Default intensities in a network perspective

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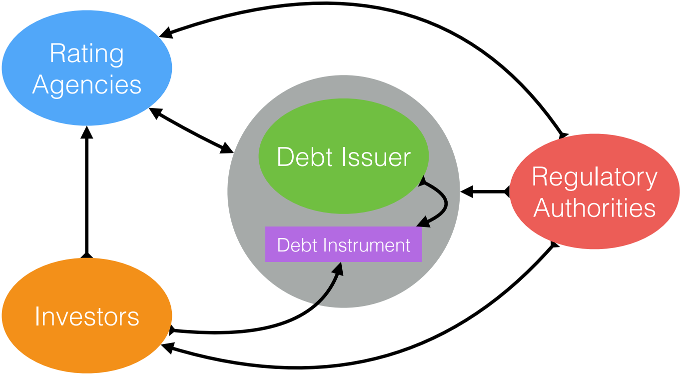
Default risk



Default risk and default intensity

- Time-t-conditional survival and default probabilities:

$$S_t(T) = P_t(\tau > T) = E_t\left\{\exp\left(-\int_t^T \lambda_s\, ds\right)\right\} \tag{1}$$

$$PD_t(T) = P_t(t < \tau \leq T) = E_t\left\{\int_t^T \exp\left(-\int_t^s \lambda_u\, du\right)\lambda_s\, ds\right\} \tag{2}$$

  - Time of default s: counting process N_t with intensity λ_s
  - Default intensities λ_s, $s > t$.

Default risk and default intensity

- How to model default intensity λ_t?
  - Standard reduced form model, Duffie et al. (JFE, 2007) ▸ Duffie et al. (2007)
  - Reduced form estimation with forward intensity, Duan et al. (JoE, 2012) ▸ Duan et al. (2012)
  - Structural model, Bharath and Shumway (RFS, 2008)
  - Credit Default Swap (CDS) spreads, Pan and Singleton (JF, 2008)

CDS spreads

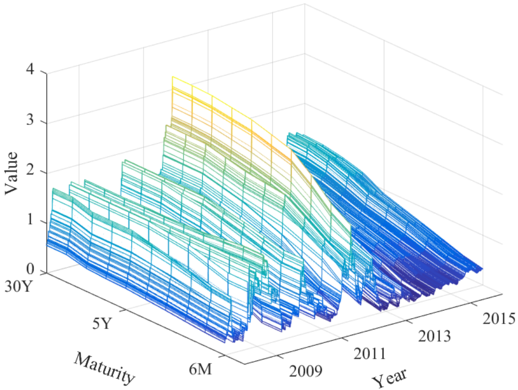


Figure 1: CDS spreads $y_t(\tau)$ for Deutsche Bank

CDS spreads and default intensity

Example: consider a CDS contract with T years maturity and quarterly premium payments.

- At issue, the present value of CDS-provider leg and CDS-buyer leg should be equal,

$$\underbrace{CDS_t(T)\cdot\frac{1}{4}\sum_{j=1}^{4T}\mathsf{E}_t\left\{\delta(\frac{j}{4})q(\frac{j}{4})\right\}}_{\text{CDS-provider leg, credit event not occur}}=\underbrace{L\sum_{j=1}^{4T}\mathsf{E}_t\left[\delta(\frac{j}{4})\left\{q(\frac{j-1}{4})-q(\frac{j}{4})\right\}\right]}_{\text{CDS-buyer leg, credit event occurs}} \tag{3}$$

where $CDS_t(T)$ is (annualized) spread at issue; $q(s)$ is survival probability; $\delta(s)$ is time discount factor for s years; L is loss given default (LGD); E_t expectation at t.

CDS spreads and default intensity

- With risk-neutral default intensity λ_t:

$$q(s) = \exp\{-\lambda_t(T)s\} \tag{4}$$

- Combing (3) and (4):

$$\lambda_t(T) = 4\log\left\{1 + \frac{CDS_t(T)}{4L}\right\} \tag{5}$$

- Focus on CDS spreads, equal to DI λ_t indicator.

CDS spreads are curves

- How to model the dynamics?
- Convenient factors: Level, Slope and Curvature
- Comovements of factors indicate inter-dependency
    - Systemic risk
    - Network connectedness

Long-run default intensity factor

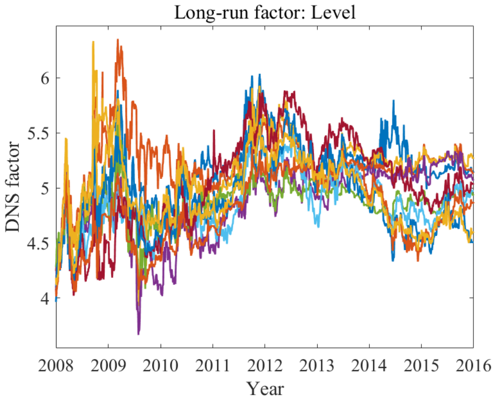


Figure 2: Long-run(Level) factor l_{it}, daily data from 2008.01.01 to 2015.12.31 for 10 G-SIBs (Global Systemically Important Banks).

Pairwise directional connectedness: Level

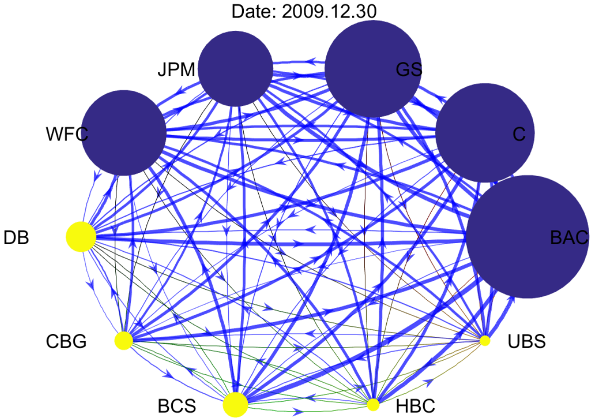


Figure 3: Node size indicates the "TO connectedness", and edge thickness indicates the average edge weight.

Challenges

- Dynamic DIs among G-SIBs
  - Term structure of CDS spreads
  - DI factors: Level (Long-run), Slope (Short-run) and Curvature (Middle-run) factors
- Network among DI factors
  - US vs European banks connections
  - Network dynamics

Outline

CDS spreads dynamics

Details

- Dynamic Nelson-Siegel (DNS) model

Example

$$y_{it}(\tau) = l_{it} + s_{it}\left\{\frac{1-\exp(-\delta_i\tau)}{\delta_i\tau}\right\} + c_{it}\left\{\frac{1-\exp(-\delta_i\tau)}{\delta_i\tau} - \exp(-\delta_i\tau)\right\} + \upsilon_{it}(\tau) \quad (6)$$

$$\begin{pmatrix} l_{it} \\ s_{it} \\ c_{it} \end{pmatrix} = \begin{pmatrix} \alpha_i^l & 0 & 0 \\ 0 & \alpha_i^s & 0 \\ 0 & 0 & \alpha_i^c \end{pmatrix} \begin{pmatrix} l_{i,t-1} \\ s_{i,t-1} \\ c_{i,t-1} \end{pmatrix} + \begin{pmatrix} \varepsilon_{i,t}^l \\ \varepsilon_{i,t}^s \\ \varepsilon_{i,t}^c \end{pmatrix} \quad (7)$$

where $\upsilon_{it}(\tau) \sim i.i.d.\,\mathrm{N}(0, \sigma_i(\tau))$; $y_{it}(\tau)$ is CDS spreads at maturity τ; $\tau = (\tau_1, \cdots, \tau_K) = (6M, 1Y, \cdots, 30Y), K = 10$; δ is *decay* parameter.

- Reduce term structure dimension:
  - 3 factors: Level, l_{it}; Slope, s_{it}; Curvature, c_{it}

VAR modeling of DNS factors

- VAR modeling for each factor, l_t, s_t, c_t, respectively.

$$x_t = \sum_{k=1}^{p} A_k x_{t-k} + u_t, \; u_t \sim i.i.d. \, \mathrm{N}(0, \Sigma) \tag{8}$$

$$x_t = (x_{1t}, x_{2t}, \cdots, x_{Nt})^\top$$

  - x_t represents l_t, s_t, c_t separately;
  - N number of banks, $N = 10$;
  - A_k, $N \times N$ parameter matrix; p lag order;
  - Σ is $N \times N$ residual covariance matrix, $\Sigma = cov(u_t)$.

Generalized variance decomposition (GVD)

- H-step GVD matrix $D = [d_{ij}]$, Koop et al.(1996)

$$\tilde{d}_{ij} = \frac{\sigma_{jj}^{-1} \sum_{h=0}^{H-1} (e_j^\top \Theta_h \Sigma e_j)^2}{\sum_{h=0}^{H-1} (e_i^\top \Theta_h \Sigma \Theta_h^\top e_i)} \tag{9}$$

$$d_{ij} = \frac{\tilde{d}_{ij}}{\sum_{j=1}^{N} \tilde{d}_{ij}} \tag{10}$$

  where $x_t = \Theta(L) u_t, \Theta(L) = \Theta_0 + \Theta_1 L + \dots \Theta_h L^h + \dots.$
  $\Sigma = \mathsf{E}(u_t u_t^\top)$, σ_{jj} is its jth diagonal element.
  $e_j = (0, 0, \dots, 1, \dots, 0)$, a zero vector except jth element unity.
  H is forecast horizon, $H = 12$

- d_{ij} captures the fraction of variable i's $H-$step forecast error variance arising from the shock attributed to variable j.

Pairwise directional connectedness

- d_{ij} represents the pairwise directional connectedness from variable j to variable i

	x_1	x_2	$\cdots$	x_N	From others
x_1	d_{11}	d_{12}	$\cdots$	d_{1N}	$\sum_{j=1}^{N} d_{1j},\ j \neq 1$
x_2	d_{21}	d_{22}	$\cdots$	d_{2N}	$\sum_{j=1}^{N} d_{2j},\ j \neq 2$
$\vdots$	$\vdots$	$\vdots$	$\ddots$	$\vdots$	$\vdots$
x_N	d_{N1}	d_{N2}	$\cdots$	d_{NN}	$\sum_{j=1}^{N} d_{Nj},\ j \neq N$
To others	$\sum_{i=1}^{N} d_{i1}$ $i \neq 1$	$\sum_{i=1}^{N} d_{i2}$ $i \neq 2$	$\cdots$	$\sum_{i=1}^{N} d_{iN}$ $i \neq N$	$\frac{1}{N} \sum_{i,j=1}^{N} d_{ij}$ $i \neq j$

Directional connectedness: 'From' and 'To'

- Total directional connectedness from others to i:

$$C_{i\leftarrow\bullet} = \sum_{j=1, j\neq i}^{N} d_{ij} \qquad (11)$$

- Total directional connectedness to others from j:

$$C_{\bullet\leftarrow j} = \sum_{i=1, i\neq j}^{N} d_{ij} \qquad (12)$$

Total connectedness

- Net total directional connectedness:

$$C_i = C_{\bullet \leftarrow i} - C_{i \leftarrow \bullet} \tag{13}$$

- Total connectedness:

$$C = \frac{1}{N} \sum_{i,j=1, j \neq i}^{N} d_{ij} \tag{14}$$

Data

- CDS spreads, from Datastream
  - $N = 10$ Global Systemically Important Banks (G-SIBs) with CDS contracts
  - Daily data, 20080101 - 20151231 (2088 observations), for each maturity $\tau = (\tau_1, \tau_2, \cdots, \tau_K) = (6M, 1Y, 2Y, 3Y, 4Y, 5Y, 7Y, 10Y, 20Y, 30Y), K = 10$

List of banks

Table 1: Banks

	Institution	Ticker	Country
1	Bank of America	BAC	United States
2	Citygroup	C	United States
3	Goldman Sachs	GS	United States
4	J.P.Morgan	JPM	United States
5	Wells Fargo	WFC	United States
6	Deutsche Bank	DB	Germany
7	Commerzbank	CBG	Germany
8	Barclays Bank	BCS	United Kingdom
9	HSBC Bank	HBC	United Kingdom
10	UBS	UBS	Switzerland

DNS factors

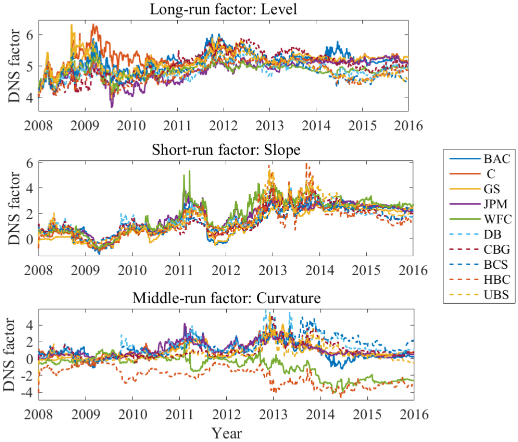


Figure 4: DNS factors with daily period: 2008.01.01 - 2015.12.31.

Static connectedness: Level

Table 2: Static Connectedness: Level factor

	BAC	C	GS	JPM	WFC	DB	CBG	BCS	HBC	UBS	**FROM**
BAC	19.95	14.00	13.27	12.39	12.84	6.79	5.01	5.27	5.06	5.43	80.05
C	16.85	17.91	14.13	13.05	13.47	5.98	4.14	4.76	4.65	5.05	82.09
GS	16.46	18.54	20.03	14.03	14.95	3.58	2.39	2.74	3.48	3.81	79.97
JPM	17.42	17.73	16.22	15.67	15.17	4.12	2.96	3.11	3.76	3.83	84.33
WFC	16.16	16.35	15.05	14.57	15.88	5.27	3.81	3.96	4.38	4.56	84.12
DB	11.82	13.05	12.26	11.61	11.06	12.28	6.50	7.02	6.96	7.45	87.72
CBG	10.29	10.84	10.84	9.81	9.47	12.29	12.49	8.26	7.58	8.13	87.51
BCS	8.84	10.46	10.22	9.57	8.99	12.97	8.40	12.71	8.55	9.29	87.29
HBC	11.37	12.94	12.45	11.48	11.10	10.05	7.05	8.12	7.88	7.56	92.12
UBS	11.27	12.57	11.74	10.89	10.40	10.45	6.03	8.98	7.44	10.23	89.77
TO	120.47	126.48	116.17	107.40	107.44	71.49	46.30	52.23	51.87	55.11	85.50
NET	40.42	44.39	36.20	23.07	23.33	-16.23	-41.22	-35.07	-40.25	-34.65	-

Note: Data period: 2008.01.01 - 2015.12.31 with daily data.

Static connectedness: Slope

Table 3: Static Connectedness: Slope factor

	BAC	C	GS	JPM	WFC	DB	CBG	BCS	HBC	UBS	FROM
BAC	46.65	11.91	8.89	7.71	4.36	4.94	4.66	2.97	4.20	3.72	53.35
C	12.66	15.97	7.80	9.58	9.54	8.19	6.87	7.91	16.05	5.44	84.03
GS	12.20	14.42	9.73	11.00	9.83	9.74	7.55	7.87	10.72	6.93	90.27
JPM	7.00	8.76	3.72	12.13	6.42	10.56	5.48	8.52	33.71	3.70	87.87
WFC	10.08	13.86	6.86	13.84	17.56	8.27	6.26	7.12	10.68	5.48	82.44
DB	8.04	10.09	5.74	9.11	6.73	21.65	10.49	10.29	9.18	8.67	78.35
CBG	6.71	8.88	4.34	9.00	12.05	10.43	10.56	8.14	24.48	5.40	89.44
BCS	6.86	8.93	5.14	7.67	5.07	17.13	13.26	17.49	8.59	9.86	82.51
HBC	3.04	3.73	2.07	3.41	3.00	15.07	9.32	13.14	39.23	8.00	60.77
UBS	6.22	8.11	4.53	7.16	5.41	15.48	11.06	12.36	17.83	11.85	88.15
TO	72.81	88.67	49.09	78.48	62.41	99.81	74.95	78.31	135.43	57.21	79.72
NET	19.46	4.64	-41.18	-9.39	-20.02	21.45	-14.49	-4.20	74.67	-30.94	-

Note: Data period: 2008.01.01 - 2015.12.31 with daily data.

Static connectedness: Curvature

Table 4: Static Connectedness: Curvature factor

	BAC	C	GS	JPM	WFC	DB	CBG	BCS	HBC	UBS	FROM
BAC	22.08	10.89	6.26	6.82	1.19	16.77	9.25	10.36	0.18	16.20	77.92
C	6.40	19.77	7.55	8.62	1.73	16.19	9.16	14.00	2.64	13.94	80.23
GS	10.83	18.24	14.09	9.34	3.53	15.65	7.11	8.35	3.77	9.10	85.91
JPM	14.59	17.26	4.77	31.00	7.07	5.12	3.82	5.56	6.62	4.19	69.00
WFC	5.47	4.60	0.76	8.19	40.90	1.40	0.69	1.69	33.18	3.13	59.10
DB	1.50	5.91	3.35	4.34	0.33	52.11	10.00	11.48	2.57	8.39	47.89
CBG	0.68	2.17	1.16	1.18	0.10	17.45	40.38	10.49	5.35	21.03	59.62
BCS	1.10	5.07	2.60	3.53	0.23	27.17	13.86	29.46	0.12	16.86	70.54
HBC	0.12	2.83	2.80	1.55	0.11	1.71	0.53	2.10	84.39	3.85	15.61
UBS	0.83	5.29	3.53	3.35	0.09	20.97	12.03	17.13	0.35	36.41	63.59
TO	41.52	72.26	32.78	46.92	14.38	122.44	66.45	81.17	54.77	96.69	62.94
NET	-36.40	-7.97	-53.12	-22.09	-44.72	74.55	6.84	10.64	39.17	33.10	-

Note: Data period: 2008.01.01 - 2015.12.31 with daily data.

Static connectedness

- Total connectedness: Long-term > Short-term > Middle-term
- The net effects are mostly positive among US banks while negative among European banks
- There are positive spill-out effects from US banks to European counterparts

Dynamic total connectedness: Level

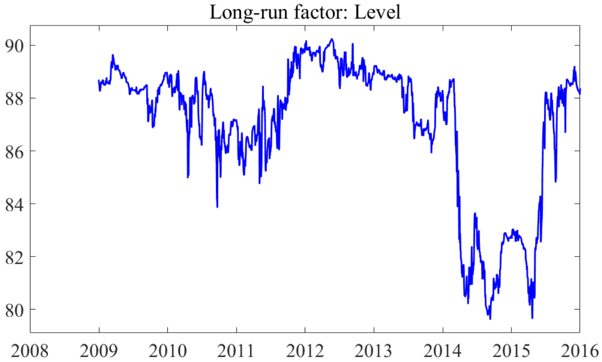


Figure 5: Rolling total connectedness from 2009.01.01 - 2015.12.31 with one-year rolling window estimation (260 observations). Forecast horizon $H = 12$ days.

Dynamic total connectedness: Slope

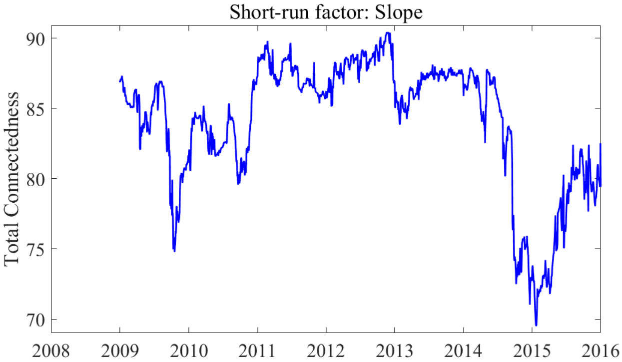


Figure 6: Rolling total connectedness from 2009.01.01 - 2015.12.31 with one-year rolling window estimation (260 observations). Forecast horizon $H = 12$ days.

Dynamic total connectedness: Curvature

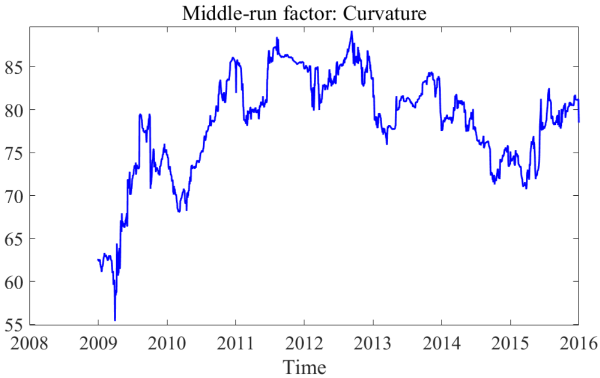


Figure 7: Rolling total connectedness from 2009.01.01 - 2015.12.31 with one-year rolling window estimation (260 observations). Forecast horizon $H = 12$ days.

Dynamic connectedness: Level

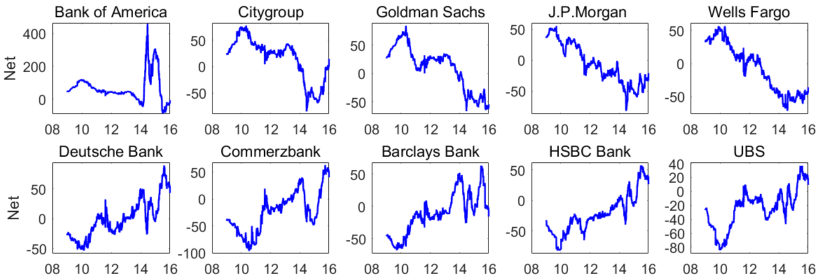


Figure 8: Rolling net connectedness: Level factor

Dynamic connectedness: Slope

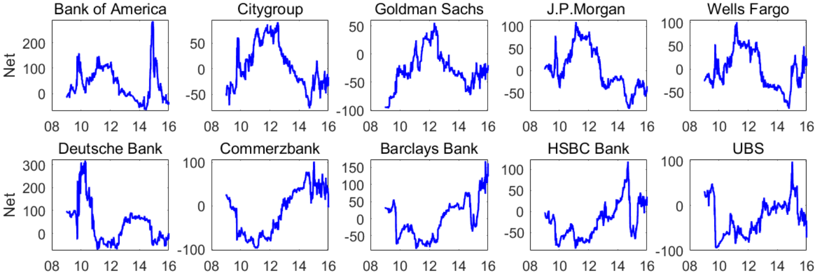


Figure 9: Rolling net connectedness: Slope factor

Dynamic connectedness: Curvature

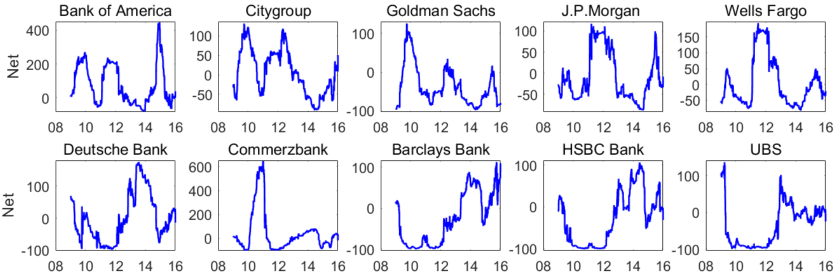


Figure 10: Rolling net connectedness: Curvature factor

Dynamic connectedness

- Net 'To' connectedness from US banks consistently decreases while spill-over risk from European banks uniformly rises up, especially in the long term.
- In the short term, it reveals a similar pattern after certain lags.
- Bank of America (BAC) is a significant risk transmitter in 2014-2015:
  - Due to the 2008 acquisition of Countrywide Finance, BAC took huge losses on distressed Countrywide mortgages.
  - In March, 2014, it announced an unexpected $6 billion in mortgage related legal expenses.
  - Another $16 billion in penalties in August.
  - In April, BAC disclosed a significant accounting error of $4 billion capital loss undetected for several years, which felled bank shares by over 6%.
  - It panicly stroke investors and simultaneously triggered large shocks to other financial institutions.

Pairwise directional connectedness: Level

Figure 11: Node size indicates the "TO connectedness", and edge thickness indicates the average edge weight.

Pairwise directional connectedness: Slope

Figure 12: Node size indicates the "TO connectedness", and edge thickness indicates the average edge weight.

Pairwise directional connectedness: Curvature

L-connectedness across US and Europe

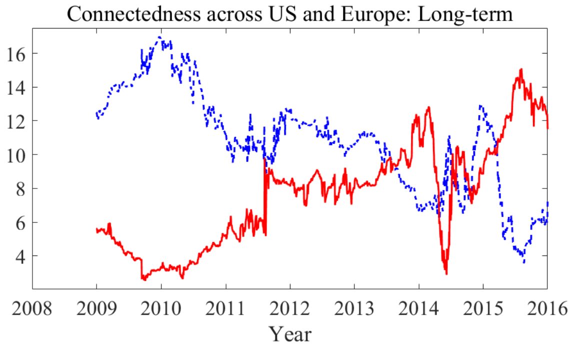


Figure 13: Long-term connectedness across US and Europe. The blue dashed line denotes From US to Europe; the red line denotes From Europe to US.

S-connectedness across US and Europe

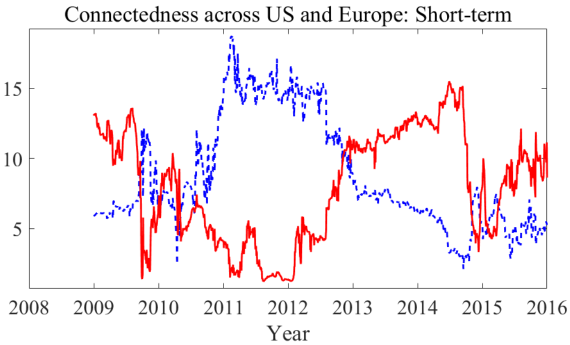


Figure 14: Short-term connectedness across US and Europe. The blue dashed line denotes From US to Europe; the red line denotes From Europe to US.

C-connectedness across US and Europe

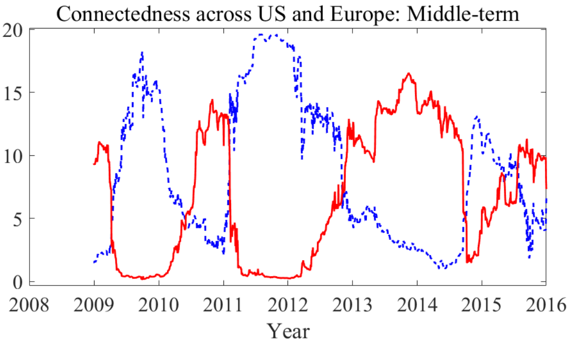


Figure 15: Middle-term connectedness across US and Europe. The blue dashed line denotes From US to Europe; the red line denotes From Europe to US.

What drives total connectedness?

- Regress on macro variables:

$$C_{\omega,t} = \alpha_\omega + \beta_\omega^\top M_{t-1} + \varepsilon_{\omega,t}, \quad \varepsilon_{\omega,t} \sim \mathrm{N}(0, \sigma^2) \tag{15}$$

where $C_{\omega,t}$ total connectedness, $\omega = \{l, s, c\}$.
M_{t-1} state variables.

State variables

M_t, 8 state variables, see also Adrian and Brunnermeier (2016)

1. Change in the three-month yield
2. Change in the slope of the yields curve
3. Short term 'TED spread' - short-term funding liquidity risk
4. Change in the credit spread
5. Market return of S&P500
6. Excess return of real estate sector over financial sector
7. VIX
8. Common principal components (CPC) variance explained

CPC of CDS spreads

- For covariance matrices across maturities of each firm i, Ψ_i, the CPC model hypothesis:

$$H_{CPC}: \Psi_i = \Gamma \Lambda_i \Gamma^\top, \; i = 1, ..., N \tag{16}$$

  - Ψ_i are $K \times K$ positive definite covariance matrices;
  - $\Gamma = (\gamma_1, ..., \gamma_K)$ is an $K \times K$ orthogonal eigenvector matrix;
  - $\Lambda_i = \text{diag}(\lambda_{i1}, ..., \lambda_{iK})$ is the diagonal matrix of eigenvalues.

- Variance explained by the first common principle component

Summary of variables

Table 5: Summary of variables

	Mean	Std. Dev.	Skewness	Kurtosis	Min	Max
Total connectedness: Level	86.99	2.63	-1.26	3.47	79.61	90.26
Total connectedness: Slope	84.07	4.60	-1.15	3.49	69.52	90.44
Total connectedness: Curvature	78.37	6.09	-0.88	3.66	55.39	89.18
Three month yield change	0.01	1.18	0.22	7.84	-7.00	6.00
Term spread change	0.00	5.76	-0.15	6.24	-48.00	25.00
TED spread	29.35	19.21	2.85	11.67	8.76	133.50
Credit spread change	-0.15	2.78	0.34	11.46	-14.00	28.00
Market return	0.05	1.11	-0.27	7.69	-6.90	6.84
Real estate excess return	0.00	0.93	0.01	10.92	-6.00	6.98
VIX	20.17	8.04	1.58	5.27	10.32	56.65
CPC factor variance explained	50.77	15.06	0.26	2.69	13.35	92.64

Note: Data period: 2009.01.01 - 2015.12.31 with daily data. The change, return data, and CPC factor variance explained are in percentage.

Drivers of total connectedness

Table 6: Drivers of total connectedness

	Level		Slope		Curvature	
	NW	HH	NW	HH	NW	HH
Three month yield	0.010	0.010	-0.007	-0.007	-0.003	-0.003
change	(0.682)	(0.590)	(-0.490)	(-0.385)	(-0.197)	(-0.184)
Term spread	-0.016	-0.016	-0.009	-0.009	0.001	0.001
change	(-0.888)	(-0.746)	(-0.453)	(-0.406)	(0.025)	(0.026)
TED spread	0.125***	0.125**	0.153***	0.153**	-0.363***	-0.363***
	(2.483)	(1.906)	(3.286)	(2.289)	(-4.473)	(-5.811)
Credit spread	0.056***	0.056**	0.044**	0.044*	0.042*	0.042*
change	(3.035)	(2.107)	(2.108)	(1.631)	(1.543)	(1.644)
Market return	-0.046***	-0.046**	-0.018	-0.018	-0.022	-0.022
	(-2.550)	(-2.082)	(-0.953)	(-0.805)	(-0.954)	(-1.044)
Real estate excess	-0.005	-0.005	-0.021	-0.021	-0.023	-0.023
return	(-0.260)	(-0.213)	(-1.061)	(-0.950)	(-1.078)	(-1.110)
VIX	0.298***	0.298***	-0.010	-0.010	-0.120*	-0.120**
	(4.886)	(4.545)	(-0.170)	(-0.151)	(-1.428)	(-1.924)
CPC factor	0.303***	0.303***	0.434***	0.434***	0.260***	0.260***
variance explained	(7.996)	(8.543)	(11.793)	(11.994)	(9.119)	(7.677)
Adjusted R^2 (%)	23.04	23.04	19.91	19.91	29.79	29.79

Note: $***$, $**$, $*$ denotes the significance at the level of 10%, 5% and 1% respectively. 'NW' presents that the t-statistics displayed in parentheses are calculated by Newey-West standard errors allowing for up to 5 periods of autocorrelation. 'HH' represent the t-statistics displayed in parentheses are calculated by Hansen and Hodrick (1978) standard errors with 5 periods of lag.

Forecasting model

- CDS spreads forecast at horizon h

$$\widehat{y}_{i,t+h|t}(\tau) = \widehat{\alpha}_{i1,t+h|t} + \widehat{\alpha}_{i2,t+h|t}\left\{\frac{1-\exp(-\delta\,\tau)}{\delta\,\tau}\right\} + \widehat{\alpha}_{i3,t+h|t}\left\{\frac{1-\exp(-\delta\,\tau)}{\delta\,\tau} - \exp(-\delta\,\tau)\right\} \quad (17)$$

where $\widehat{\alpha}_{is,t}, s = 1,2,3$ denotes l_{it}, s_{it}, c_{it} respectively,

- Without other banks (DNS-AR(1))

$$\widehat{\alpha}_{is,t+h|t} = \widehat{c}_{is} + \widehat{\gamma}_{is}\,\widehat{\alpha}_{is,t} \quad (18)$$

- With other banks (DNS-VAR(1))

$$\widehat{\alpha}_{is,t+h|t} = \widehat{c}_{is} + \widehat{\gamma}_{is}\,\widehat{\alpha}_{is,t} + \widehat{\phi}_{js}\,\widehat{\alpha}_{js,t}, j \neq i \quad (19)$$

Out of sample forecast

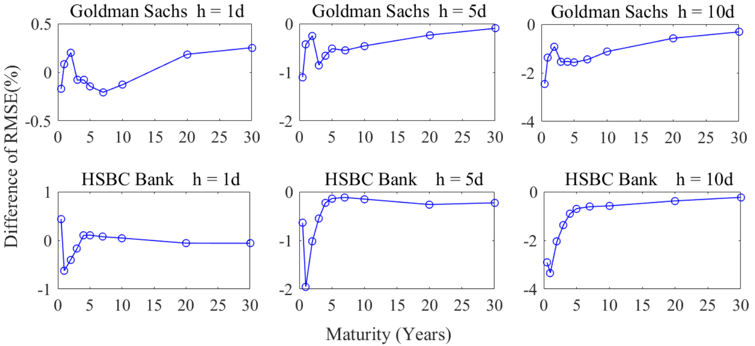


Figure 16: Difference of RMSE of CDS spreads forecast between network DNS model and DNS model. The forecast period is 2011.01.01 - 2013.12.31.

Out of sample forecast

Table 7: US and EU: difference of RMSE

	h	6M	1Y	2Y	3Y	4Y	5Y	7Y	10Y	20Y	30Y
	1d	0.156	0.029	0.094	-0.031	-0.102	-0.076	-0.029	-0.026	0.158	0.198
US	5d	-0.132	-0.235	-0.116	-0.356	-0.318	-0.108	0.140	-0.037	-0.031	0.092
	10d	-0.609	-0.637	-0.209	-0.480	-0.597	-0.566	-0.161	-0.290	-0.121	0.111
	1d	0.264	-0.162	-0.110	-0.027	0.091	0.022	-0.018	-0.041	0.048	0.081
EU	5d	-0.486	-0.973	-0.516	-0.318	-0.058	-0.098	-0.237	-0.354	-0.174	-0.011
	10d	-1.580	-1.388	-0.685	-0.446	-0.388	-0.524	-0.700	-0.804	-0.309	-0.014

Note: RMSE difference of CDS spreads forecast between network DNS model and DNS model. The values of US and EU banks are averaged in total. The forecast period is 2011.01.01 - 2013.12.31.

Out of sample forecast

Table 8: Forecast comparison: DM test (1 day)

h	6M	1Y	2Y	3Y	4Y	5Y	7Y	10Y	20Y
					1d				
BAC	1.036	2.356**	0.703	-2.514**	-2.105**	-2.954***	-2.389**	-1.286	3.402***
C	3.259***	-2.933***	-1.270	-3.529***	0.156	3.543***	4.836***	4.593***	-0.968
GS	-3.290***	1.906*	4.159***	-2.043**	-2.034**	-3.774***	-6.257***	-3.802***	5.118***
JPM	3.202***	-2.067**	-4.887***	-7.285***	0.754	4.240***	4.331***	1.772*	1.666*
WFC	1.437	3.347***	7.637***	6.896***	-4.741***	-9.662***	-5.940***	-4.403***	10.599***
DB	2.859***	-2.218**	-4.947***	-6.677***	2.902***	4.732***	4.827***	2.006**	-1.064
CBG	-2.258**	4.540***	4.045***	3.719***	0.560	-4.488***	-4.772***	-1.648*	4.138***
BCS	7.258***	-6.434***	-6.738***	-0.524	8.014***	7.809***	2.624***	-1.156	-0.406
HBC	3.041***	-6.318***	-5.654***	-2.964***	2.325**	2.404**	2.195**	1.939*	-3.762***
UBS	-0.533	2.535**	3.148***	2.773***	-3.367***	-4.665***	-6.062***	-7.829***	7.208***

Note:

- The value is t-statistics of Diebold-Mariano test, $H_0 : \mu = 0$ in the regression $e^2_{t,net} - e^2_t = \mu + \varepsilon_t$, where $e_{t,net}$ and e_t denote the forecast error of network DNS model and DNS model respectively.
- The test is modified with robust Newey-West variances for heteroscedasticity and autocorrelation with the lags equal to the forecast horizon.
- $*$, $**$, $***$ denotes a significance level of 1%, 5%, and 10%.
- The forecast period is 2011.01.01 - 2013.12.31.

Out of sample forecast

Table 9: Forecast comparison: DM test (5 days and 10 days)

h	6M	1Y	2Y	3Y	4Y	5Y	7Y	10Y	20Y
					5d				
BAC	0.027	0.242	-0.763	-1.618	-0.896	-0.911	-0.362	-0.615	-0.479
C	0.178	-2.284**	-2.459**	-2.490**	0.840	3.394***	4.498***	3.255***	-1.285
GS	-2.329**	-1.035	-0.656	-2.747***	-2.316**	-1.811*	-2.223**	-1.913*	-0.996
JPM	0.348	-0.660	-1.559	-2.667***	-1.047	0.560	1.347	-0.155	-0.599
WFC	0.124	0.863	2.756***	2.576***	-1.383	-3.892***	-2.022**	-1.570	2.431**
DB	-0.572	-1.703*	-2.158**	-2.799***	-0.073	0.421	0.415	-1.344	-2.286**
CBG	-2.955***	-1.140	-1.377	-1.104	-1.050	-1.748*	-2.187**	-1.625	-0.613
BCS	0.976	-2.924***	-2.126**	-0.141	1.372	1.414	-0.485	-1.840*	-0.852
HBC	-0.993	-3.938***	-2.475**	-1.690*	-0.944	-0.530	-0.559	-0.930	-1.994**
UBS	-0.891	0.571	1.185	0.847	-0.731	-1.839*	-2.878***	-2.929***	1.124
					10d				
BAC	-0.219	-0.130	-0.349	-0.778	-0.779	-0.958	-0.503	-0.583	-0.438
C	-0.760	-2.301**	-1.992**	-1.955*	-0.107	1.855*	2.939***	2.075**	-0.405
GS	-1.896*	-1.153	-0.888	-1.851*	-2.224**	-2.579***	-2.751***	-2.149**	-1.096
JPM	0.031	-0.726	-1.051	-1.710*	-0.890	-0.301	0.041	-0.807	-0.771
WFC	0.111	0.588	2.065**	2.056**	-0.140	-2.124**	-1.075	-0.871	1.405
DB	-1.265	-1.098	-0.891	-1.489	-0.981	-0.972	-0.782	-2.014**	-1.792*
CBG	-2.696***	-1.534	-1.379	-1.079	-0.985	-1.220	-1.464	-1.299	-0.787
BCS	-0.295	-1.843*	-1.256	-0.170	-0.154	-0.789	-2.253**	-3.134***	-0.901
HBC	-2.296**	-3.564***	-2.595***	-2.037**	-1.758*	-1.426	-1.555	-1.750*	-1.405
UBS	-0.964	0.029	0.614	0.609	-0.127	-1.086	-2.235**	-2.289**	0.780

Summary

- Default intensity network are inter-temporal various
  - Long-, short- and middle-run factors are distracted among Global bank default intensity.
  - Total long-run connectedness are relatively large
- US and European bank default risks are dynamically intertwined
  - US banks have relatively larger fallout effects to European banks overall, which is reverse during European sovereignty debt crisis period
- Time varying PD connectedness serves as an indicator for systemic risk.
  - The TED spread, credit spread and VIX are main determinants.

Default intensities in a network perspective

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References

Adrian, T. and Brunnermeier, M. K.
CoVaR
American Economic Review **106**(7): 1705–1741, 2016

Diebold, F.X. and Yilmaz, K.
On the network topology of variance decompositions: Measuring the connectedness of financial firms
Journal of Econometrics **182**(1): 19–134, 2014

References

Diebold, F.X. and Li, C.
Forecasting the term structure of government bond yields
Journal of Econometrics **14**(4): 337–364, 2006

Duan, J.-C. and Fulop, A.
Multiperiod corporate default prediction with the partially-conditioned forward intensity
Working paper

References

Duan, J.-C. and Sun, J. and Wang, T.
Multiperiod corporate default prediction—a forward intensity approach
Journal of Econometrics **170**(1): 191–209, 2012

Duffie, D., Saita, L. and Wang, K.
Multi-period corporate default prediction with stochastic covariates
Journal of Financial Economics **83**(3): 635–665, 2007

Lee, S.H. and Urrutia, J.L.
Analysis and prediction of insolvency in the property-liability insurance industry: a comparison of logit and hazard models
The Journal of Risk and Insurance **63**(1): 121–130, 1996

References

Nelson, C.R. and Siegel, A.F.
Parsimonious modeling of yield curves
The Journal of Business **60**(4): 473–489, 1987

Kuan, C.M., Yeh, J.H. and Hsu, Y.C.
Assessing value at risk with CARE, the Conditional Autoregressive Expectile models
Journal of Econometrics **150**(2): 261–270, 2009

References

Ohlson, J.A.
Financial ratios and the probabilistic prediction of bankruptcy
Journal of Accounting Research **18**(1): 109–131, 1980

Orth, W.
Multi-period credit default prediction with time-varying covariates
Journal of Empirical Finance **21**(C): 214–222, 2013

References

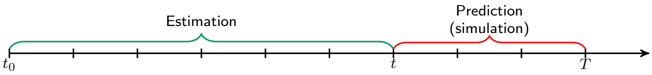
Prastyo, D.D and Härdle, W.K.
Localising forward intensities for multiperiod corporate default
SFB working paper, 2014

Shumway, T.
Forecasting bankruptcy more accurately: a simple hazard model
The Journal of Business **74**(1): 101–124, 2001

Duffie et al. (2007)

Return

- Specify $\lambda_t = \exp(c + \alpha^\top u_t + \beta^\top y_t)$
  - Macro factors: $u_t = (u_{1t}, \dots, u_{kt})^\top$
  - Firm-specific factors: $y_t = (y_{1t}, \dots, y_{mt})^\top$
  - Intercept c, α, β constant over time and across firms
- Simulation of λ_t necessary for multi-period prediction
- Time series models for u_t and y_t required
- Models for u_t and y_t estimated for each company ($n \approx 3000$)



Duan et al. (2012)

Return

- Survival and default probabilities with forward intensity

$$S_t(T) = \exp\left\{-\int_t^T \lambda_t(s)\,ds\right\} \tag{20}$$

$$PD_t(T) = \int_t^T \exp\left\{-\int_t^s \lambda_t(u)\,du\right\}\lambda_t(s)\,ds \tag{21}$$

where default *forward* intensity $\lambda_t(s)$ represents the counterpart λ_s at time of default s, $s > t$.

Duan et al. (2012)

Return

- Model forward intensity directly,

$$\lambda_t(s) = \exp\{c + \alpha(s)^\top u_t + \beta(s)^\top y_t\}$$

- Covariates u_t, and y_t equivalent to Duffie et al. (2007)
- No need for time series model of $(u_t, y_t)^\top$
- Loadings $\alpha(s)$ and $\beta(s)$ depend only on prediction horizon
- Direct estimation of $\alpha(s)$ and $\beta(s)$ via qML
- Parameters: $(1 + m + k) \cdot 2 \cdot 37$

Dynamic Nelson-Siegel model

Return

- Dynamic version of Nelson et al. (1987) yield curve model by Diebold et al. (2006)
- Curve dynamics driven by three latent factors:
  - *level*: L_t, long-term factor
  - *slope*: S_t, short-term factor
  - *curvature*: C_t, middle-term factor
- Latent factors identified as the first three principal components of yields

▸ Return

- Spot yield curve given by

$$y_t(T) = L_t + S_t \left[\frac{1 - \exp\{-(T-t)\,\delta\}}{(T-t)\,\delta} \right] + C_t \left[\frac{1 - \exp\{-(T-t)\,\delta\}}{(T-t)\,\delta} - \exp\{-(T-t)\,\delta\} \right], \tag{22}$$

  where δ is called *decay* factor and T is the maturity

- The forward curve is given by

$$F_t(T) = y_t(T) + y_t'(T)\,(T-t) \tag{23}$$

$$= L_t + S_t \exp\{-(T-t)\,\delta\} + C_t\,\delta\,(T-t) \exp\{-(T-t)\,\delta\}. \tag{24}$$

Deutsche Bank (DB): CDS spreads

DNS model

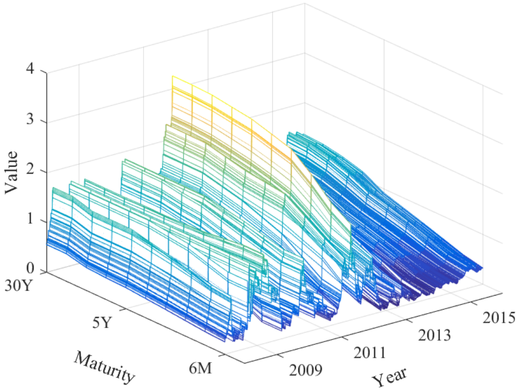


Figure 17: CDS spreads $y_t(\tau)$ for Deutsche Bank

DB: factor loadings

▸ DNS model

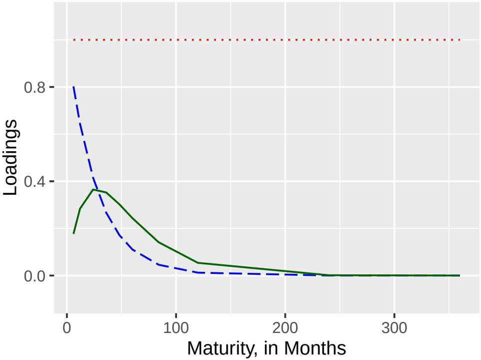


Figure 18: Factor loadings of CDS term structure, $\delta = 0.037$

DB: DNS factors

▸ DNS model

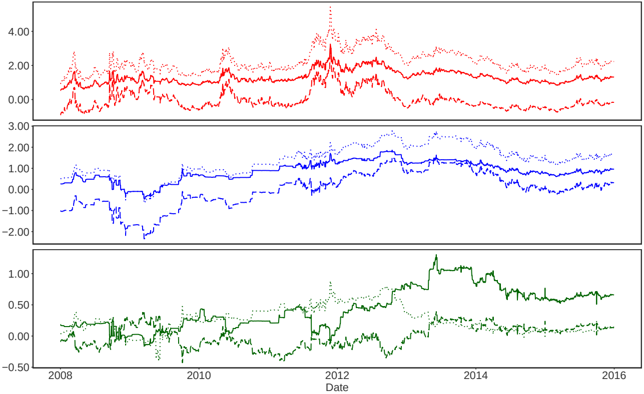


Figure 19: Solid: l_t, $-s_t$, c_t ; Dotted: Level, $y_t(10y)$, Slope, $y_t(10y) - y_t(6m)$, Curvature, $y_t(5y) - 0.5\{y_t(10y) + y_t(6m)\}$; Dashed: PC1, PC2, PC3

DB: fitted CDS spreads

▸ DNS model

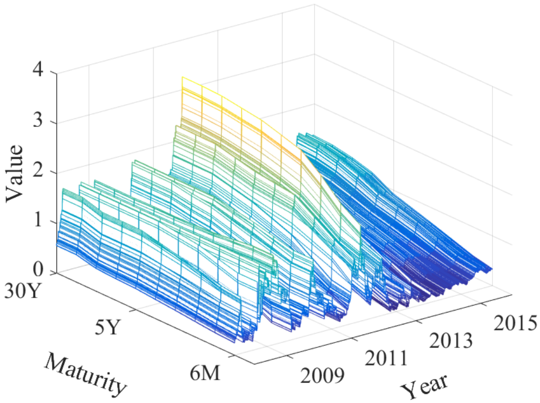


Figure 20: Fitted CDS spreads $\widehat{y}_t(s)$

DB: estimated residuals

DNS model

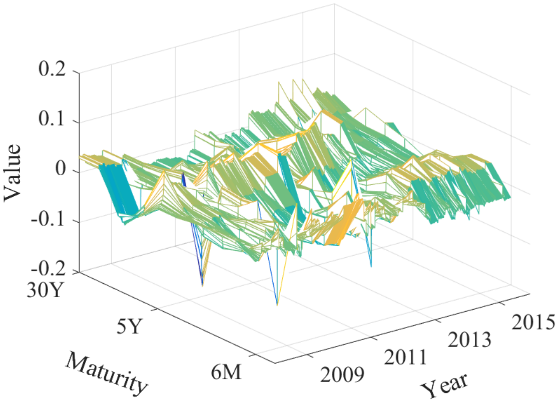


Figure 21: Estimated residuals

DB: residual statistics

▸ DNS model

Table 10: In-sample residuals of the fitted DNS model

s	Mean	Std	Min	Max	MAE	RMSE
6M	0.0040	0.0262	-0.0884	0.0816	0.0226	0.0265
1Y	-0.0019	0.0248	-0.1434	0.1119	0.0210	0.0249
2Y	-0.0042	0.0284	-0.0712	0.0554	0.0247	0.0287
3Y	-0.0077	0.0188	-0.0589	0.0579	0.0152	0.0203
4Y	-0.0006	0.0208	-0.0399	0.0751	0.0160	0.0208
5Y	0.0174	0.0376	-0.1800	0.0890	0.0340	0.0415
7Y	0.0022	0.0185	-0.0524	0.0486	0.0151	0.0186
10Y	-0.0049	0.0214	-0.0717	0.0516	0.0136	0.0219
20Y	-0.0070	0.0167	-0.0377	0.0351	0.0145	0.0181
30Y	0.0028	0.0205	-0.0432	0.0736	0.0181	0.0207