GRADUATE SCHOOL OF BUSINESS

Prepared for 2014 Financial Stability Conference

A Liquidity Index

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Motivation

- Extreme liquidity cases
  - Lehman
    - $4 on Friday, bankruptcy on Sunday
    - Summer trouble started
    - Prior to Labor day talked to KDB
    - Tuesday (9/9) stock fell 45%
    - Thursday (9/11) JPM demanded $3 bn
  - Bear
    - March 14, 2008: Bailout talk began, stock at $30
    - March 16: $2
    - March 17: $10
  - Starr-Merrill $30.6 billion Deal (7¢ out of $1)
  - Buffett buying GS $115
  - AIG
  - Wachovia
  - Morgan Stanley's spread is 10%

Motivation

- Liquidity and systemic risk
  - Three types of systemic risk ("Systemic Risk: A Survey" by the European Central Bank in 2000)
    - bank run
    - contagion
    - failure in interbank systems
  - Fourth kind -- liquidity-induced systemic risk
    - Allen and Carletti (2013, JMCB)
    - Shin (2009, JEP)
    - Adrian and Shin (2010, FED)
- Simultaneous (drastic) price falls (Allen and Carletti)
  - price co-movements
    - Binici, Köksal and Orman (2013): Turkish banking system
  - correlation
    - Huang, Zhou, and Zhu (2009): asset correlation

Liquidity Quantification Model

- How much discount should be applied due to lack of liquidity?
  - How to devise a model that can generate 93% discount?
  - no current market risk model can
  - no diffusion model can
- Can this model explain the recent crisis?
- Can this model be used for analyzing systemic risk?

Liquidity Quantification Model

- Gamma analogy
  - Perfect liquidity = delta hedging
  - Example: ATM option near maturity
    - Always sells when price is low (b/c delta is low)
    - Always buys when price is high (b/c delta is high)
  - Money lost = liquidity premium
  - Higher gamma securities ~ higher liquidity risk
- Demand/Supply squeeze
  - Liquidity is option
- Theoretical framework
  - Equilibrium pricing
  - An example
  - CAPM for the utility
- Combined with structural credit models

Liquidity Quantification Model

- Basic approach
  - pricing kernel

$$C_t^{(n)} = \mathbb{E}_t^{(n)}[M_{t,T} C_T]$$

Liquidity Quantification Model

- Basic approach
  - pricing kernel

$$C_t^{(n)} = \mathbb{E}_t^{(n)}[M_{t,T}C_T]$$

$$\begin{cases} C_t^{(1)} = \mathbb{E}_t^{(1)}[M_{t,T}C_T] = e^{-k(T-t)}\mathbb{E}_t^{(1)}[\max\{S_T - K, 0\}] \\ C_t^{(\infty)} = \mathbb{E}_t^{(\infty)}[M_{t,T}C_T] = e^{-r(T-t)}\hat{\mathbb{E}}_t[\max\{S_T - K, 0\}] \end{cases}$$

Liquidity Quantification Model

- Basic approach
  - pricing kernel

$$C_t^{(n)} = \mathbb{E}_t^{(n)}[M_{t,T}C_T]$$

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$$C_t^{(1)} = \frac{1}{P_{t,T}} + \beta_{t,T}^{\$}\left[\mathbb{E}_t^{(1)}[S_T] - \frac{1}{P_{t,T}}\right]$$

$$k = r + \beta_{t,T}(\mu - r)$$

$$\beta_{t,T} = \frac{S_t}{C_t}\frac{\mathrm{cov}[C_T, S_T]}{\mathrm{cov}[S_T]}$$

Liquidity Quantification Model

- Basic approach
  - pricing kernel

$$C_t^{(n)} = \mathbb{E}_t^{(n)}[M_{t,T}C_T]$$

$$\begin{cases} C_t^{(1)} = \mathbb{E}_t^{(1)}[M_{t,T}C_T] = e^{-k(T-t)}\mathbb{E}_t^{(1)}[\max\{S_T - K, 0\}] \\ C_t^{(\infty)} = \mathbb{E}_t^{(\infty)}[M_{t,T}C_T] = e^{-r(T-t)}\hat{\mathbb{E}}_t[\max\{S_T - K, 0\}] \end{cases}$$

$$C_t^{(1)} = \frac{1}{P_{t,T}} + \beta_{t,T}^{\$}\left[\mathbb{E}_t^{(1)}[S_T] - \frac{1}{P_{t,T}}\right]$$

$$k = r + \beta_{t,T}(\mu - r)$$

$$\beta_{t,T} = \frac{S_t}{C_t}\frac{\mathrm{cov}[C_T, S_T]}{\mathrm{cov}[S_T]}$$

$$\boxed{\begin{cases} C_{t_i} = P_{t_i,t_{i+1}}\left(\mathbb{E}[C_{t_{i+1}}] - \beta_i^{\$}\left\{\mathbb{E}[S_{t_{i+1}}] - \frac{1}{P_{t_i,t_{i+1}}}S_{t_i}\right\}\right) \\ C_t^* = P_{t,T}\left(\mathbb{E}[C_T] - \beta^{\$}\left\{\mathbb{E}[S_T] - \frac{1}{P_{t,T}}S_t\right\}\right) \end{cases}}$$

Liquidity Quantification Model

	164.8721		164.8721
100.0000		100.0000	
	60.6531		60.6531
	84.8721		84.8721
34.4516		34.4516	
	0.0000		0.0000

		202.8115			202.8115
	142.4119				
100.0000		100.0000		100.0000	100.0000
	70.2189				
		49.3069			49.3069
		122.8115			122.8115
	64.4115				
32.8388		20.0000		31.2232	20.0000
	8.7366				
		0.0000			0.0000

			237.7443		237.7443
		178.1312			
	133.4658		133.4658		133.4658
100.0000		100.0000		100.0000	
	74.9256		74.9256		74.9256
		56.1384			
			42.0620		42.0620
			157.7443		157.7443
		99.4755			
	57.5753		53.4658		53.4658
31.6697		24.0508		29.7762	
	10.8189		0.0000		0.0000
		0.0000			
			0.0000		0.0000

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Liquidity vs. Economic Default

- Equity as a call option
  - single debt: Merton
  - multiple debts:
    - Geske (good)
    - Leland/Leland-Toft (not good)
    - barrier (not good)
- Liquidity default -- accounting default
  - firm does not have enough liquid assets to pay of liabilities due at hand
  - $A^* < K1$
  - firm could default while profitable
- Economic default -- negative equity value
  - firm's total asset value is less than total debt value
  - $A < K1 + D2 + \ldots + Dn$
- $A^* < A$ (liquidity discount model)

Data

- We obtain constituent stocks in Russell 1000 financial sector index
- January 1997 to July 2011, a total of 175 months
- The data are collected from CRSP-CRSP/ COMPUSTAT MERGED
- The sample size varies over time
  - The peak of the sample size (402 banks) is in December 2012 and the bottom of the sample size (189 banks) is in January 1997
  - The average size is 306 banks and median is 308 banks

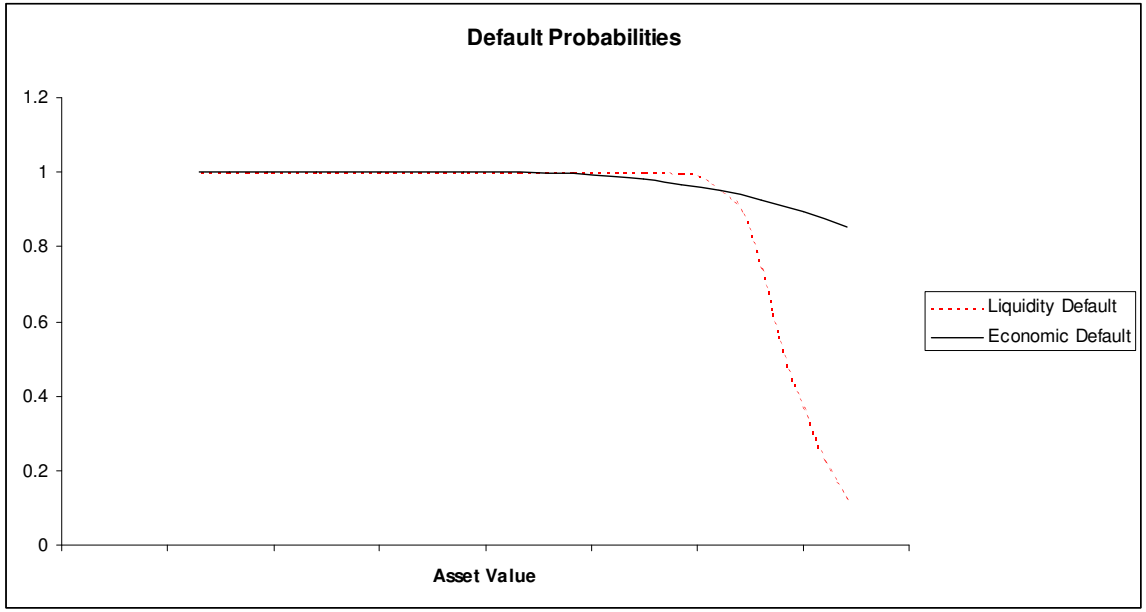
Data

- Commercial
  - US commercial (305/129/229/236)
  - non-US commercial (90/42/64/63)
- Regional
  - eastern (71/35/55/59) Signature Bank
  - southern (108/35/74/75) Citizens Bancorp of Virginia
  - western (58/25/42/45) America California Bank
  - central (70/34/56/59) First Bank of Ohio
  - regional non-US (5/3/4/4)
  - super regional (10/7/7/8) Wells Fargo, Capital One
- Other
  - diversified (18/6/10/11) Bank of America, UBS
  - fiduciary (7/4/5/5) BNY-M
  - mortgage (2/1/1/2)
  - money center (1/1/1/1)
- Total of 8 sectors (max/min/mean/median)

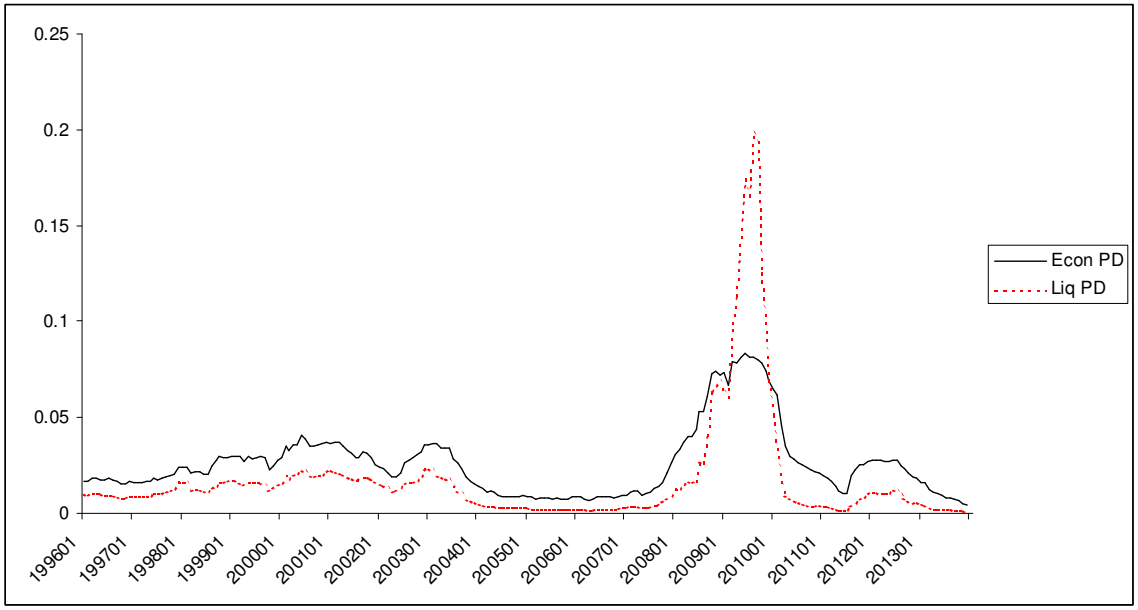
Calibration

- Collect from CompuStat for K1, K2 and set T1=1 and T2=2
- Collect from CRSP market cap (E) and equity volatility (σE)
- Use eqns (6) and $\sigma = \sigma_E \frac{E}{V} \frac{1}{\partial E / \partial V}$ to solve for asset value (A) and asset volatility (σ)
- Use A and σW=0.6 to solve for W
- Use W and σW to solve for A* by setting K=W(1-4(10%-s))
  - where s is the spread computed as log of total market debt value over book debt value
- Compute liquidity index as A*/A

Probability of Default

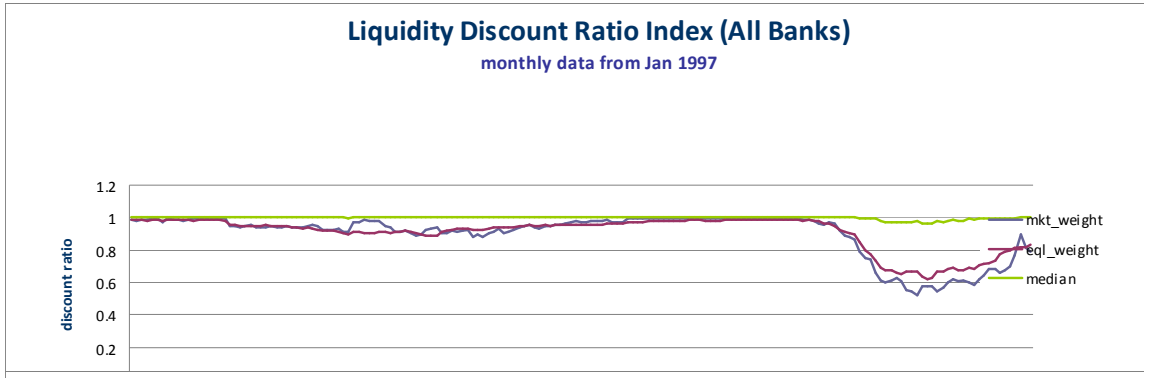


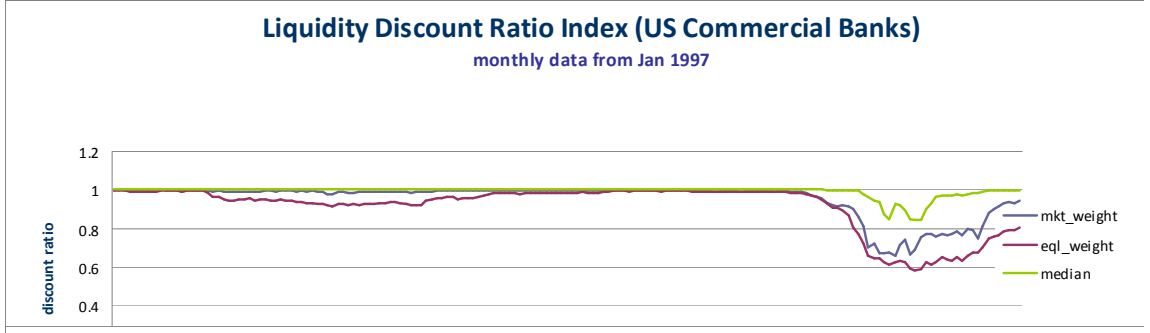
Probability of Default

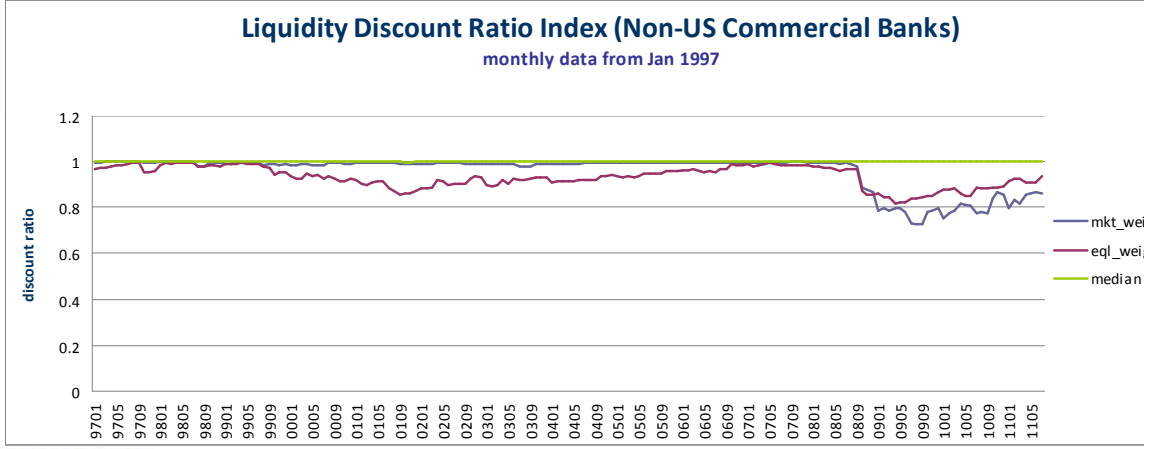


Liquidity Index

All banks

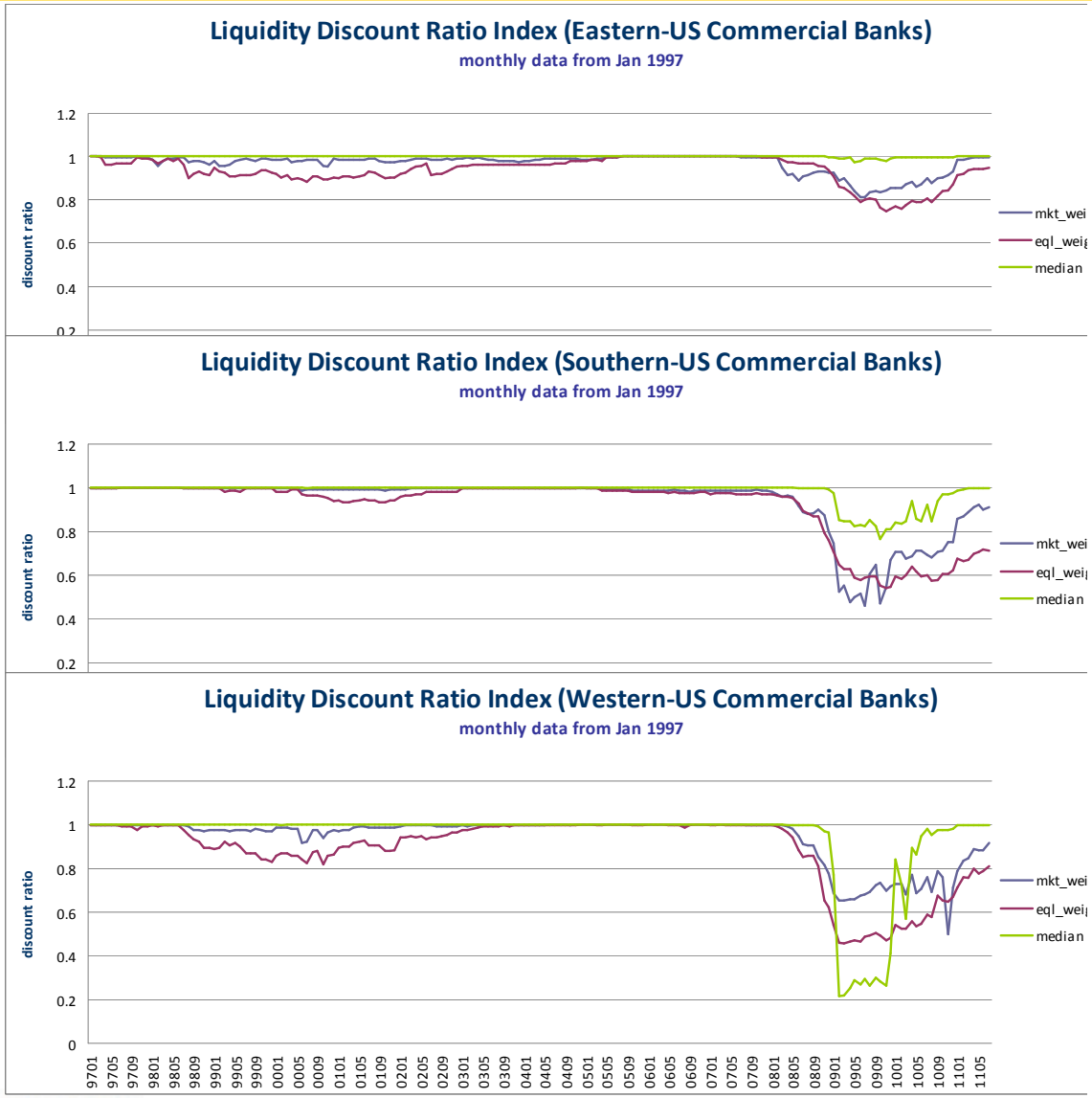






Liquidity Index

Regional banks



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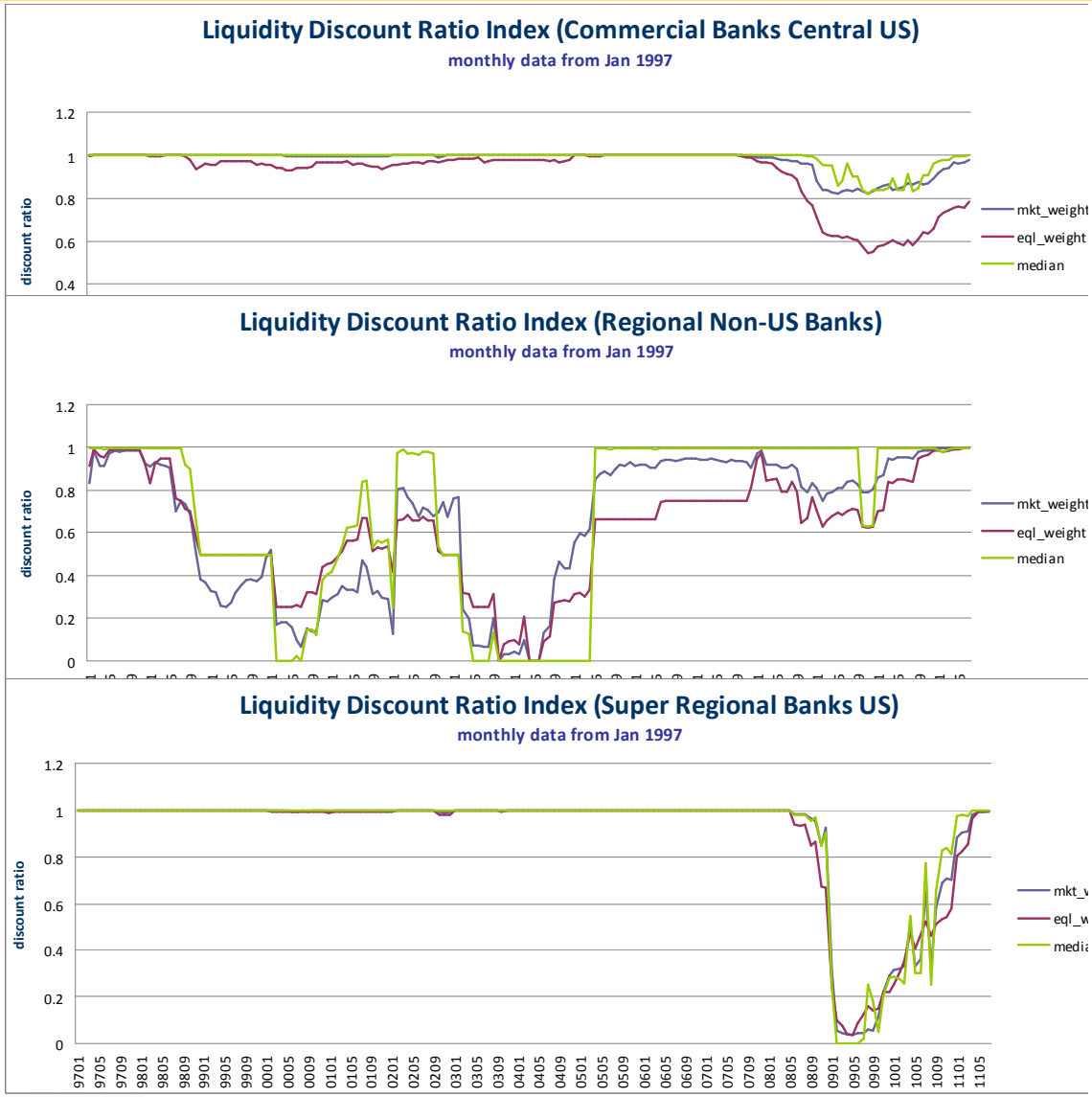
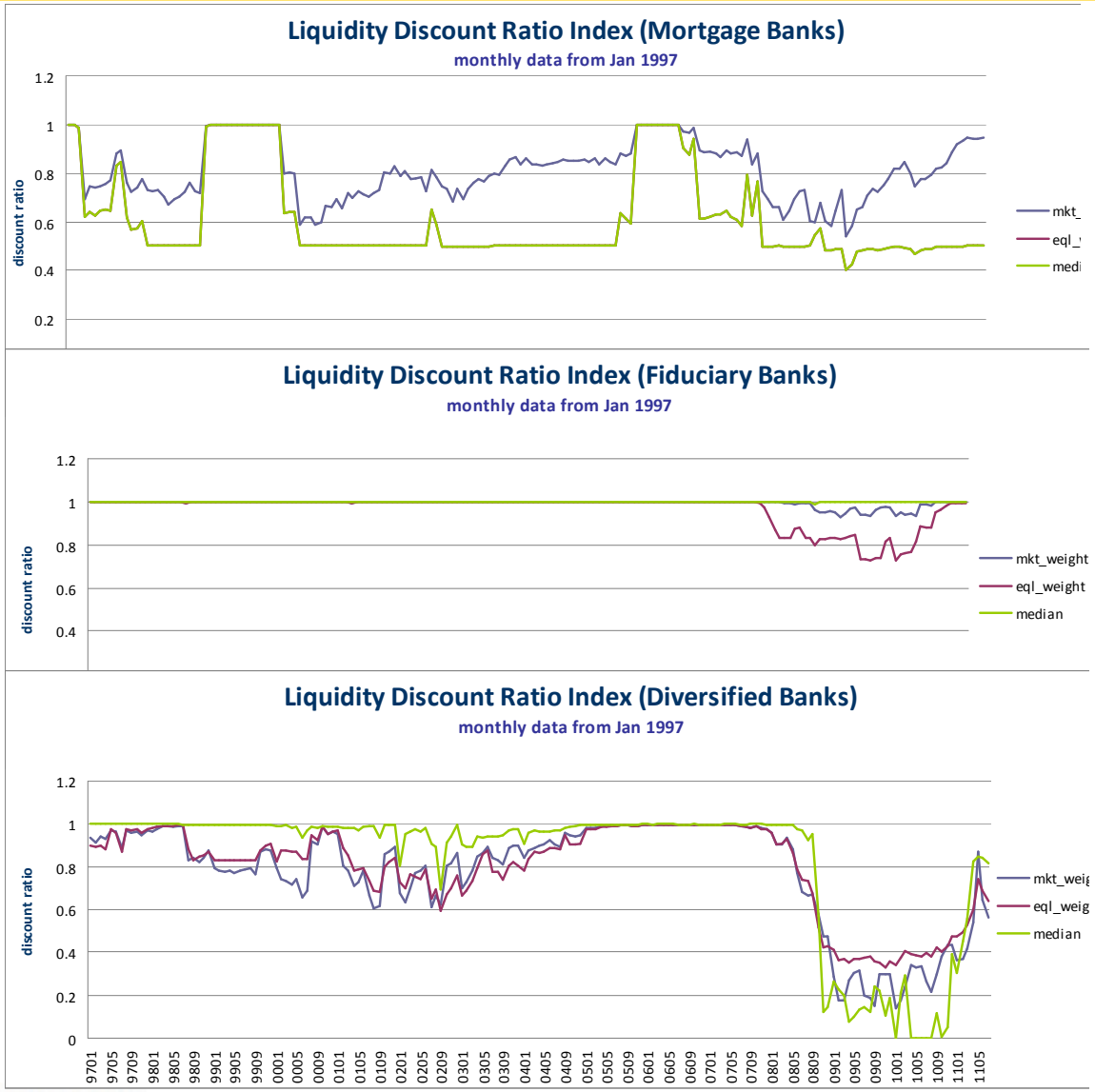
Liquidity Index

Regional banks



Liquidity Index

Special banks



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Liquidity Quantification Model

- Liquidity Discount (%)

	Liquidity Discount By Bank Type							
	central	eastern	non us	southern	western	supper regional	diversifie d	fiduciary
Mean	8.706	6.31	6.709	8.716	11.495	10.863	20.434	3.65
Median	2.935	3.952	6.478	2.167	5.171	0.117	14.122	0.126
Maximum	45.853	25.064	18.309	45.657	54.725	96.541	66.947	27.452
Minimum	0.073	0.067	0.197	0.07	0.076	0.065	0.199	0.066
Std. Dev.	13.427	6.248	4.59	14.077	15.881	25.28	20.572	7.496
Skewness	1.673	1.271	0.459	1.618	1.546	2.284	1.027	1.933
Kurtosis	4.191	3.991	2.32	3.905	4.174	6.768	2.827	5.321
Jarque-Be	91.997	54.251	9.515	82.361	79.782	255.637	30.994	148.304
Probabilit	0	0	0.009	0	0	0	0	0

Implications

- PCA analysis

A: Proportion of Variations Explained by Principal Component							
Using Rolling 3-Year PCA Analysis from Janauary 1997 to July 2(							
Number	Mean	Std Dev	Max	Min	P75	P50	P25
1	0.835	0.131	0.975	0.465	0.951	0.858	0.744
2	0.117	0.101	0.404	0.014	0.19	0.071	0.033
3	0.029	0.03	0.168	0.003	0.033	0.017	0.008
4	0.01	0.007	0.028	0.001	0.015	0.009	0.004
5	0.006	0.006	0.027	0.001	0.008	0.004	0.002
6	0.002	0.002	0.01	0	0.004	0.002	0.001
7	0.001	0.001	0.003	0	0.001	0	0
8	0	0	0	0	0	0	0

Implications

- PCA analysis

B: Marginal Contribution to Variations of 1st PC and Combined 1st and 2r							
	1st PC						
	Mean	Std Dev	Max	Min	P75	P50	P25
central	0.065	0.109	0.917	-0.35	0.113	0.096	0.022
eastern	0.032	0.146	0.2	-0.651	0.124	0.071	0.029
non us	**0.075**	**0.37**	**1.253**	**-3.428**	**0.162**	**0.058**	**0.043**
southern	0.01	0.167	1.267	-0.508	0.101	0.031	-0.059
western	-0.027	0.353	0.32	-2.221	0.157	0.107	-0.009
supper reg	0.068	0.117	0.371	-0.101	0.081	0.006	0
diversifie	**0.75**	**0.778**	**5.924**	**0.043**	**0.731**	**0.563**	**0.308**
fiduciary	0.027	0.051	0.261	-0.003	0.049	0.001	0.001
	Combined 1st PC and 2nd PC						
	Mean	Std Dev	Max	Min	P75	P50	P25
central	0.079	0.058	0.286	-0.082	0.117	0.103	0.036
eastern	0.069	0.086	0.217	-0.174	0.14	0.078	0.035
non us	**0.136**	**0.136**	**0.854**	**-0.269**	**0.172**	**0.099**	**0.048**
southern	0.042	0.099	0.188	-0.315	0.115	0.064	-0.024
western	0.053	0.214	0.367	-0.577	0.163	0.122	-0.002
supper reg	0.067	0.109	0.347	-0.012	0.081	0.009	0.002
diversifie	**0.529**	**0.362**	**1.603**	**0.126**	**0.7**	**0.471**	**0.22**
fiduciary	0.026	0.051	0.264	-0.001	0.049	0.001	0.001

Implications

- Persistence (unit root) test

	Null Hypothesis: A unit root					
	Augmented Dickey-Fuller			Phillips-Perron		
	t-Statistic	Prob.*	Lag	Adj. t-Stat	Prob.*	Bandwidth
2	-1.268	0.188	3	-0.66	0.43	9
3	-1.07	0.257	1	-1.198	0.211	7
4	-0.98	0.292	0	-0.97	0.296	3
5	-0.677	0.423	3	-0.175	0.622	8
6	-1.328	0.17	3	-1.062	0.26	8
7	**-1.988**	**0.045**	2	**-1.777**	**0.072**	8
8	-0.598	0.457	0	-0.613	0.451	3
9	**-3.125**	**0.002**	11	-1.519	0.121	2
*MacKinnon (1996) one-sided p-values.						

Implications

- Co-integration Rank Test (Trace)

A: Unrestricted Cointegration Rank Test (Trace)				
Lags interval: 0				
No. of CE(s)	Eigenvalue	Statistic	Critical Value	Prob.**
None *	0.549	262.317	169.599	0
At most 1	0.201	123.824	134.678	0.181
At most 2	0.145	84.735	103.847	0.454
At most 3	0.134	57.47	76.973	0.581
At most 4	0.081	32.382	54.079	0.835
At most 5	0.046	17.697	35.193	0.855
At most 6	0.042	9.443	20.262	0.694
At most 7	0.011	1.95	9.165	0.788
Trace test indicates 1 cointegrating eqn(s) at the 0.05 level				
* denotes rejection of the hypothesis at the 0.05 level				
**MacKinnon-Haug-Michelis (1999) p-values				

Implications

- Co-integration Rank Test (Trace)

B: Unrestricted Cointegration Rank Test (Trace)				
Lags interval: 1				
No. of CE(s)	Eigen value	Statistic	Critical Value	Prob.**
None *	0.402	232.589	169.599	0
At most 1	0.231	143.538	134.678	0.014
At most 2	0.173	98.083	103.847	0.113
At most 3	0.142	65.155	76.973	0.282
At most 4	0.118	38.631	54.079	0.54
At most 5	0.053	16.817	35.193	0.894
At most 6	0.036	7.428	20.262	0.868
At most 7	0.006	1.008	9.165	0.951
Trace test indicates 2 cointegrating eqn(s) at the 0.05 level				
* denotes rejection of the hypothesis at the 0.05 level				
**MacKinnon-Haug-Michelis (1999) p-values				

Implications

- Co-integration Rank Test (Maximum Eigenvalue)

A: Unrestricted Cointegration Rank Test (Maximum Eigenvalue				
No. of CE(s)	Eigenvalue	Statistic	Critical Value	Prob.**
None *	0.549	138.494	53.188	0
At most 1	0.201	39.089	47.079	0.275
At most 2	0.145	27.265	40.957	0.673
At most 3	0.134	25.088	34.806	0.441
At most 4	0.081	14.684	28.588	0.838
At most 5	0.046	8.254	22.3	0.942
At most 6	0.042	7.493	15.892	0.609
At most 7	0.011	1.95	9.165	0.788
Max-eigenvalue test indicates 1 cointegrating eqn(s) at the 0.05 level				
* denotes rejection of the hypothesis at the 0.05 level				
**MacKinnon-Haug-Michelis (1999) p-values				

Implications

- Co-integration Rank Test (Maximum Eigenvalue)

B: Unrestricted Cointegration Rank Test (Maximum Eigenvalue				
No. of CE(s)	Eigen value	Statistic	Critical Value	Prob.**
None *	0.402	89.051	53.188	0
At most 1	0.231	45.454	47.079	0.074
At most 2	0.173	32.929	40.957	0.299
At most 3	0.142	26.524	34.806	0.344
At most 4	0.118	21.814	28.588	0.286
At most 5	0.053	9.389	22.3	0.879
At most 6	0.036	6.42	15.892	0.74
At most 7	0.006	1.008	9.165	0.951
Max-eigenvalue test indicates 1 cointegrating eqn(s) at the 0.05 level				
* denotes rejection of the hypothesis at the 0.05 level				
**MacKinnon-Haug-Michelis (1999) p-values				

Implications

- Connectivity test (Error Correction Model)

Panel A		central	eastern	non us	southern	western	supper regional	diversified	fiduciary
CointEq1	Coeff	**-0.05**	**-0.046**	-0.014	**-0.068**	**-0.062**	**-0.263**	**-0.076**	**-0.031**
	St error	**-0.01**	**-0.011**	-0.011	**-0.009**	**-0.018**	**-0.032**	**-0.037**	**-0.015**
central (-	Coeff	0.078	0.037	0.043	0.115	0.264	**0.672**	0.053	0.277
	St error	-0.095	-0.102	-0.111	-0.084	-0.169	**-0.311**	-0.358	-0.144
eastern (-	Coeff	0.082	0.124	-0.023	**0.179**	0.062	**0.628**	-0.085	0.158
	St error	-0.082	-0.088	-0.096	**-0.073**	-0.146	**-0.27**	-0.311	-0.125
non us (-1	Coeff	-0.048	-0.056	-0.001	***0.113***	**0.397**	0.047	0.129	0.047
	St error	-0.074	-0.079	-0.086	***-0.065***	**-0.131**	-0.242	-0.279	-0.112
southern (	Coeff	-0.103	***-0.188***	-0.067	**-0.211**	***-0.329***	**-0.765**	-0.502	**-0.585**
	St error	-0.102	***-0.11***	-0.12	**-0.091**	***-0.182***	**-0.336**	-0.387	**-0.155**
western (-	Coeff	-0.02	-0.059	-0.036	**-0.097**	***-0.162***	**-0.41**	-0.033	0.075
	St error	-0.055	-0.059	-0.064	**-0.049**	***-0.098***	**-0.181**	-0.208	-0.083
supper re	Coeff	**0.064**	***0.052***	**0.071**	0.035	***0.089***	-0.013	0.15	***-0.075***
	St error	**-0.026**	***-0.028***	**-0.031**	-0.024	***-0.047***	-0.087	-0.1	***-0.04***
diversifie	Coeff	0.022	-0.003	0.013	**0.04**	0.058	-0.019	-0.038	0.039
	St error	-0.022	-0.024	-0.026	**-0.02**	-0.039	-0.073	-0.084	-0.033
fiduciary (	Coeff	0.053	0.037	**-0.132**	0.045	0.085	-0.27	0.095	***0.15***
	St error	-0.054	-0.057	**-0.063**	-0.048	-0.095	-0.176	-0.202	***-0.081***
R-squared		0.372	0.2	0.081	0.493	0.293	0.396	0.068	0.177
Adj. R-squared		0.342	0.161	0.036	0.469	0.259	0.367	0.022	0.137
F-statistic		12.155	5.141	1.798	19.959	8.496	13.462	1.49	4.414
Log likelihood		-260.855	-272.684	-287.579	-240.239	-360.682	-466.446	-490.837	-332.72
Schwarz SC		3.284	3.421	3.593	3.045	4.438	5.661	5.943	4.115

Implications

- Connectivity test (Error Correction Model)

Panel A		central	eastern	non us	southern	western	supper regional	diversified	fiduciary
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eastern (-	Coeff	0.082	0.124	-0.023	**0.179**	0.062	**0.628**	-0.085	0.158
	St error	-0.082	-0.088	-0.096	**-0.073**	-0.146	**-0.27**	-0.311	-0.125
non us (-1	Coeff	-0.048	-0.056	-0.001	***0.113***	**0.397**	0.047	0.129	0.047
	St error	-0.074	-0.079	-0.086	***-0.065***	**-0.131**	-0.242	-0.279	-0.112
southern (	Coeff	-0.103	***-0.188***	-0.067	**-0.211**	***-0.329***	**-0.765**	-0.502	**-0.585**
	St error	-0.102	***-0.11***	-0.12	**-0.091**	***-0.182***	**-0.336**	-0.387	**-0.155**
western (-	Coeff	-0.02	-0.059	-0.036	**-0.097**	***-0.162***	**-0.41**	-0.033	0.075
	St error	-0.055	-0.059	-0.064	**-0.049**	***-0.098***	**-0.181**	-0.208	-0.083
supper re	Coeff	**0.064**	***0.052***	**0.071**	0.035	***0.089***	-0.013	0.15	***-0.075***
	St error	**-0.026**	***-0.028***	**-0.031**	-0.024	***-0.047***	-0.087	-0.1	***-0.04***
diversifie	Coeff	0.022	-0.003	0.013	**0.04**	0.058	-0.019	-0.038	0.039
	St error	-0.022	-0.024	-0.026	**-0.02**	-0.039	-0.073	-0.084	-0.033
fiduciary (	Coeff	0.053	0.037	**-0.132**	0.045	0.085	-0.27	0.095	***0.15***
	St error	-0.054	-0.057	**-0.063**	-0.048	-0.095	-0.176	-0.202	***-0.081***
R-squared		0.372	0.2	0.081	0.493	0.293	0.396	0.068	0.177
Adj. R-squared		0.342	0.161	0.036	0.469	0.259	0.367	0.022	0.137
F-statistic		12.155	5.141	1.798	19.959	8.496	13.462	1.49	4.414
Log likelihood		-260.855	-272.684	-287.579	-240.239	-360.682	-466.446	-490.837	-332.72
Schwarz SC		3.284	3.421	3.593	3.045	4.438	5.661	5.943	4.115

Implications

- Connectivity test (Error Correction Model)

Panel A		central	eastern	non us	southern	western	supper regional	diversified	fiduciary
CointEq1	Coeff	**-0.05**	**-0.046**	-0.014	**-0.068**	**-0.062**	**-0.263**	**-0.076**	**-0.031**
	St error	**-0.01**	**-0.011**	-0.011	**-0.009**	**-0.018**	**-0.032**	**-0.037**	**-0.015**
central (-	Coeff	0.078	0.037	0.043	0.115	0.264	**0.672**	0.053	0.277
	St error	-0.095	-0.102	-0.111	-0.084	-0.169	**-0.311**	-0.358	-0.144
eastern (-	Coeff	0.082	0.124	-0.023	**0.179**	0.062	**0.628**	-0.085	0.158
	St error	-0.082	-0.088	-0.096	**-0.073**	-0.146	**-0.27**	-0.311	-0.125
non us (-1	Coeff	-0.048	-0.056	-0.001	***0.113***	**0.397**	0.047	0.129	0.047
	St error	-0.074	-0.079	-0.086	***-0.065***	**-0.131**	-0.242	-0.279	-0.112
southern (	Coeff	-0.103	***-0.188***	-0.067	**-0.211**	***-0.329***	**-0.765**	-0.502	**-0.585**
	St error	-0.102	***-0.11***	-0.12	**-0.091**	***-0.182***	**-0.336**	-0.387	**-0.155**
western (-	Coeff	-0.02	-0.059	-0.036	**-0.097**	***-0.162***	**-0.41**	-0.033	0.075
	St error	-0.055	-0.059	-0.064	**-0.049**	***-0.098***	**-0.181**	-0.208	-0.083
supper re	Coeff	**0.064**	***0.052***	**0.071**	0.035	***0.089***	-0.013	0.15	***-0.075***
	St error	**-0.026**	***-0.028***	**-0.031**	-0.024	***-0.047***	-0.087	-0.1	***-0.04***
diversifie	Coeff	0.022	-0.003	0.013	**0.04**	0.058	-0.019	-0.038	0.039
	St error	-0.022	-0.024	-0.026	**-0.02**	-0.039	-0.073	-0.084	-0.033
fiduciary (	Coeff	0.053	0.037	**-0.132**	0.045	0.085	-0.27	0.095	***0.15***
	St error	-0.054	-0.057	**-0.063**	-0.048	-0.095	-0.176	-0.202	***-0.081***
R-squared		0.372	0.2	0.081	0.493	0.293	0.396	0.068	0.177
Adj. R-squared		0.342	0.161	0.036	0.469	0.259	0.367	0.022	0.137
F-statistic		12.155	5.141	1.798	19.959	8.496	13.462	1.49	4.414
Log likelihood		-260.855	-272.684	-287.579	-240.239	-360.682	-466.446	-490.837	-332.72
Schwarz SC		3.284	3.421	3.593	3.045	4.438	5.661	5.943	4.115

Implications

- Connectivity test (Error Correction Model)

Panel B										
Cointegrating Eq:		central	eastern	non us	southern	western	supper regional	diversified	fiduciary	C
CointEq1	Coeff	1	**3.255**	**-0.847**	**1.039**	**-2.439**	**0.454**	-0.158	-1.885	-0.778
	St error		**-0.388**	**-0.329**	**-0.229**	**-0.275**	**-0.109**	-0.119	-0.303	-1.718

Implications

- Causality test

	central		eastern		non us		southern		western		supper regional		diversifiec
Excluded	Chi-sq	Prob.	Chi-sq	Prob.	Chi-sq	Prob.	Chi-sq	Prob.	Chi-sq	Prob.	Chi-sq	Prob.	Chi-sq
central (-1)			0.13	0.719	0.154	0.695	1.876	0.171	2.446	0.118	**4.66**	0.031	0.022
eastern (-	0.996	0.318			0.057	0.812	**6**	0.014	0.178	0.673	**5.419**	0.02	0.076
non us (-1	0.417	0.518	0.507	0.476			2.997	0.083	**9.111**	0.003	0.037	0.847	0.215
southern	1.015	0.314	2.925	0.087	0.31	0.578			***3.259***	0.071	**5.179**	0.023	1.68
western (	0.126	0.722	0.988	0.32	0.32	0.572	3.972	0.046			**5.156**	0.023	0.025
supper re	**5.761**	0.016	***3.312***	0.069	**5.307**	0.021	2.27	0.132	***3.534***	0.06			2.235
diversifie	0.963	0.326	0.02	0.888	0.265	0.607	**4.177**	0.041	2.165	0.141	0.071	0.79	
fiduciary (	0.968	0.325	0.421	0.516	4.468	0.035	0.911	0.34	0.798	0.372	2.356	0.125	0.221
All	10.646	0.155	6.521	0.48	10.367	0.169	**32.881**	0	**29.053**	0	**19.686**	0.006	3.589
Chi-squared test statistics for lag exclusion (DF=8)													
Chi-Squar	16.545		8.122		10.371		33.064		29.125		21.072		3.747
P-Value	0.035		0.422		0.24		0		0		0.007		0.879

Implications

- Causality test

	central	eastern	non us	southern	western	supper regional	diversified	fiduciary
Granger Caused by tl	1	2	2	4	3	4	0	2
Granger Cause the o	1	2	2	5	3	5	1	2
Interconnect	2	4	4	9	6	9	1	4
Influence	0	0	0	1	0	1	1	0

Implications

- Monthly regressions
  - A: IND

	yield_slop	fund_rate	default_p	liq_all	vix_ret	fsi	sen	liq_std	R Square	Adjusted	F test
Coefficier	0.090415	0.052511	-0.00866	-0.00683					0.0892	0.0678	0.0423
T-Statitics	1.6	1.41	-0.11	-1.68							
Coefficier	0.0894	0.052175	-0.00767	-0.00691	-0.07676				0.0574	0.0295	0.0729
T-Statitics	1.58	1.4	-0.1	-1.69	-0.47						
Coefficier	0.20492	0.136806	0.477695	-0.00373		-0.22034			0.111	0.0847	0.0012
T-Statitics	3.13	3.07	0.168455	-0.91		-3.23					
Coefficier	0.086702	0.050352	-0.00956	-0.00713			0.008921		0.068	0.0404	0.0348
T-Statitics	1.54	1.36	-0.12	-1.75			1.46				
Coefficier	0.119494	0.054744	0.0042	0.016644				-0.02574	0.0939	0.0671	0.0049
T-Statitics	2.11	1.5	0.06	1.71				-2.65			

Implications

- Monthly regressions
  - B: CPI

	yield_slop	fund_rate	default_p	liq_all	vix_ret	fsi	sen	liq_std	R Square	Adjusted	F test
Coefficier	-0.04397	-0.02557	-0.0814	-0.01048					0.0892	0.0678	0.003
T-Statitics	-0.77	-0.68	-1.04	-2.55							
Coefficier	-0.04577	-0.02616	-0.07966	-0.01062	-0.13558				0.0928	0.0659	0.0053
T-Statitics	-0.8	-0.7	-1.02	-2.57	-0.81						
Coefficier	-0.00063	0.006338	0.102683	-0.00931		-0.0834			0.0966	0.0699	0.0039
T-Statitics	-0.01	0.14	0.59	-2.2		-1.18					
Coefficier	-0.04362	-0.02536	-0.08132	-0.01046			-0.00084		0.0893	0.0624	0.007
T-Statitics	-0.76	-0.67	-1.04	-2.53			-0.14				
Coefficier	-0.05607	-0.0265	-0.08675	-0.02025				0.010712	0.0954	0.0686	0.0043
T-Statitics	-0.96	-0.71	-1.11	-2.03				1.07			

Implications

- Monthly regressions
  - C: UMR

	yield_slop	fund_rate	default_p	liq_all	vix_ret	fsi	sen	liq_std	R Square	Adjusted	F test
Coefficier	0.00488	0.004241	0.006557	0.00094					0.0086	-0.0147	0.8302
T-Statitics	0.35	0.46	0.34	0.92							
Coefficier	0.004609	0.004152	0.00682	0.00092	-0.0205				0.0101	-0.0192	0.886
T-Statitics	0.33	0.44	0.35	0.9	-0.5						
Coefficier	-0.01571	-0.01092	0.000382			0.039618			0.0383	0.0098	0.2478
T-Statitics	-0.94	-0.96	0.37			2.28					
Coefficier	0.005407	0.004548	0.006686	0.000983			-0.00127		0.0126	-0.0166	0.8271
T-Statitics	0.38	0.49	0.34	0.96			-0.82				
Coefficier	-0.00156	0.003747	0.003712	-0.00425				0.005696	0.0395	0.0111	0.2302
T-Statitics	-0.11	0.41	0.19	-1.74				2.33			

Implications

- Quarterly regressions
  - A: IND

	yield_slop	fund_rate	default_p	liq_all	vix_ret	fsi	sen	liq_std	R Square	Adjusted	F test
Coefficier	0.306565	0.155533	-0.05931	-0.02129					0.1455	0.1254	0
T-Statitics	3.04	2.34	-0.43	-2.92							
Coefficier	0.304479	0.154842	0.138796	-0.02144	-0.15768				0.1469	0.1217	0.0001
T-Statitics	3.01	2.32	0.68	-2.93	-0.53						
Coefficier	0.617618	0.384521	1.261881	-0.01285		-0.59857			0.2598	0.2379	0
T-Statitics	5.5	5.02	4.37	-1.84		-5.11					
Coefficier	0.302818	0.153354	-0.06022	-0.02159			0.009002		0.1489	0.1237	0
T-Statitics	2.99	2.3	-0.43	-2.96			0.82				
Coefficier	0.393816	0.162234	-0.02073	0.04915				-0.07723	0.2415	0.219	0
T-Statitics	4.05	2.58	-0.16	2.94				-4.62			

Implications

- Quarterly regressions
  - B: CPI

	yield_slop	fund_rate	default_p	liq_all	vix_ret	fsi	sen	liq_std	R Square	Adjusted	F test
Coefficier	-0.19364	-0.11591	-0.23444	-0.03318					0.1902	0.1711	0
T-Statitics	-1.72	-1.56	-1.52	-4.08							
Coefficier	-0.19759	-0.11722	-0.23061	-0.03347	-0.29825				0.1941	0.1703	0
T-Statitics	-1.75	-1.58	-1.49	-4.11	-0.91						
Coefficier	-0.03838	-0.00161	0.425034	-0.02897		-0.29878			0.2118	0.1885	0
T-Statitics	-0.29	-0.02	1.24	-3.49		-2.15					
Coefficier	-0.20474	-0.12236	-0.23714	-0.03408			0.026661		0.2127	0.1894	0
T-Statitics	-1.83	-1.66	-1.55	-4.23			2.2				
Coefficier	-0.22318	-0.11818	-0.2475	-0.05703				0.026151	0.1986	0.1748	0
T-Statitics	-1.95	-1.59	-1.6	-2.89				1.33			

Implications

- Quarterly regressions
  - C: UMR

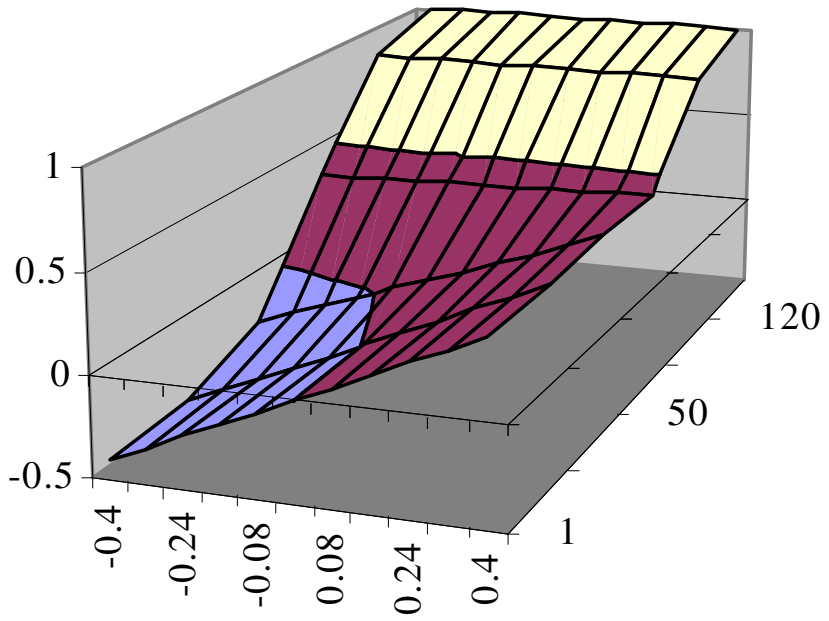
	yield_slop	fund_rate	default_p	liq_all	vix_ret	fsi	sen	liq_std	R Square	Adjusted	F test
Coefficier	0.00188	0.010142	0.017041	0.003274					0.0263	0.0034	0.3358
T-Statitics	0.08	0.63	0.51	1.87							
Coefficier	0.002068	0.010204	0.016859	0.003288	0.014194				0.0265	-0.0023	0.4686
T-Statitics	0.08	0.64	0.5	1.87	0.2						
Coefficier	-0.06009	-0.03548	-0.24617	0.001593		0.119247			0.1158	0.0896	0.0008
T-Statitics	-2.18	-1.88	-3.46	0.92		4.14					
Coefficier	0.003307	0.010972	0.017389	0.00339			-0.00343		0.036	0.0075	0.283
T-Statitics	0.14	0.69	0.52	1.94			-1.3				
Coefficier	-0.01831	0.008591	0.008112	-0.01303				0.017872	0.1277	0.1018	0.0003
T-Statitics	-0.78	0.57	0.26	-3.23				4.43			

Conclusion

- Liquidity model
- Liquidity index
  - persistent
  - co-integrative
  - inter-connected
  - sensitive
  - predictive
- Implications toward Systemic risk
  - liquidity PD versus economic PD
  - high correlation (simultaneous price falls)
- Further evidence
  - liquidity expected short falls (CCAR)
  - expected loss and unexpected loss

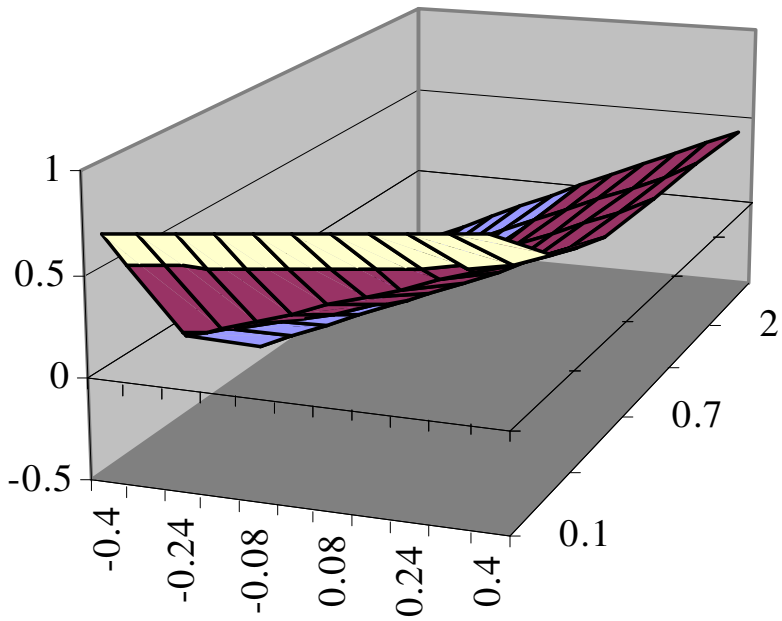
Correlation

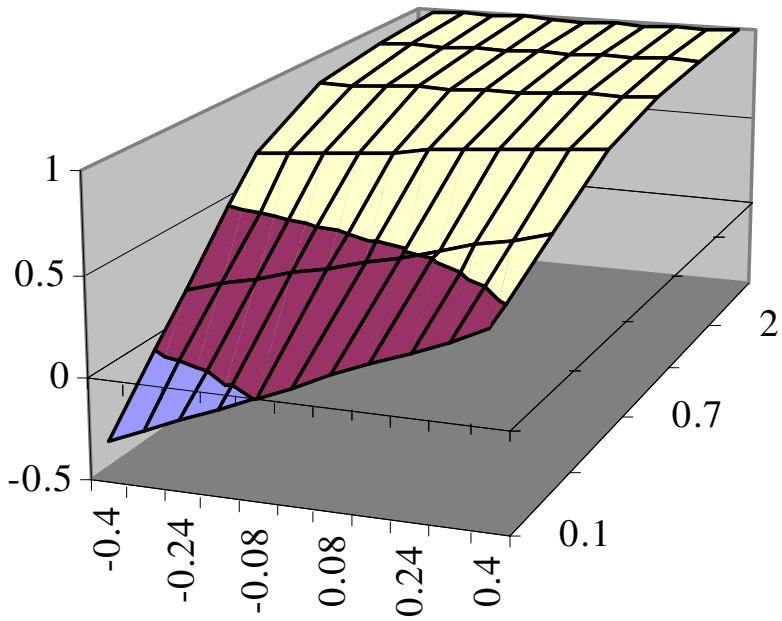
- K (larger K more severe liquidity discount)



Correlation

- σ_K (uncertainty about liquidity discount)



Correlation

- $\sigma_i = \sigma_j$ (idiosyncratic uncertainty)