The myth of the credit spread puzzle

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Credit spread puzzle

- Corporate bond yield spreads in structural model are lower than in the data
- Most pronounced for investment grade bonds
- Eom, Helwege, and Huang(2004), Leland(2006), Cremers, Driessen, Maenhout(2008), Bao(2009), Zhang, Zhou, and Zhu(2009), Chen, Collin-Dufresne, Goldstein(2009), Chen(2010), Huang and Huang(2012), and others
- Huang and Huang(2012) show that a range of standard structural models give very similar results *once they are calibrated to* ***historical default rates*** *and* ***the equity premium***

Our contribution

- The Merton model can capture
  - **average** level of investment grade spreads
  - **time series variation** in investment grade spreads

- Crucial for our conclusions:
  - Calibrate to **long-term** historical default rates
  - A short history of default rates will most often lead to the conclusion of a credit spread puzzle even if there is none

- Default probabilities maybe higher than we think

The Merton model: assumptions

- The value of the firm's assets follows a geometric Brownian motion under the risk neutral measure

$$\frac{dV_t}{V_t} = (r - \delta)dt + \sigma dW_t^Q$$

  and

$$\frac{dV_t}{V_t} = (\pi + r - \delta)dt + \sigma dW_t^P$$

  under the actual measure where π the asset risk premium and δ is the firm payout rate
- It is useful to define the asset Sharpe ratio as $\theta = \frac{\mu - r}{\sigma}$

The Merton model: credit spread

- At time 0 the firm has issued two claims, equity and a zero coupon bond with face value F maturing at time T
- If $V_T \geq d \times F$ (where d may be different from one) at time T bondholders get back the face value, otherwise firm defaults and bondholders receive a fixed recovery R
- Chen, Collin-Dufresne, and Goldstein(2009) [CDG] show that the credit spread is given as

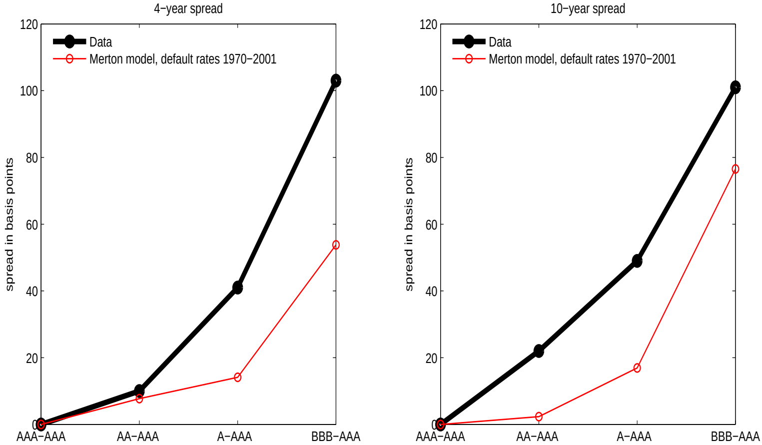
$$(y - r) = -\left(\frac{1}{T}\right) \log \left(1 - (1 - R)N\left[N^{-1}(\pi^P) + \theta\sqrt{T}\right]\right)$$

  where y is the corporate bond yield
- Fixing θ and R the relation between π^P and $y - r$ is close to linear, so we can use this formula to compare historical average default rates and spreads

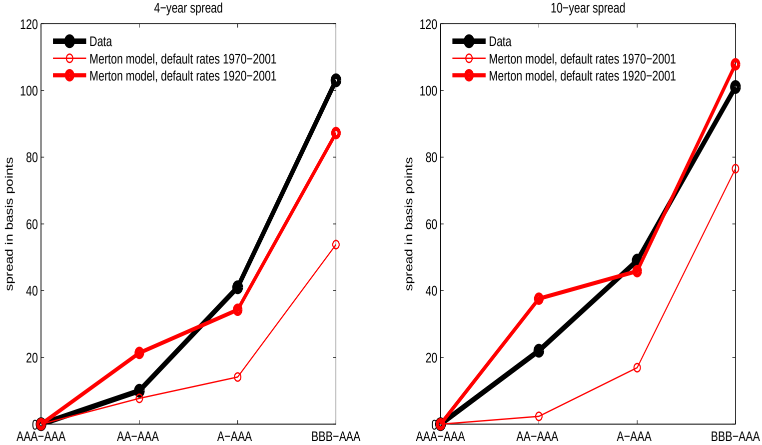
The Merton model:
Chen, Collin-Dufresne, Goldstein(2009) test

- Chen, Collin-Dufresne, Goldstein(2009)
  - estimate the Sharpe ratio to be $\theta = 0.22$
  - use a recovery rate $R = 0.449$
  - use average historical default rates from 1970-2001

Chen, Collin-Dufresne, and Goldstein (2009) test



Chen, Collin-Dufresne, and Goldstein (2009) test: using long-run default rates the puzzle disappears



Historical default rates play crucial role in literature

- Focus in literature is on the 10-year BBB-AAA spread
- 10-year BBB default rate is very important for this spread
- Most studies calibrate to "short" history (post 1970) of default rates
  - Cremers, Driessen, and Maenhout(2008) and Huang and Huang(2012) use a 10-year cumulative BBB default frequency of 4.39% - based on 1970-1998 Moody's data
  - Chen, Collin-Dufresne, Goldstein (2009) and Chen(2010) use a 10-year cumulative BBB default frequency of 4.89% - based on 1970-2001 Moody's data
- We run a simulation study to assess the accuracy of 4.39%
  - How Moody's calculate historical default rates guide setup

Simulation setup

- In year 1-cohort we have 1,000 identical firms
- Simulate 10-year default frequency of this cohort
- In year 2 there is a new cohort of 1,000 identical firms; simulate 10-year default frequency
- Do this for 18 cohorts; calculate average 10-year default rate
- Repeat simulation 100,000 times.

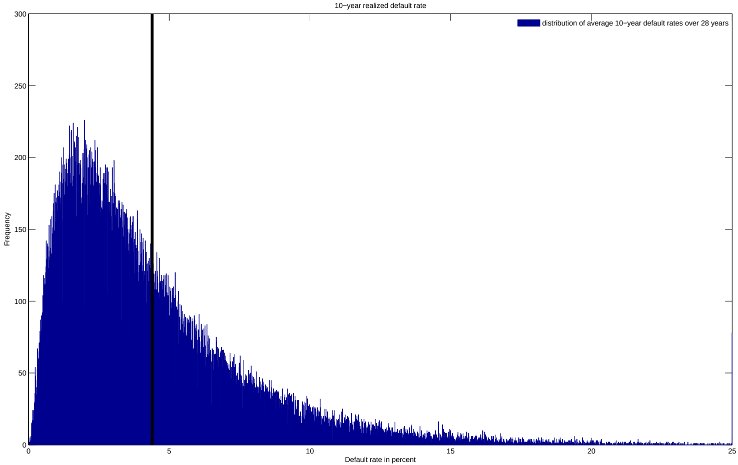
Correlation structure crucial in simulation

- Choose parameters such that 10-year default prob is 4.39%
- We introduce systematic risk by assuming that

$$W_{iT}^{P} = \sqrt{\rho} W_{sT} + \sqrt{1-\rho} W_{iT}$$

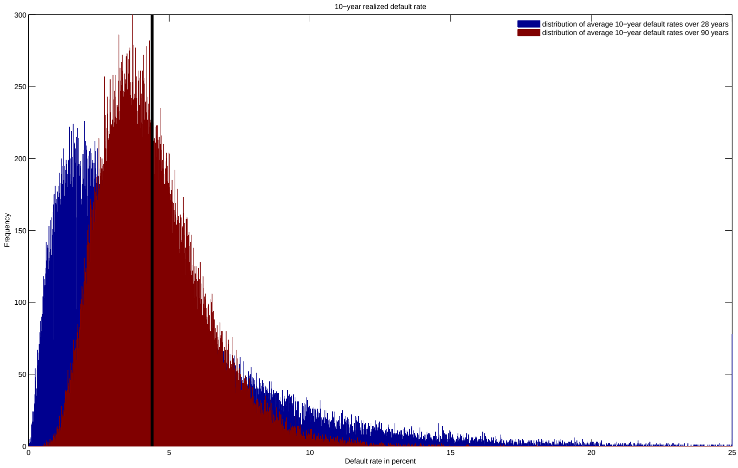
  where W_i is a Wiener process specific for firm i, and W_s is a Wiener process common to all firms.
- We set $\rho = 0.25$ (based on Cremers, Driessen, and Maenhout(2008))

Simulation results: Skewed and wide distribution



P(def rate< 2.20%)=29.7%

Distribution tighter when using 90 years of data



P(def rate< 2.20%)=7.8%

Even very modest correlation leads to high dispersion

Systematic risk	mean	Quantiles						
ρ		0.005	0.025	0.25	0.5	0.75	0.975	0.995
0%	4.39%	4.02%	4.11%	4.29%	4.39%	4.49%	4.68%	4.78%
5%	4.39%	1.72%	2.16%	3.37%	4.21%	5.20%	7.62%	9.01%
10%	4.39%	1.07%	1.50%	2.91%	4.03%	5.46%	9.36%	11.87%
15%	4.41%	0.68%	1.07%	2.55%	3.85%	5.67%	10.84%	14.29%
20%	4.39%	0.45%	0.77%	2.24%	3.64%	5.73%	12.27%	16.76%
25%	4.38%	0.28%	0.56%	1.94%	3.45%	5.81%	13.50%	18.80%
30%	4.39%	0.18%	0.39%	1.69%	3.25%	5.84%	14.86%	21.17%
35%	4.38%	0.11%	0.27%	1.43%	3.02%	5.86%	16.19%	23.62%
40%	4.40%	0.06%	0.18%	1.23%	2.85%	5.88%	17.44%	26.04%
45%	4.39%	0.03%	0.12%	1.02%	2.59%	5.78%	19.02%	28.39%
50%	4.36%	0.02%	0.07%	0.82%	2.37%	5.73%	20.02%	30.20%

Potential concern with using default rates from 1920

- So far
  - A long history of default rates is necessary to get decent estimates of expected default probabilities
  - Puzzle disappears when using default rates from 1920 to explain spreads post 1985
- But
  - Spread data are from 1985- while default rates are from 1920-
  - Maybe a BBB rating meant something different during the first half of 20th century
  - Note: The default probability of BBB certainly varies over time; argument here concerns average level over long period
- If this is the case then spreads would also be higher in the early period compared to the later period, but
  - Average BBB-AAA spread 1920-2012 is 119bps
  - Average BBB-AAA spread 1970-2012 is 112bps
  - $\Rightarrow$ very similar

Potential concern with using default rates from 1920

- We can also test without making *any* assumption about ratings being "stable"
- Test the model using both spreads and default rates from 1920-2012
- Default rates from 1920-2012
  - 20-year AAA default rate is 1.712%
  - 20-year BBB default rate is 13.761%
- With these estimates – and using CDG's formula – the 20-year BBB-AAA spread is <u>126bps</u>
- The average actual BBB-AAA spread *measured over the same 1920-2012* is <u>119bps</u>

⇒ Merton model matches average BBB-AAA spread 1920-2012

Time series variation of spreads in the Merton model

- We have shown that the Merton model matches average spreads
- What about the time series variation?
- Need to look at individual bonds

We test the Merton model using individual bonds

- Corporate bond quotes for the period 1987-2012
  - Monthly quotes from the Lehman Brothers fixed income database 1987-1996
  - Daily quotes from Merrill Lynch 1997-2012
- Use only noncallable bonds issued by industrial firms
- Estimate daily leverage, payout rate, and asset volatility from CRISP/Compustat

Details

We allow for firm heterogeneity within rating and fit to historical default frequencies

- For each calendar year
  1. Fix the default boundary parameter d
  2. Calculate for each quote in that year a default probability corresponding to the bond maturity
  3. Calculate average default probabilities within the year separately for maturities 1, 2, 3,...,10 years and ratings AAA, AA, A, and BBB
  4. Find d by minimizing

$$\min_{\{d\}} \sum_{r=AAA}^{BBB} \sum_{t=1}^{20} N_{rt} |\overline{\pi}_{rt}^{P}(d) - \hat{\pi}_{rt}^{P}|.$$

     where $\hat{\pi}_{rt}^{P}$ are the historical default rates for the period **1920-2012**
- Average over 26 yearly estimates of d
- Result: Boundary is $\hat{d} = 1.036\%$ of face value of debt $\Rightarrow$ We set boundary to face value

RESULTS

Average spread to AAA-yields

	1987Q2-2012Q2		
	Bond maturity		
	short (0-2y)	medium (2-4y)	long (4-30y)
A			
Actual spread	39	32	40
Model spread	14	36	51
BBB			
Actual spread	141	117	121
Model spread	109	112	113
spec			
Actual spread	321	537	435
Model spread	219	306	248

Investment grade spreads matched

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...except for shortest maturities

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Speculative grade spreads too low

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	Bond maturity		
	short (0-2y)	medium (2-4y)	long (4-30y)
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Actual spread	39	32	40
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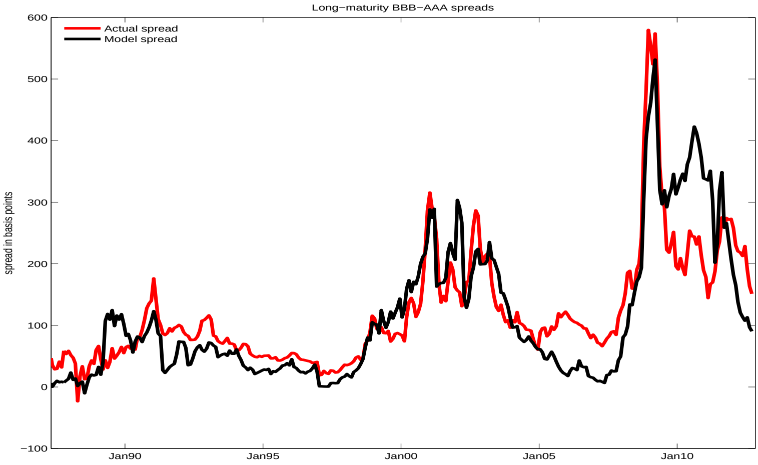
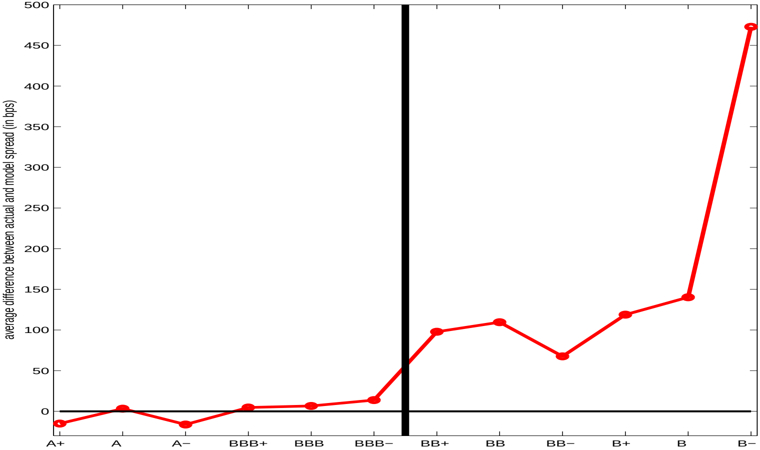
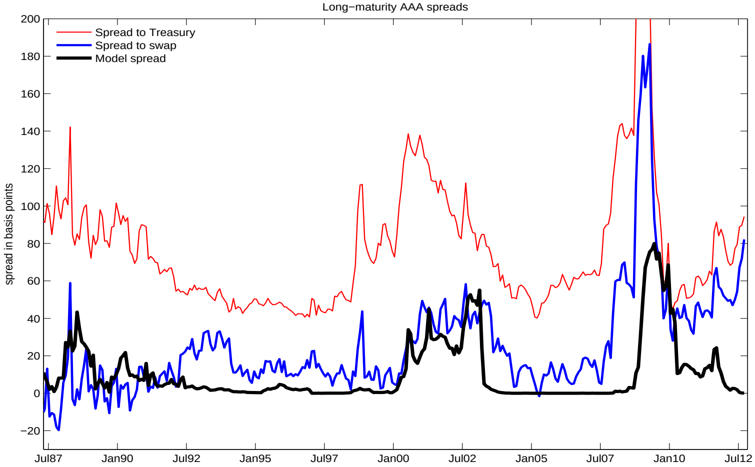
Time series variation: long-term BBB-AAA spread matched



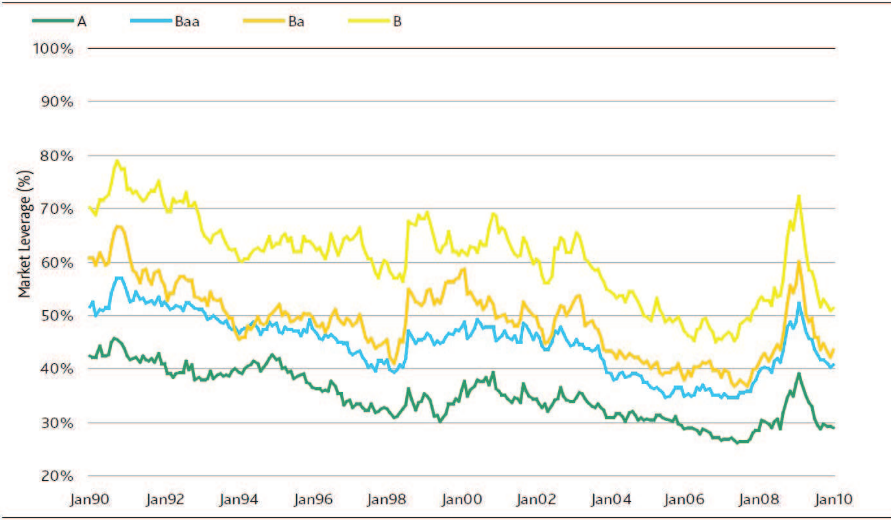
The Merton model underpredicts speculative grade spreads



Long-term AAA spread



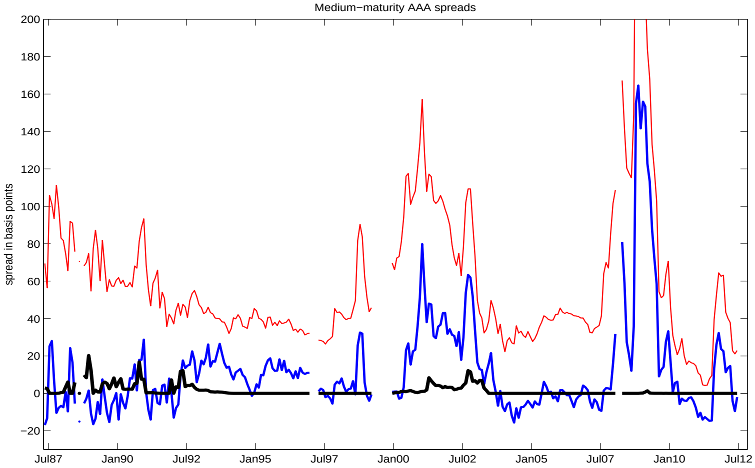
Time series variation: market leverage



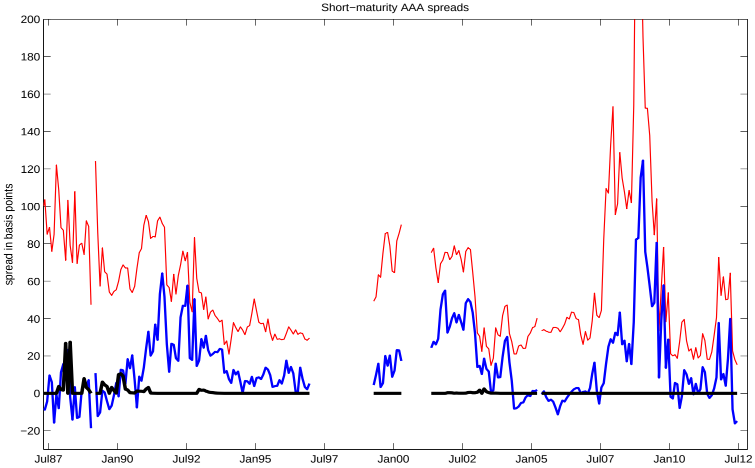
Conclusion

- The Merton model:
  - Matches average investment grade spreads well
  - Captures the time series variation of the BBB-AAA spread
- This is likely to hold for a wide range of structural models
- Default rates:
  - Using a *long* history is crucial to calibrate models
  - Using a *short* history will often give rise to a credit spread puzzle
- Average default rates from "recent" past may be lower than underlying expected default probabilities

Medium-term AAA



Short-term AAA



Assumptions

- Face value of debt F: Debt in Current Liabilities + Long-term debt (book values)
- Firm value V_0: Equity value + face value of debt
- Payout ratio δ: (last dividend annualized + last year's interest payments + share buy backs)/V_0
- Asset volatility is given as

$$\sigma_{A,t}^2 = (1 - L_t)^2 \sigma_{E,t}^2 + L^2 \sigma_{D,t}^2 + 2L_t(1 - L_t)\rho_{ED,t}$$

  where L_t is the leverage ratio $F_t/V_{0,t}$.
- Volatility of equity $\sigma_{E,t}$: Volatility of past three years daily returns scaled by $\sqrt{255}$.
- $(1 - L_t)\sigma_{E,t}$ is a lower bound on asset volatility
- Schaefer and Strebulaev(2008,JFE) estimate σ_A by using equity and bond returns.
- We use estimates of $\frac{\sigma_{A,t}}{(1-L_t)\sigma_{E,t}}$ as a function of leverage from Schaefer and Strebulaev and multiply on $(1 - L_t)\sigma_{E,t}$:

$$\begin{aligned}\sigma_A \quad = \quad & \Big[1_{\{L<0.25\}} + 1.05 * 1_{\{0.25<L<0.35\}} + 1.10 * 1_{\{0.35<L<0.45\}} + \\ & +1.20 * 1_{\{0.45<L<0.55\}} + 1.40 * 1_{\{0.55<L<0.75\}} + \\ & +1.80 * 1_{\{L>0.75\}}\Big](1 - L)\sigma_E\end{aligned}$$

Back