Online Appendix to: Is there a tradeoff between low bond risk premiums and financial stability?

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Data sources

The Baa–Aaa spread

The Baa–Aaa spread is the difference between the end-of-period quarterly values of Moody's Seasoned Baa and Aaa Corporate Bond Yields. The data series are available at: http://research.stlouisfed.org/fred2/series/BAA; and http://research.stlouisfed.org/fred2/series/AAA.

The Kim–Wright ten-year term premium

The term premium on ten-year U.S. Treasuries is an end-of-quarter estimate from Don H. Kim and Jonathan H. Wright, 2005, "An arbitrage-free three-factor term structure model and the recent behavior of long-term yields and distant-horizon forward rates," *Finance and Economics Discussion Series*, No. 2005-33, Board of Governors of the Federal Reserve System, August.

Term premium data from 1990 through 2013 can be found at www.federalreserve.gov/econresdata/researchdata/feds200533.html.

Term premium data before 1990 were kindly provided to the author by economists at the Board of Governors of the Federal Reserve System.

The expected corporate bond premium (EBP)

EBP estimates are taken from data underlying Simon Gilchrist and Egon Zakrajsek, 2012, "Credit spreads and business cycle fluctuations," *American Economic Review*, Vol. 102, June, pp. 1692–1720. Quarterly values of EBP are computed by averaging the monthly values of EBP available at: http://people.bu.edu/sgilchri/Data/data.htm.

The real federal funds rate

The real federal funds rate is the difference between the end-of-period quarterly values of the effective federal funds rate and the percentage change from a year ago in the Consumer Price Index.

The data series are available at:
http://research.stlouisfed.org/fred2/series/FEDFUNDS;
http://research.stlouisfed.org/fred2/series/CPIAUCSL.

A dating algorithm to identify large increases in bond risk premiums

Are large increases in bond risk premiums more likely to occur when risk premiums are at a low level? To answer this question, we need a method of dating "large" increases in a time series of risk premiums. I select the largest trough-to-peak increases in the quarterly time series of EBP, the Baa–Aaa spread, and the Kim–Wright ten-year term premium via the following dating algorithm:

Let RP_t equal the time t value of the quarterly risk premium series under consideration. Define a local trough as any RP_t such that $RP_{t-1} > RP_t < RP_{t+1}$ and a local peak as any RP_t such that $RP_{t-1} < RP_t > RP_{t+1}$. Then an up cycle is defined as the quarter following a local trough until and including the quarter in which the next local peak occurs. I compute the trough-to-peak increase for each up cycle and select a threshold above which an up cycle's increase is defined as a "large increase."

For this study, I consider thresholds that generate 12 "large" increases in the 60-year Baa–Aaa and Kim–Wright term premium sample and eight "large" increases in the 40-year EBP sample. These thresholds correspond to an unconditional hazard of one large increase every five years. Table A1 describes the large increases in each series.

Table A1: Largest increases in risk premiums

A. Baa–Aaa spread

Average Level: 1954–2013: .98
Median Level: 1954–2013: .86

Largest trough-to-peak cycles:

Trough		Peak		Trough-to-peak Increase
2007:Q3	0.85	2008:Q4	3.38	2.53
1978:Q3	0.73	1980:Q2	2.13	1.40
1974:Q1	0.61	1975:Q2	1.85	1.24
1981:Q3	1.43	1981:Q4	2.32	0.89
1970:Q2	0.77	1970:Q4	1.48	0.71
1982:Q2	2.11	1982:Q3	2.69	0.58
2011:Q2	0.76	2011:Q4	1.32	0.56
1990:Q1	0.84	1990:Q4	1.38	0.54
2001:Q2	0.79	2002:Q2	1.32	0.53
1983:Q4	1.18	1984:Q3	1.69	0.51
1957:Q2	0.72	1957:Q4	1.22	0.50
1997:Q3	0.55	1998:Q4	1.01	0.46

Table A1 (continued): Largest increases in risk premiums

B. EBP
Average Level 1973–2012: .04
Median Level: 1973–2012: –.03

Largest trough-to-peak cycles:

Trough		Peak		Trough-to-peak Increase
2008:Q2	0.65	2008:Q4	2.40	1.76
2007:Q1	–0.63	2008:Q1	0.88	1.51
1999:Q4	–0.14	2000:Q4	1.31	1.45
2001:Q4	0.26	2002:Q3	1.23	0.96
1974:Q1	0.00	1974:Q4	0.86	0.86
1987:Q2	0.04	1987:Q3	0.48	0.44
1986:Q2	0.20	1986:Q4	0.64	0.44
1980:Q4	–0.04	1981:Q2	0.40	0.44

C. Kim–Wright ten-year term premium
Average Level: 1954–2013: 1.17
Median Level: 1954–2013: 0.92

Largest trough-to-peak cycles:

Trough		Peak		Trough-to-peak Increase
1979:Q3	1.70	1980:Q2	3.53	1.83
1983:Q1	3.83	1984:Q2	5.62	1.79
1986:Q4	1.99	1987:Q3	3.51	1.52
1998:Q3	–0.05	1999:Q4	1.36	1.41
1981:Q2	4.09	1981:Q3	5.32	1.22
1980:Q4	3.08	1981:Q1	4.29	1.21
2012:Q3	–0.81	2013:Q4	0.38	1.19
2000:Q4	0.15	2001:Q2	1.30	1.15
2008:Q4	–0.07	2009:Q2	1.05	1.11
1974:Q4	1.51	1975:Q1	2.53	1.02
1993:Q3	1.46	1994:Q2	2.47	1.01
2010:Q3	–0.20	2011:Q1	0.80	1.00

A discrete time model of the hazard of a large increase in risk premiums

I model the hazard of a large increase in bond risk premiums. Start by indexing each quarter in the risk-premium time series. Let $I_t = 1$ if quarter *t* is part of an up cycle that exceeds the threshold necessary to be classified as a "large" increase in risk premiums and $I_t = 0$ otherwise. This index partitions the time series into quarters that are part of large increases in risk premiums and quarters that are not. I wish to model the hazard of switching from $I_t = 0$ to $I_{t+1} = 1$.

I assume that the data are generated with a continuous time process with a proportional hazard,

$$h(\tau, \boldsymbol{X}) = h_0(\tau)e^{\beta'\boldsymbol{X}} \qquad (1)$$

$h_0(\tau) = \gamma\rho\tau^{\rho-1}$ is the baseline Weibull hazard. τ is the time since the last large increase in risk premiums and **X** are covariates that shift the hazard. The Weibull specification allows for the build-up of risk over time via duration dependence in the baseline hazard. If $\rho > 1$, the baseline hazard increases with the time since the last large increase in risk premiums; if $\rho < 1$, the baseline hazard decreases with the time since the last large increase in risk premiums; and if $\rho = 1$, the baseline hazard becomes the exponential model with constant hazard.

When the data are generated by equation 1, Prentice and Gloeckler (1978)[1] derive the discrete time hazard with time-varying covariates and show that the probability that a large increase in risk premiums beginning at time *t* is Pr_t :

$$Pr_t = 1 - e^{-h_t e^{\beta' X_t}} \qquad (2)$$

where $h_t = e^{\alpha + (\rho - 1)\ln(\tau)}$ is the Weibull baseline hazard.

Let d_t be a dummy variable equal to 1 if the large increase in risk premiums begins at time *t+1* and 0 otherwise. The discrete time log-likelihood function is[2]

$$Ln\, L = \sum_{t=1}^{T_{at\,risk}} d_t \ln\left(\frac{Pr_t}{1 - Pr_t}\right) + \sum_{t=1}^{T_{at\,risk}} \ln(1 - Pr_t) \qquad (3)$$

where $T_{at\,risk}$ is the number of time periods at risk (number of quarters with $I_t = 0$).

[1] R. L. Prentice and L. A. Gloeckler, 1978, "Regression analysis of grouped survival data with application to the breast cancer data," *Biometrics*, Vol. 34, pp. 57–67.
[2] See P. Allison, 1982, "Discrete-time methods for the analysis of event histories," *Sociological Methodology*, Vol. 13, pp. 61–98.

I estimate equation 3 via maximum likelihood and report in table A2 the estimated coefficients of a number of different specifications of covariates in $\mathbf{X}_t$ and thresholds necessary for an up cycle to be classified as large.

Table A2: Hazard of a large increase in risk premiums

Dependent variable	EBP	EBP	Baa–Aaa spread	Baa–Aaa spread	KW ten-year term premium	KW ten-year term premium
Sample dates:	1973:Q1–2012:Q4	1973:Q1–2012:Q4	1954:Q3–2013:Q4	1954:Q3–2013:Q4	1954:Q3–2013:Q4	1954:Q3–2013:Q4
Increase necessary to be coded as a large increase (frequency)	Greater than 86 bps (4 in 40 years)	Greater than 43 bps (8 in 40 years)	Greater than 57 bps (6 in 60 years)	Greater than 45 bps (12 in 60 years)	Greater than 121 bps (6 in 60 years)	Greater than 99 bps (12 in 60 years)
Hazard model coefficients (levels)	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Constant	−2.00* (1.06)	−2.59*** (0.94)	−3.77* (2.21)	−4.95*** (1.78)	−11.82*** (4.32)	−5.11*** (1.07)
ρ	.42 (.41)	0.83 (.42)	0.88 (.43)	1.54 (.42)	2.26 (.79)	1.10 (.26)
EBP_t	−.28 (1.03)	.16 (0.98)				
$(Baa–Aaa)_t$			.32 (1.20)	0.92 (1.03)	1.18 (0.93)	1.67*** (0.45)
(Real fed funds rate)$_t$	.001 (0.22)	.08 (0.13)	.12 (0.17)	0.05 (0.15)	1.05*** (0.39)	0.06 (0.11
Goodness of fit						
LogLiK	−17.22	−30.21	−26.81	−43.98	−17.6	−38.52
AUC	0.64	0.64	.50	0.64	0.9	0.76

Dependent variable	EBP	EBP	Baa-Aaa Spread	Baa-Aaa Spread	KW ten-year term premium	KW ten-year term premium
Sample dates:	1973:Q1–2012:Q4	1973:Q1–2012:Q4	1954:Q3–2013:Q4	1954:Q3–2013:Q4	1954:Q3–2013:Q4	1954:Q3–2013:Q4
Increase necessary to be coded as a large increase (frequency)	greater than 86 bps (4 in 40 years)	greater than 43 bps (8 in 40 years)	greater than 57 bps (6 in 60 years)	greater than 45 bps (12 in 60 years)	greater than 121 bps (6 in 60 years)	greater than 99 bps (12 in 60 years)
Hazard model coefficients (levels)	**(7)**	**(8)**	**(9)**	**(10)**	**(11)**	**(12)**
Constant	−1.71* (1.02)	−2.25** (0.99)	−4.96* (2.82)	−6.21*** (1.98)	−5.60*** (1.98)	−5.19*** (1.42)
ρ	0.24* (.42)	0.67 (.42)	1.03 (.52)	1.72 (.46)	0.92 (.46)	1.17 (.29)
Average($EBP_{t-3 \rightarrow t}$)	−0.68 (1.18)	−0.07 (1.05)				
Average($Baa\text{-}Aaa_{t-3 \rightarrow t}$)			0.63 (1.39)	1.32 (0.97)	1.49* (0.76)	1.88*** (0.71)
Average(real fed funds rate$_{t-3 \rightarrow t}$)	0.18 (0.24)	0.09 (0.13)	0.28 (0.20)	0.23 (0.17)	0.24 (0.24)	−0.06 (0.11)
Goodness of fit						
LogLiK	−16.83	−29.76	−25.53	−41.46	−22.74	−41.6
AUC	0.72	0.62	0.68	0.7	0.81	0.71

Dependent variable	EBP	EBP	Baa–Aaa spread	Baa–Aaa spread	KW ten-year term premium	KW ten-year term premium
Sample dates:	1973:Q1–2012:Q4	1973:Q1–2012:Q4	1954:Q3–2013:Q4	1954:Q3–2013:Q4	1954:Q3–2013:Q4	1954:Q3–2013:Q4
Increase necessary to be coded as a large increase (frequency)	Greater than 86 bps (4 in 40 years)	Greater than 43 bps (8 in 40 years)	Greater than 57 bps (6 in 60 years)	Greater than 45 bps (12 in 60 years)	Greater than 121 bps (6 in 60 years)	Greater than 99 bps (12 in 60 years)
Hazard model coefficients (levels)	**(13)**	**(14)**	**(15)**	**(16)**	**(17)**	**(18)**
Constant	−2.88**	−2.41***	−3.88***	−3.94***	−3.01***	−3.04***
	(1.20)	(0.77)	(1.18)	(0.88)	(1.13)	(0.78)
ρ	0.56	0.79	0.93	1.40	0.61	0.91
	(0.40)	(0.32)	(0.33)	(0.31)	(0.35)	(0.28)
$(EBP)_t - (EBP)_{t-4}$	0.13	0.5				
	(0.60)	(0.69)				
$(Baa–Aaa)_t - (Baa–Aaa)_{t-4}$			−0.15	−0.33	0.9	2.04***
			(0.69)	(0.53)	(0.89)	(0.59)
$(\text{Real fed funds rate})_t -$	−0.17	−0.07	−0.04	−0.22	0.40**	0.27**
$(\text{Real fed funds rate})_{t-4}$	(0.25)	(0.15)	(0.19)	(0.20)	(0.17)	(0.11)
$(\text{KW ten-year term prem})_t -$	0.99	0.51	1.48**	1.09**	−0.5	−0.49
$(\text{KW ten-year term prem})_{t-4}$	(0.70)	(0.43)	(0.60)	(0.52)	(0.52)	(0.34)
Goodness of fit						
LogLiK	−15.2	−28.54	−23.69	−39.75	−26.3	−36.75
AUC	0.78	0.68	0.83	0.78	0.69	0.79