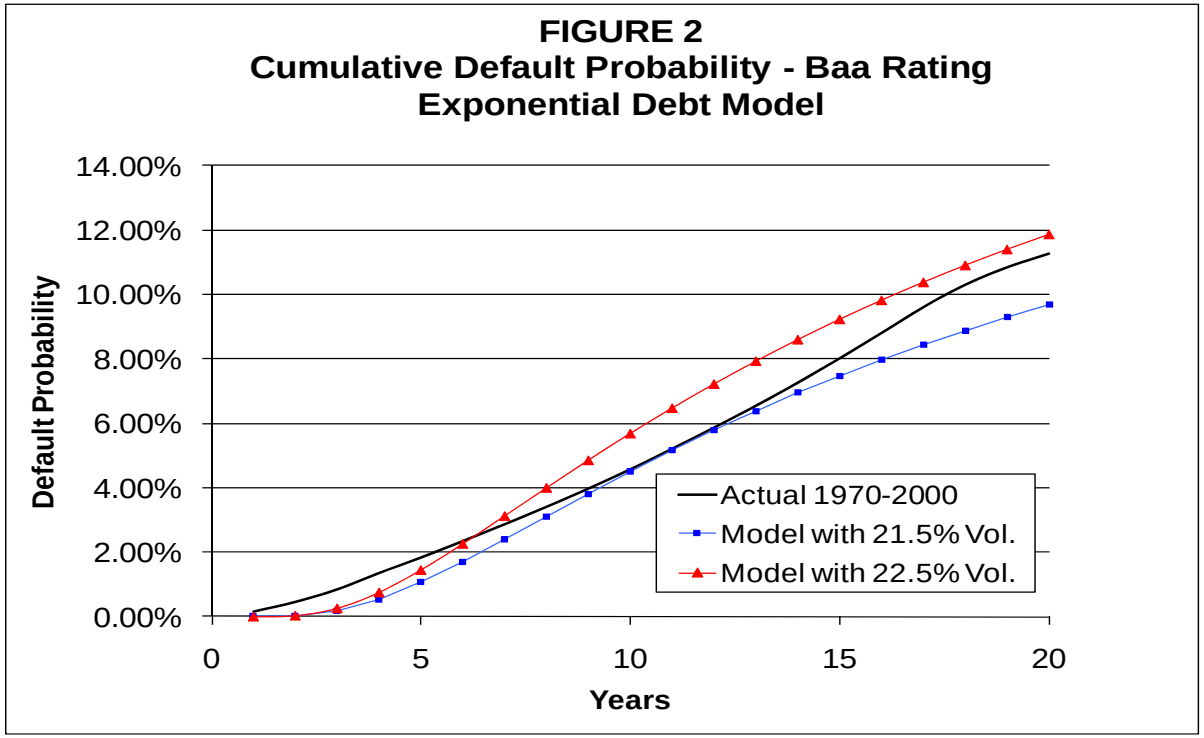
Since 1994, almost every assumption has been relaxed, in many cases retaining ***closed form results***. I will discuss some here, but can't cover them all!

Underlying asset not traded (relaxes Assumption 7)

- Concern that arbitrage pricing will fail, formulas therefore wrong even with diffusion process
- Ericsson & Reneby (***Financial Letters*** 2004) show if *any* other contingent claim is traded (e.g. equity) then approach is OK for debt valuation.

Jump- diffusion process (relaxes Assumption 2)

- **Problem with diffusion:** *default risk rate **must** go to zero as horizon ➔ 0 (a mathematical property of diffusion processes)*
- ***Any* model assuming a pure diffusion process will be *incapable* of explaining shorter term default probabilities, spreads**



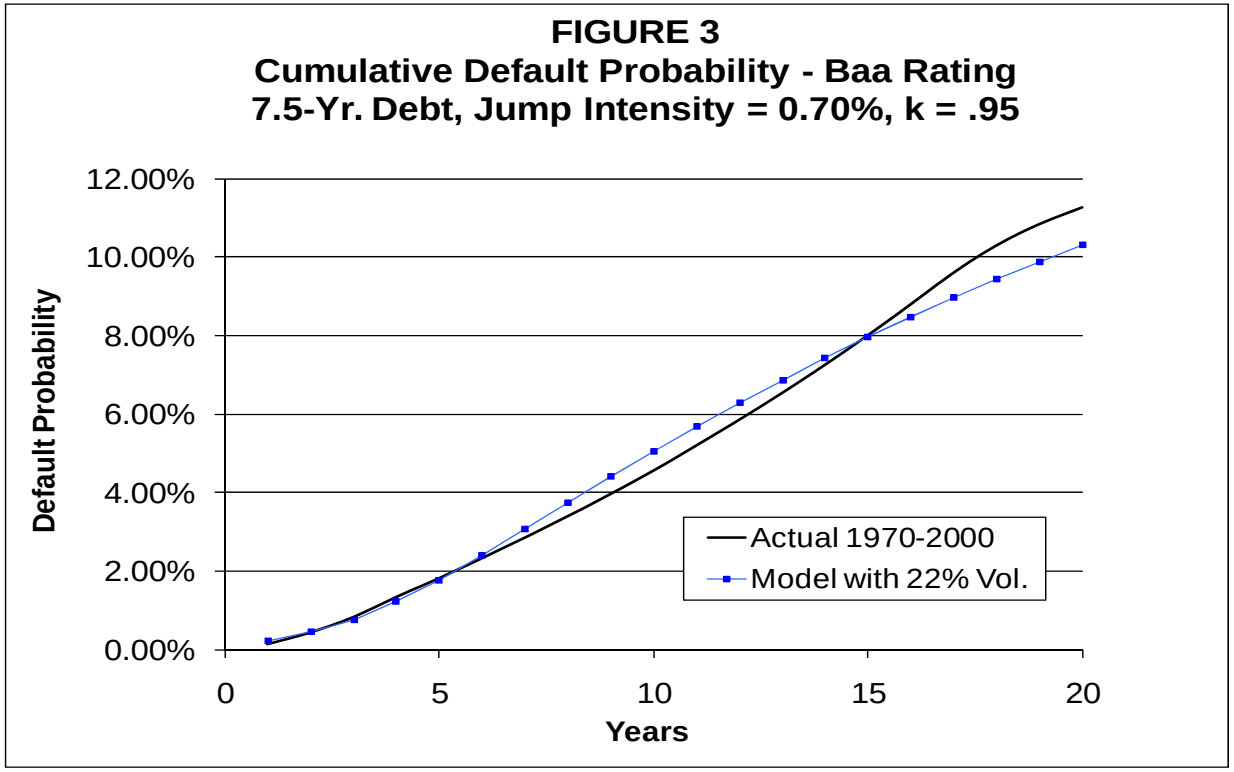
Long-term default probabilities (but not short) are spanned by model with volatilities between 21.5% and 22.5% (Schaefer & Strebulaev 2008)

This is why I have some quibble with results reported in Eom et al. (2004)

(they claim L&T model *overestimates* spreads, particularly at short maturities)

Jump-diffusion models *can* explain short end of the default, spread curve

- Zhou (*JBF*, 2001), Hilberink and Rogers (*F&S*, 2002), Huang and Huang (2003), Leland (*Princeton Lectures* 2006), Le Courtois and Quittard-Pinon (*DEF* 2008), Chen and Kou (*MF*, 2009). Latter 4 papers have ***closed form solutions***



Finite Debt Maturity (relaxes Assumption 10)

- ***Convenient technically*:** no time dependence
- ***But unrealistic***, and can't consider term structure of credit spreads
- **Leland-Toft** (1996): Maturity T, straight line amortization rate P/T. Roll-over of principal preserves time independence—but complex

o **Leland** (1994b, 1998): ***Exponential debt model***

- o Infinite life debt, BUT retired proportionately (at par) at rate ***m***
- o Debt of each vintage declines exponentially, replaced with new debt that with same principal (and declines exponentially)
- o Total debt principal, coupon remains time independent
- o Average maturity of debt $T = \int_0^\infty t(me^{-mt})dt = \frac{1}{m}$
- o Debt service $\boldsymbol{c + mP = c + P/T}$ (coupon plus retired principal)
  - Increased debt service raises default barrier, spreads, etc.

- **Formulas for debt value *D*, firm value *v*, default barrier V_B are similar in form to original Leland (1994) formulas:**

$$D = \frac{C + mP}{r + m}\left(1 - \left(\frac{V_0}{V_B}\right)^{-y_1}\right) + (1-\alpha)V_B\left(\frac{V_0}{V_B}\right)^{-y_1}$$

$$v = V + \frac{\tau C}{r}\left(1 - \left(\frac{V_0}{V_B}\right)^{-y}\right) - \alpha V_B\left(\frac{V_0}{V_B}\right)^{-y}$$

$$V_B = \frac{\dfrac{(C + mP)\,y_1}{(r + m)} - \dfrac{\tau C y}{r}}{1 + (1-\alpha)\,y_1 + \alpha y}$$

where $$y_1 = \frac{(r - \delta - .5\sigma^2) + ((r - \delta - .5\sigma^2)^2 + 2((r + m)\sigma^2)^{0.5}}{\sigma^2}$$

$$y = y_1 \quad \textit{with} \quad m = 0$$

- ***m*** = 0 is the special case of infinite-life debt.

- **Good news:** virtually every result with infinite life debt can easily be extended to include finite average maturity.

But: In these models, longer maturity ➔ higher firm value

Dynamic Capital Structure (relaxes Assumption 8)

- Dynamics pioneered by Fischer, Heinkel & Zechner (*JF* 1989)
  - Goldstein, Leland & Ju (*JB* 2001), Leland (*JF* 1998), Dangl & Zechner (*JFI* 2003), Ju & Ou-Yang (*JB* 2006), Strebulaev (*JF* 2007)

    Upward restructuring (lumpy if refinancing costs)

    No downward restructuring (externalities?) except for Strebulaev, Dangl & Zechner (wp 2007), Ju & Ou-Yang
- Collin-Dufresne & Goldstein (2001): *mean-reverting leverage ratio*

Implications:

- Higher spreads, lower optimal leverage (Morellec 2008: not enough)
- For empirical studies: Hennessy & Whited (2005), Strebulaev (2007)
  - Different optimal behavior at restructure points vs. in between
- Related results based on real options: Tserlukevich (*JFE* 2008), Barclay, Morellec, & Smith (*JB* 2006)

Endogenous Investment (relaxes Assumption 1):

- ***Lumpy investment, risky debt with refinance costs (most closely related)***
  - Early work: Brennan & Schwartz (*JF* 1984), Mello & Parsons (*JF* 1992) [Dixit & Pindyck (1994) *real options without debt financing*]
  - Mauer &Triantis (*JF* 1994), Mauer & Ott (2000), Childs, Mauer & Ott (*JFE* 2005), Titman & Tsyplakov (*RF* 2007), Hackbarth & Mauer (this conference)

    Investment options exercised late with debt financing

    Hackbarth & Mauer: debt priority can eliminate over (under) investment

- ***Continuous investment, riskless bank debt (modified "Q-theory")***
  - Early work: Hayashi (*Emet* 1982), Abel and Eberly (*AER* 1994)
  - Hennessy & Whited (*JF* 2005), Hennessy, Levy, & Whited (*JFE* 2007), Gamba and Triantis (*JF* 2008), Bolton, Chen, &Wang (this conference)

    Costly but riskless external financing

    Cash provides flexibility in lowering future external financing costs

    Financing constraints/costs determine "effective" marginal q

Agency Costs: Precursor: Mello and Parsons (1992)

STOCKHOLDERS vs. BONDHOLDERS:

- Comparing value of decisions optimizing ***total firm vs. equity value***
  - Asset Risk decisions and Hedging ("Asset Substitution")
    - Leland (1998), Ericsson (2000), Morellec & Smith (2007), Decamps & Djembissi (2007), Bolton, Chen & Wang (2009, this conference)
  - Investment decisions ("Over- vs. Under-Investment") [Myers 1977]
    - Papers above on "lumpy investment"

STOCKHOLDERS vs . MANAGERS (relaxes Assumption 14)

- ***Value lost by managers maximizing their utility/compensation***
  - Morellec (2004), Morellec, Nikolov, Schurhoff (2008), Lambrecht & Myers (2008), Bhagat et al. (2009, this conference paper)
  - DeMarzo & Sannikov (*JF* 2006), Albuquerque & Wang (2008), DeMarzo, Fishman, He & Wang (wp 2008): ***No risky debt*** ("Q-theory")
    - Endogenous management compensation contract; agent can divert
  - Hackbarth (*JFQA*, 2008) has overly confident/optimistic managers

(Il)liquidity (relaxes Assumption 6)

- Debt (bonds) are less liquid than equity, investors demand extra return
  - Huang & Huang (*wp* 2003) results suggest illiquidity important in spreads
  - Morellec (*JFE* 2001), Ericsson & Renault (*JF* 2006)
  - Leland (*Princeton Lectures* 2006) introduces as added discount rate on bond payments (e.g. 60 bps from Longstaff, Mithal, & Neis (*JF* 2005))
    - Needed (with jumps) to explain spreads, default rates simultaneously
    - Closed form valuation of debt, equity
    - Raises credit spreads and lowers optimal leverage
    - ***Finite optimal maturity*** (7.5 yrs., rather than infinite)

Multiple Types of Debt (relaxes Assumption 13)

- Secured Debt: Morellec (*JFE* 2001)
- Bank and Public Debt: Hackbarth, Hennessy, & Leland (*RFS* 2007)
  - Show bank debt is optimally senior

Endogenous Cash holding/Dividend Policy (relaxes Assumption 2)

- Fan and Sundaresan (*RFS* 2000), Decamps & Villeneuve (*F&S*, 2007), "Q-theory" papers

Strategic Default (relaxes Assumption 9)

- Anderson & Sundaresan (*RFS* 1996), Mella-Barral & Perraudin (*JF* 1997), Fan & Sundaresan (*RFS* 2000), Christensen, Flor, Lando & Miltersen (2000), Francois & Morellec (*JB* 2004), Broadie, Chernov & Sundaresan (*JF* 2008)

Random Default-free Interest Rates (relaxes Assumption 3)

- Longstaff & Schwartz (*JF* 1995), Acharya & Carpenter (*RFS* 2002), Ju & Ou-Yang (*JB* 2006)
  - Vasicek process for default-free rate

Personal Taxes (relaxes Assumption 15)

- Goldstein, Ju, & Leland (2001), Hennessy & Whited (2005), Morellec & Schurhoff (*RFS* 2009). . .***et al***.

Imperfect Information (relaxes Assumption 8)

- Duffie & Lando (*Emet* 2001), Lambrecht & Perraudin (2003),

  Hennessy, Livdan & Miranda (*here*), Morellec & Schurhoff (*wp* 2009)
  - Reduced value of waiting to invest, firms investment delay less

Industry Equilibrium Setting (relaxes Assumption 1)

- *Stochastic price of product drives cash flow; firms can enter and exit*
  - Precursors: Brennan Schwartz (*JF* 1985), Mello & Parsons (*JF* 1992)
  - Fries, Miller, & Perraudin (*RFS* 1997), Miao (*JF*, 2005)

Macroeconomic Equilibrium Setting (relaxes Assumption 2)

Empirical results in Collin-Dufresne, Goldstein, & Martin (*JF* 2001) suggest that ***macroeconomic common factors*** are needed to explain credit speads

- Hackbarth, Miao, & Morellec (2007): *stochastic regime shifts* (*strong, weak*)
- Strebulaev (this conference paper 2009): *Epstein-Zinn aggregate investor*
- Chen, Collin-Dufresne, & Goldstein (*RFS* 2009): *Campbell-Cochrane prefs.*
  - Combined with model generating ***countercyclical default rates***, can explain Baa-Aaa spreads (not Baa-Treasury or Aaa-Treasury spreads)
  - I suggest ***countercyclical liquidity spreads*** also could do this

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