Rollover Risk and Credit Risk

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Motivation

- What determines a firm's credit spread?
  - default premium;
  - liquidity premium, e.g., Longstaff, Mithal, and Neis (2005), and Chen, Lesmond, and Wei (2007).
- However, default premium and liquidity premium are typically treated as independent and measured separately.
- The recent credit crisis demonstrated an intricate interaction between them.
  - Deterioration of market liquidity can exacerbate default risk.
  - Lehman Brothers and Bear Stearns.
- This paper develops a model to study this interaction.
  - Firms' rollover risk as the channel: deterioration of market liquidity causes equity holders to suffer losses in rolling over maturing bonds.
  - Conflict of interest between debt and equity holders causes equity holders to default earlier, e.g., Flannery (2005) and Duffie (2009).

Summary of the Paper

- We build on Leland (1994) and Leland and Toft (1996):
  - A firm has to constantly roll over its maturing debt by issuing new debt with the same maturity and face value at market price.
  - Equity holders of the firm bear the rollover gain/loss and endogenously default when the equity value drops to zero.
- Debt rollover exposes the firm to liquidity risk in bond markets.
  - Deteriorating liquidity exacerbates default risk.
  - Tradeoff: rollover loss vs option value of keeping the firm alive.
- Flight to quality:
  - liquidity deterioration has greater effects on weaker firms.
- Short-term debt also exacerbates the liquidity effect by forcing equity holders to quickly absorb the rollover loss.
- Implications:
  - 1) Liquidity can predict defaults; 2) caution in decomposing credit spreads; 3) maturity risk; 4) highly variable fundamental and liquidity risk.

Brief Literature Review

- Growing literature on rollover risk:
  - Diminishing debt capacity: Acharya, Gale, and Yorulmzer (2009)
  - Coordination problem: Morris and Shin (2004, 2009)
  - Dynamic debt runs: He and Xiong (2009)
- Structural credit risk models focus on fundamental default risk:
  - Exogenous default threshold: Merton (1973), Longstaff and Schwartz (1995);
  - Endogenous threshold: Leland (1994) and Leland and Toft (1996).
- Empirical evidence on important liquidity effects in credit spreads:
  - e.g., Longstaff, Mithal, and Neis (2005), Ericsson and Renault (2006) and Chen, Lesmond, and Wei (2007).
  - Interpreted as a liquidity-premium effect.
  - Our model: an increase in liquidity premium also leads to higher default premium.

Model (1)

- We build on Leland and Toft (1996) with an additional feature:
  - Illiquid secondary bond markets.
- A firm repays maturing bonds by issuing new bonds at market prices.
  - The rollover gain/loss is absorbed by equity holders;
  - The firm defaults when equity value drops to zero.
- The unlevered firm value follows a log-normal process under the Q-measure:
$$\frac{dV_t}{V_t} = (r - \delta)\, dt + \sigma dZ_t.$$
  - Riskfree rate r, payout rate δ.
- In bankruptcy creditors recover α fraction of the firm value.

Model (2): Debt Structure

- The firm commits to a stationary debt structure (C, P, m):
  - aggregate face value P and annual coupon payment C;
  - each bond has maturity m;
  - debt expirations are uniformly spread across time, i.e., over $(t, t + dt)$, $\frac{1}{m}dt$ fraction of the bonds matures.
- The firm issues new bonds with the same face value, coupon rate and maturity to replace maturing bonds.
- Over $(t, t + dt)$, the net cash flow to equity holders is

$$NC_t = \delta V_t - (1 - \pi) C + \frac{1}{m} \left[\overline{d} (V_t, m) - P \right].$$

  - $\overline{d} (V_t, m)$: market value of per unit newly issued bond;
  - When the bond price drops, equity holders face rollover losses.
  - Will show the loss is greater for short-term debt.

Model (3): Endogenous Default

- The firm defaults when V_t drops to an endogenous threshold V_B.
  - At V_B, equity value $E(V_B) = 0$, i.e., the firm cannot raise any equity financing;
  - Optimality of V_B: smooth pasting $E'(V_B) = 0$.
- Intrinsic conflict of interest between debt and equity holders:
  - When the bond price falls (for either fundamental or liquidity reasons), equity holders bear the rollover loss while the maturing debt holders get paid in full.
  - Equity holders face a tradeoff: rollover loss vs option value of keeping the firm alive.

Model (4): The Secondary Bond Markets

- The secondary markets of corporate bonds are highly illiquid.
  - Large bid-ask spreads and price impact.
  - Edwards, Harris, and Piwowar (2007): bid/ask spread on corporate bonds ranges from 4 to 75 bps.
  - Bao, Pan, and Wang (2009): trading cost (bid/ask spread & price impact) ranges from 74 to 221 bps; and the cost is higher for long-term bonds.
- When a bond holder sells a bond, he only recovers a fraction $(1-k)$ of the value.
  - k represents the liquidity discount (trading cost, info problem,...)
- Each bond investor is subject to Poisson liquidity shocks with intensity ξ, a la Amihud and Mendelson (1986).
  - Upon the arrival of a liquidity shock, he has to sell his bond holdings.
- We assume no cost for trading equity and issuing new bonds.

Solving the Equilibrium

- For a given V_B, PDE for the debt value $d\left(V_t,\tau;V_B\right)$:

$$\Big(r+\underbrace{\xi k}_{\text{liquidity premium}}\Big)\, d\left(V_t,\tau\right)=c-\frac{\partial d\left(V_t,\tau\right)}{\partial\tau}+\left(r-\delta\right)V_t\frac{\partial d\left(V_t,\tau\right)}{\partial V}+\frac{1}{2}\sigma^2V_t^2\frac{\partial^2 d\left(V_t,\tau\right)}{\partial V^2}.$$

  - At the bankruptcy, $d\left(V_B,\tau;V_B\right)=\frac{\alpha V_B}{m}$, for all $\tau\in[0,m]$.
  - At maturity, $d\left(V_t,0;V_B\right)=p$, for all $V_t>V_B$.
- ODE for equity value $E\left(V\right)$:

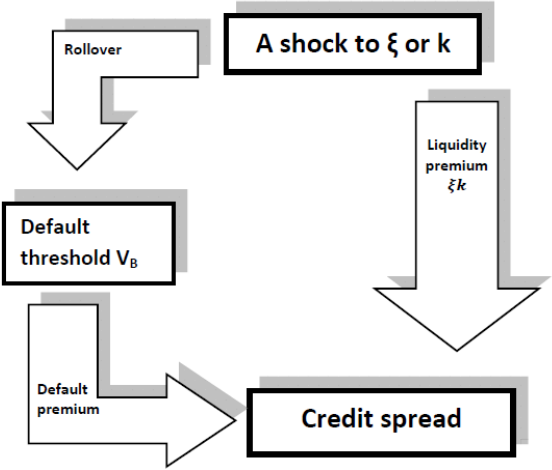
$$rE=\left(r-\delta\right)V_tE_V+\frac{1}{2}\sigma^2V_t^2E_{VV}+\delta V_t-\left(1-\pi\right)C+d\left(V_t,m\right)-p.$$

  with boundary condition $E\left(V_B\right)=0$:

  - Closed-form solution for $E\left(V\right)$ using Laplace tranformation.
- Smooth pasting $E'\left(V_B\right)=0$: closed-form solution for V_B.

Key Channels of Liquidity Effects

- Consider an unanticipated liquidity shock which increases ξ or k.
  - e.g., increased redemption risk, margin risk, or market illiquidity.

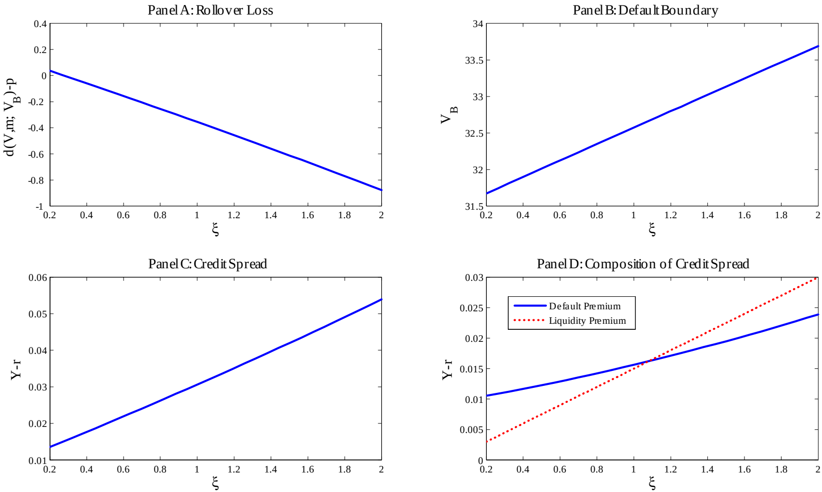


Baseline Model Parameters for Illustration

- Risk-free rate: $r = 7.5\%$.
- Tax rate: $\pi = 35\%$.
- Asset volatility $\sigma = 15\%$; payout rate $\delta = 7\%$.
- Trading cost $k = 1.5\%$; Intensity of liquidity shocks $\xi = 1$.
  - Consistent with Bao, Pan, and Wang (2009) who focus on a relatively liquid sample.
- Liquidation recovery rate: $\alpha = 0.5$.
- Debt maturities $m = 1$; total principal $P = 24.09$; total coupons $C = 2.17$.
  - Optimal debt structure when initial $V_0 = 100$.
- Current asset value: $V_t = 44$.

Market Liquidity and Endogenous Default

- Two channels of liquidity effects: liquidity premium and endogenous default risk.



Is the Liquidity-driven Default Efficient?

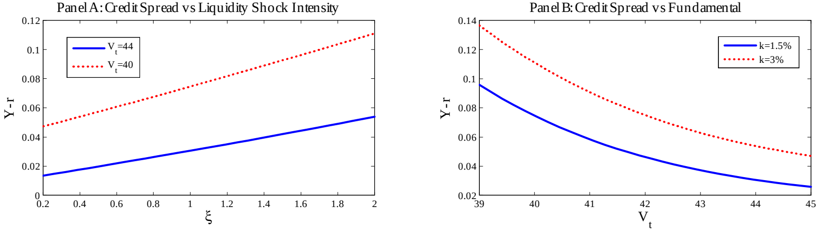
- Liquidity deterioration increases the firms' financing cost. Thus, an earlier default might be desirable to the joint interest of debt and equity holders.
- Suppose that the firm never defaults.
  - The present value of future tax shield is $\frac{\pi C}{r}$, while the present value of future bond transaction costs is $\frac{\xi k}{r}\frac{C}{r+\xi k}$.
  - Default hurts the joint interest if

$$\pi > \frac{\xi k}{r + \xi k},$$

    which always holds in our illustration.
- Thus, the increased default risk caused by liquidity deterioration originates from conflict of interest between debt and equity holders.
  - i.e., debt overhang problem of Myers (1977).

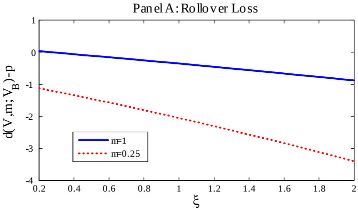
Flight to Quality

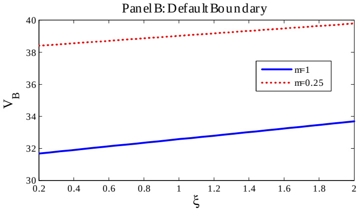
- Flight to quality: after major liquidity disruptions prices of low quality bonds drop much more than high quality bonds.
  - Market crash of 1987, LTCM crisis in 1998, attacks of 9/11 in 2001, and credit crisis of 2007/2008.
  - de Jong and Driessen (2006), Chen, Lesmond, and Wei (2007), Acharya, Amihud, and Bharath (2010)

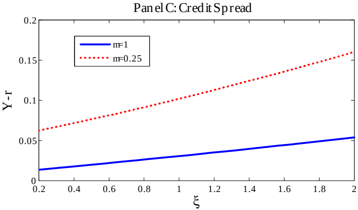


Amplification by Short-term Debt

- Shorter maturity forces equity holders to quickly realize rollover loss.
  - Rollover loss per unit of time: $\left[\overline{d}\left(V_t, m\right) - P\right] / m$.
  - More severe conflict b/w debt- and equity-holders.
- Short-term maturity makes an individual bond safer, but a firm with more short-term debt is riskier.

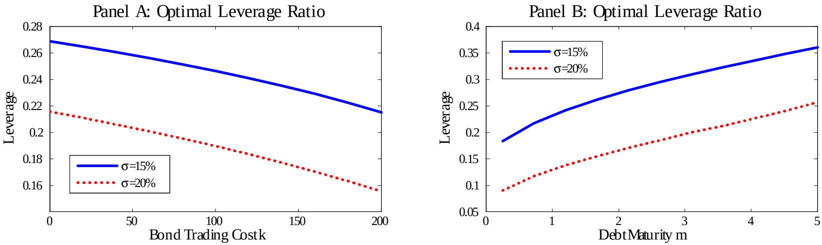






Optimal Debt Structure

- Bond market illiquidity reduces the firm's initial leverage choice.



Implications: Predicting Defaults

- Our model predicts market liquidity as a new factor for predicting bond defaults, in addition to
  - Distance to default: leverage, asset volatility
  - Firms' liquidity holdings: cash, credit lines
- The existing structural credit risk models have mixed successes:
  - Leland (2004): Leland model does a good job in capturing average default probabilities of bonds with different ratings.
  - Bharath and Shumway (2008): distance-to-default variable constructed from Merton model is not a sufficient statistic for default probability.
  - Davydenko (2007): distance to default cannot capture the cross section of bond spreads;
- Collin-Dufresne, Goldstein, and Martin (2001): standard variables cannot explain the changes of credit spreads.
- Das, Duffie, Kapadia, and Saita (2007): distance-to-default variables cannot fully capture default correlation observed in the data.

Implications: Decomposing Credit Spreads

- Both academics and policy makers have recognized the important effect of market liquidity on credit spreads, but tend to treat it as independent from default risk.
- Several studies, e.g., Longstaff, Mithal, and Neis (2005), Beber, Brandt, and Kavajecz (2008), and Schwarz (2009), decompose credit spreads to assess contributions of liquidity premium and default risk:

$$CreditSpread_{i,t} = \alpha + \beta \cdot CDS\_Spread_{i,t} + \delta \cdot LIQ_{i,t} + \epsilon_{i,t}$$

  - Default risk explains a majority part of the cross-sectional variation, although the liquidity effect is also significant.
- But these two effects are correlated through endogenous default.
  - How to classify the correlated part?
  - In the empirical analysis, the more precise measure of default risk (via traded prices) could have favored the default risk effect.

Implications: Measuring Liquidity Effects

- Several recent studies examine the impact of TAF on LIBOR-OIS spread.
  - e.g., Taylor and Williams (2009), McAndrews, Sarkar, and Wang (2008), Wu (2008).
- They tend to control for default risk using certain credit spread, such as CDS spread or LIBOR-REPO spread.
  - Example: Taylor and Williams (2009)

$$(LIBOR - OIS)_t = a \cdot (LIBOR - REPO)_t + b \cdot TAF_t + \epsilon_t$$

  - The control variables can also absorb liquidity effects and thus leading to an under-estimation.

Implications: Maturity Risk

- Our model implies that firms' debt maturity structure is an important determinant of credit risk.
- Evidence on non-financial firms with more maturing long-term debt during the recent credit crisis period had to cut down more investment and had greater credit spread increases.
  - Almeida, et al. (2009), Hu (2010).
- Evidence on credit ratings had ignored maturity risk.
  - Gopalan, Song, and Yerramilli (2009).

Implications: Managing Credit Risk

- Variability of fundamental beta and liquidity beta (like Gamma for options) is important for effectiveness of static hedges of bond price risk over a given period.
  - Transaction cost prevents institutions from continuously updating their hedges.
- Define fundamental and liquidity betas of $d\left(V_t, \xi; V_B\left(\xi\right)\right)$:

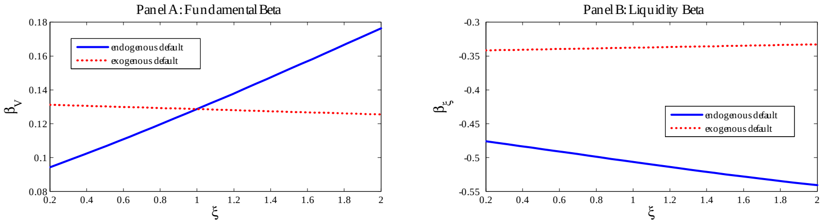
$$\beta_V \equiv \frac{\partial d\left(V_t, \xi; V_B\left(\xi\right)\right)}{\partial V},$$

and

$$\begin{aligned}\beta_\xi &\equiv \frac{\mathrm{d}d\left(V_t, \xi; V_B\left(\xi\right)\right)}{\mathrm{d}\xi} \\ &= \frac{\partial d\left(V_t, \xi; V_B\left(\xi\right)\right)}{\partial \xi} + \frac{\partial d\left(V_t, \xi; V_B\left(\xi\right)\right)}{\partial V_B} \cdot \frac{dV_B\left(\xi\right)}{d\xi}.\end{aligned}$$

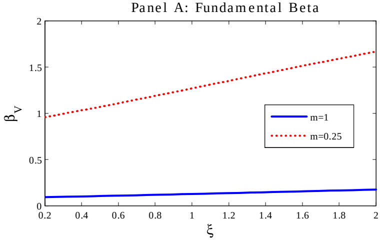
Fundamental and Liquidity Betas

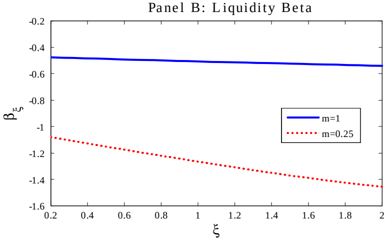
- We compare betas implied by our model with those by a structural model with an exogenous default threshold (e.g., Merton (1973) and Longstaff and Schwartz (1995)).
  - Assume that the default threshold is fixed at the baseline level.



Debt Maturity and Risk Management

- Variability of fundamental beta and liquidity beta is even greater when the firm is financed by short-term debt.





Extension

- A more elaborate secondary market:
  - Multiple types of bond investors with different frequencies of liquidity shocks;
  - Multiple classes of long-term and short-term bonds with short-term debt being more liquid.
- Endogenous market segmentation in spirit of Amihud and Mendelson (1986):
  - investors with higher liquidity needs self-select to short-term bonds;
  - liquidity effect spill over across different segments through investors' required bond returns.
- Endogenous debt maturity structure:
  - The firm trades off short-term debt's lower liquidity premium and the resulting higher default risk.

Conclusion

- A model of liquidity effects on credit spreads.
  - Two channels: liquidity premium and endogenous default.
  - The latter channel operates through firms' rollover risk.
- Several results:
  - Liquidity shocks increase credit spreads not only through higher liquidity premia, but also higher default probabilities.
  - Flight to quality: Bonds with weaker fundamentals are more exposed to liquidity shocks.
  - Shorter debt maturity exacerbates rollover risk and thus effects of liquidity deterioration on endogenous default.
- Implications:
  - 1) Liquidity can predict defaults; 2) caution against treat liquidity and default premia as independent; 3) maturity risk; 4) highly variable fundamental and liquidity risk.