FRM financialriskmeter

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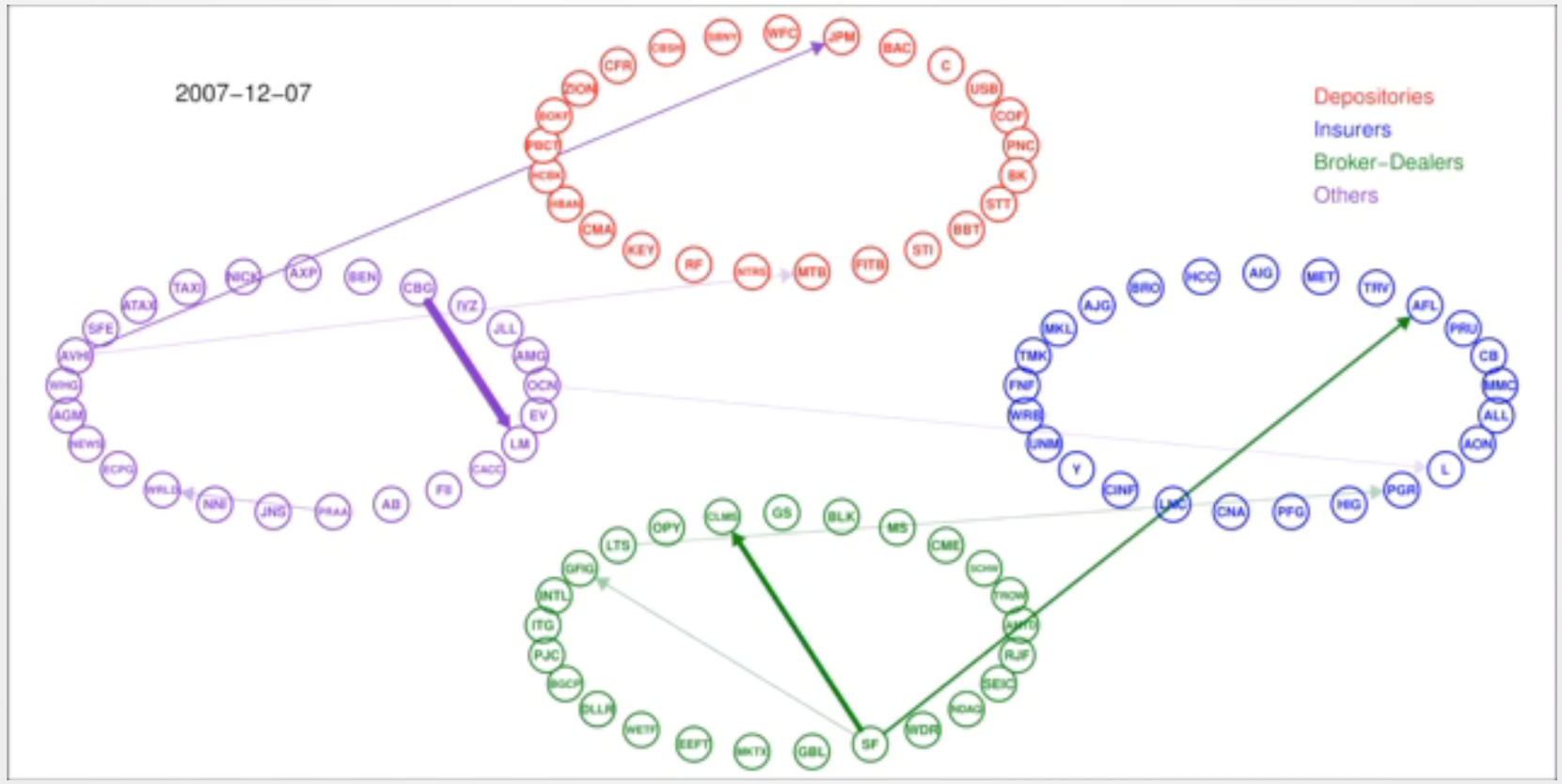
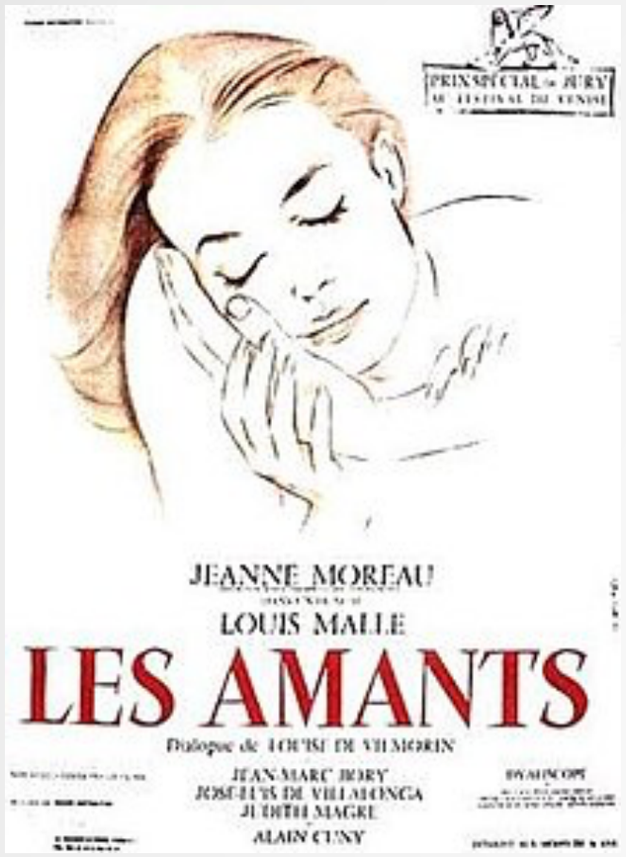
Tail Events (TE)

- TEs across companies indicate increased risk
- CoVaR measures joint TEs between 2 risk factors
- CoVaR and other risk factors?
- TENET Tail Event NETwork risk, Härdle Wang Yu (2017) J E'trics
- FRM Financial Risk Meter for joint TEs



Risk, Model Risk, Systemic Risk



The financial cycle and the business cycle are not synchronised, implying that risks can emerge especially in the periods of „disconnect" between the two cycles.", Vítor Constâncio, VP ECB, 2015

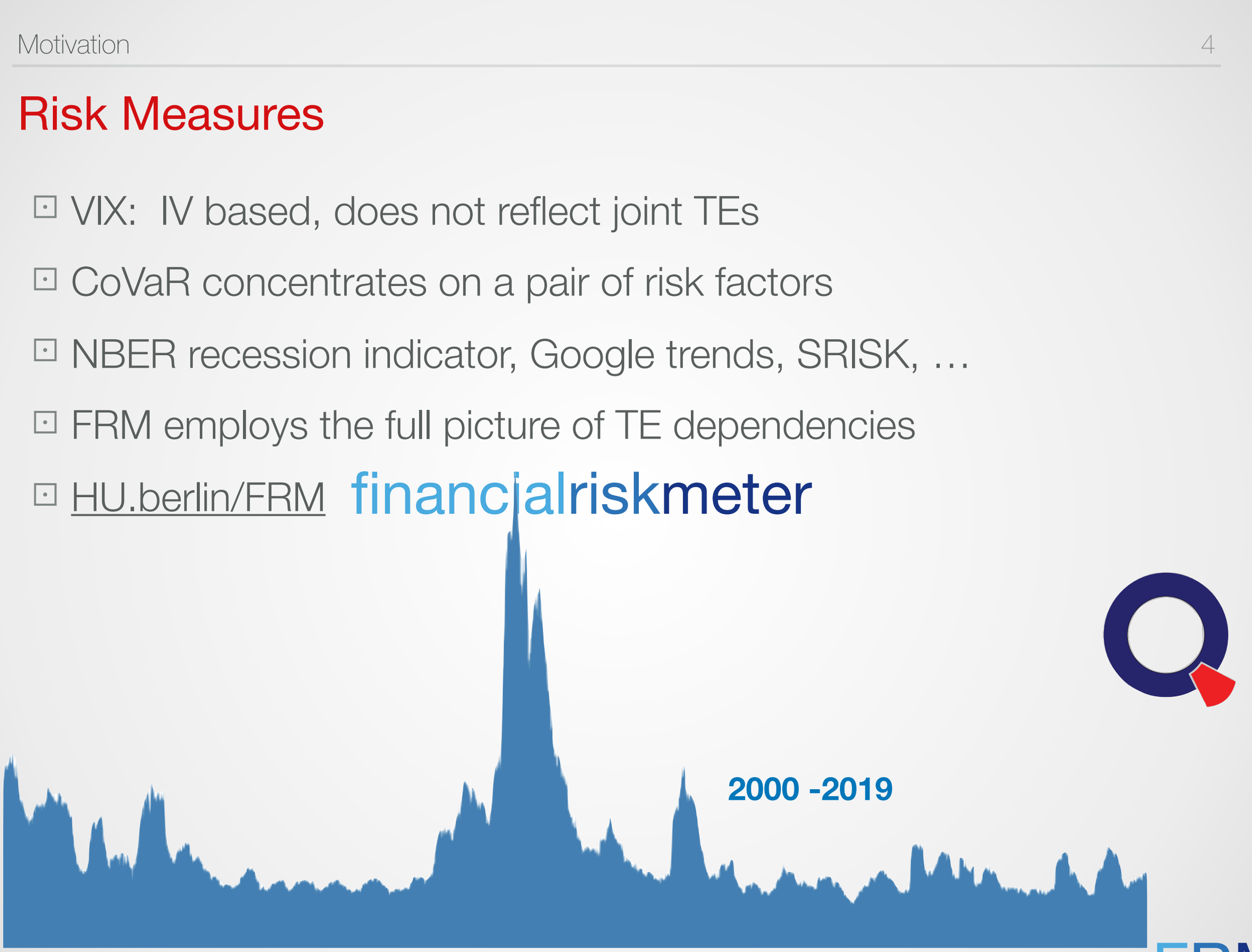
"Broadly speaking, model risk can be attributed to either an incorrect model or to an incorrect implementation of a model" , Buraschi and Corielle (2005)

„I know it when I see it", Justice Potter Stewart (1964)

- Tail Behaviour
- Ultra High Dimensions
- Nonlinear in Time and Space (=Network)

Risk Measures

- VIX: IV based, does not reflect joint TEs
- CoVaR concentrates on a pair of risk factors
- NBER recession indicator, Google trends, SRISK, …
- FRM employs the full picture of TE dependencies
- HU.berlin/FRM financialriskmeter



Outline

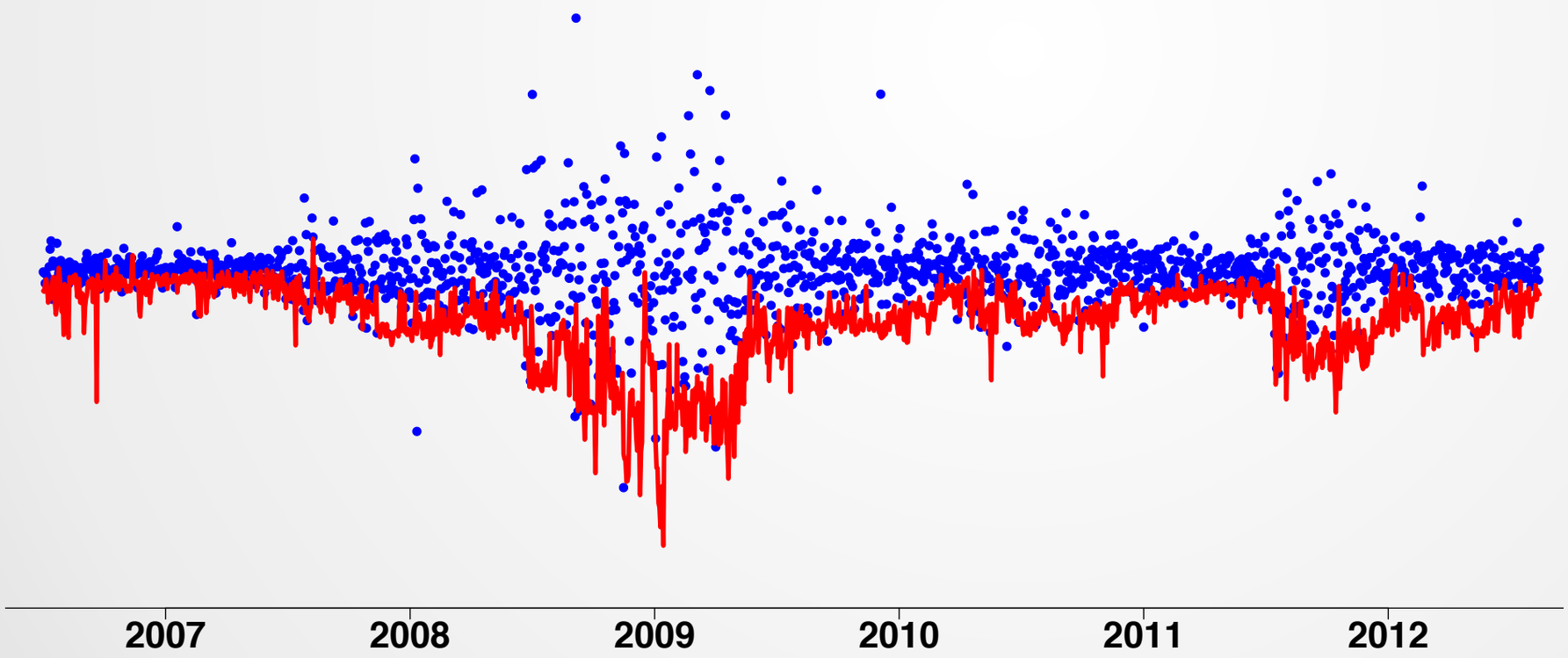
1. Motivation ✔
2. Genesis
3. FRM Framework
4. CoStress ID, Active Set
5. Extension to other asset classes
6. FRM a predictor for recession
7. Conclusions

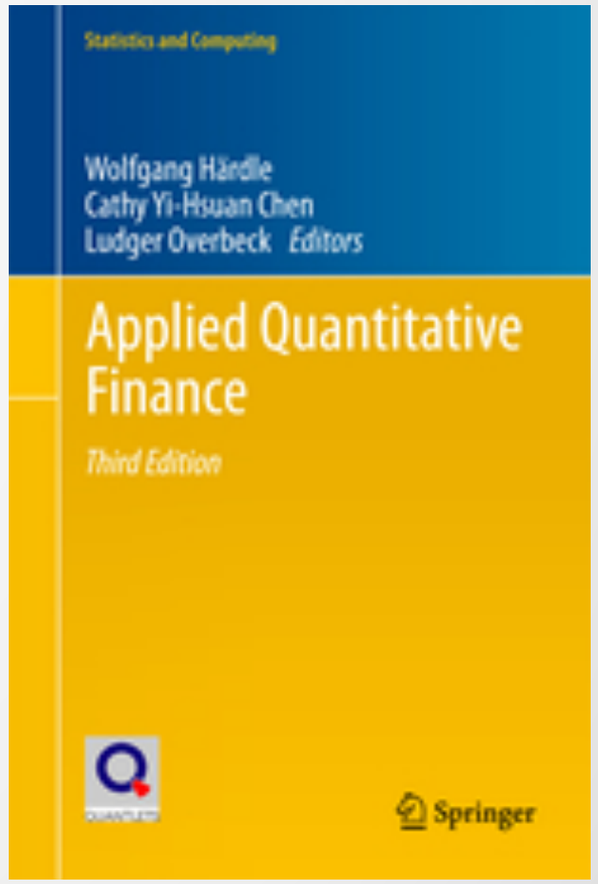
VaR Value at Risk

- Probability measure based

$$\mathrm{P}(X_{i,t} \leq VaR_{i,t}^{\tau}) \stackrel{def}{=} \tau, \quad \tau \in (0,1)$$

- $X_{i,t}$ log return of risk factor (company) *i* at *t*
- VaRs (0.99, 0.01) based on RMA, Delta Normal Method





Quantiles and Expectiles

For r.v. *Y* obtain tail event measure:

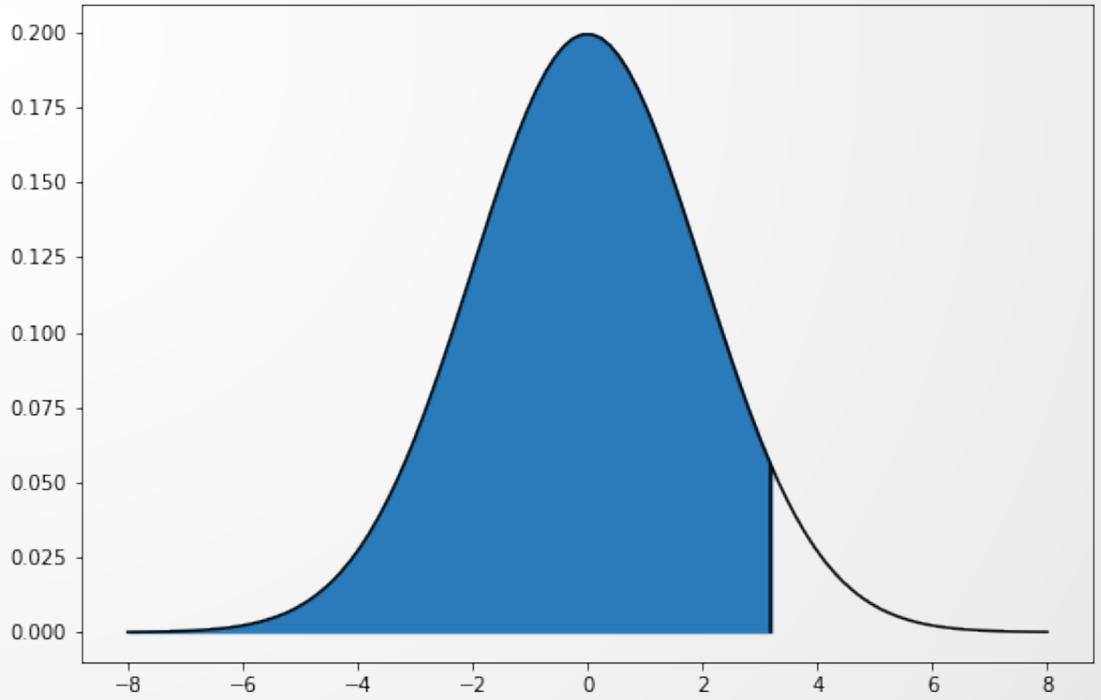
log returns

$$q^{\tau} = \arg\min_{\theta} \mathrm{E}\left\{\rho_{\tau}\left(Y - \theta\right)\right\}$$

asymmetric loss function

$$\rho_{\tau}\left(u\right) = \left|u\right|^{\alpha}\left|\tau - \mathbf{I}_{\{u<0\}}\right|$$

$\alpha = 1$ for quantiles,
$\alpha = 2$ for expectiles

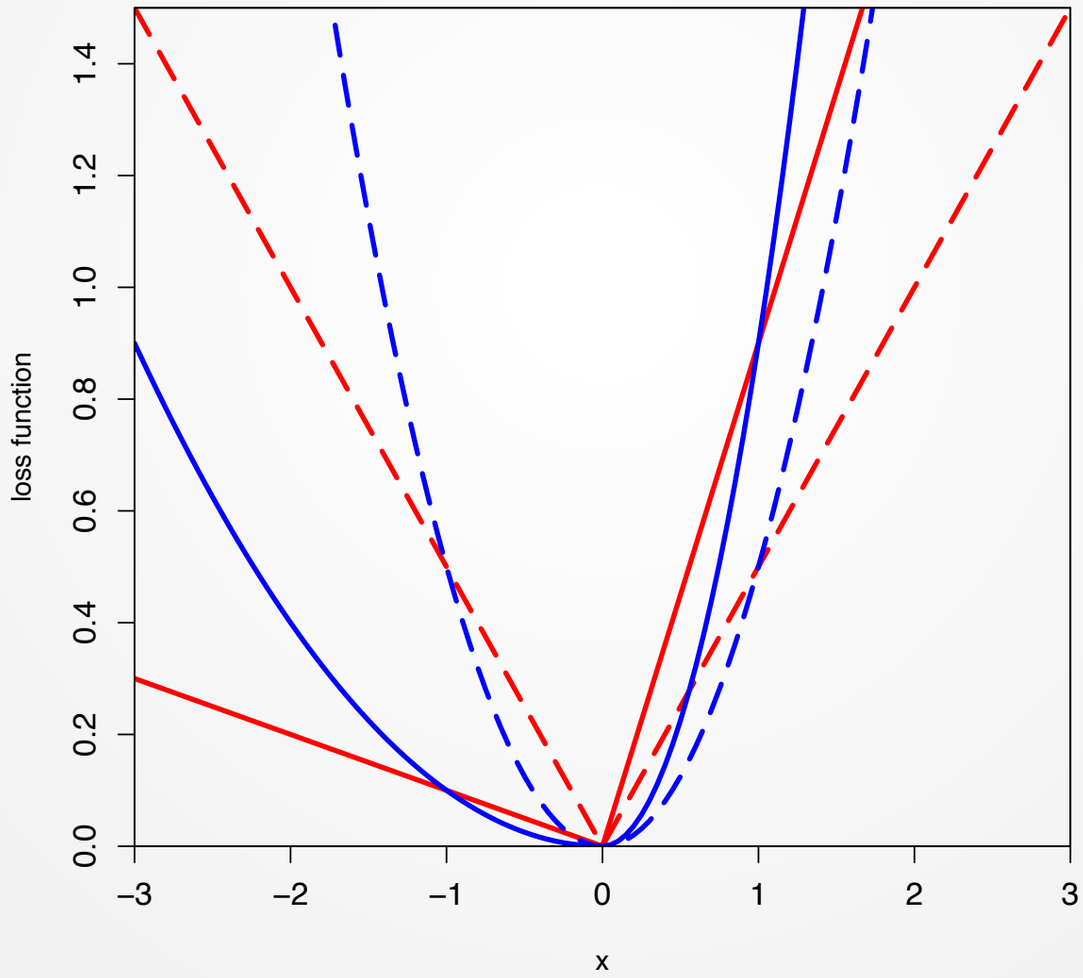


$\tau = 0.7$, $N(0,2)$ Quantile = 3.2

Expectile as Quantile

Quantiles and Expectiles

- Quantiles/Expectiles focus on TEs
- SRM Spectral Risk Measures
- LAWS algorithm fast and efficient



LQRcheck

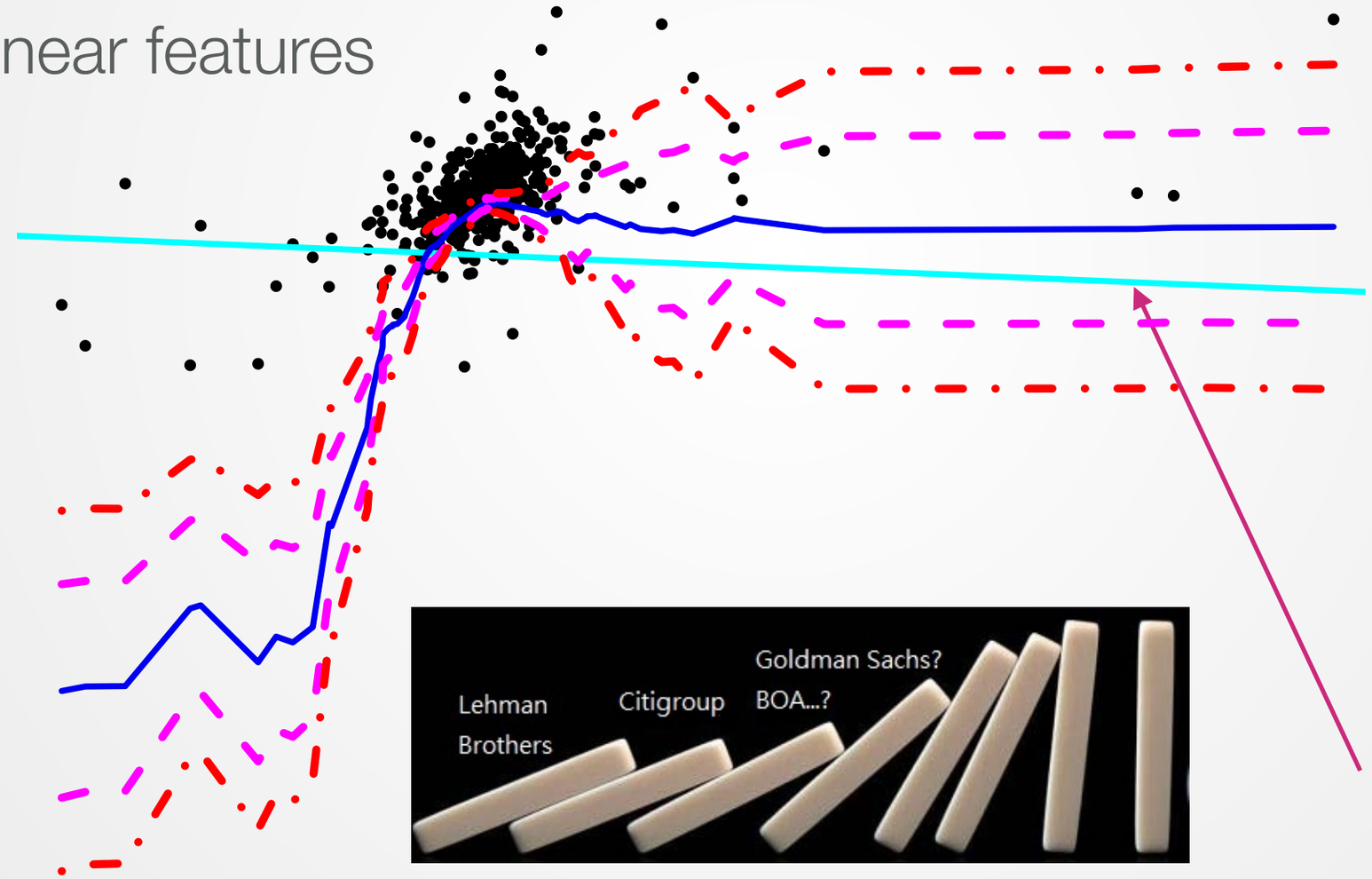
Figure: Loss function of expectiles and quantiles for $\tau = 0.5$ (dashed) and $\tau = 0.9$ (solid)

Conditional Value at Risk

- Adrian and Brunnermeier (2016) introduced CoVaR

$$\mathrm{P}\{X_{i,t} \leq CoVaR^{\tau}_{j|i,t} \mid X_{i,t} = VaR^{\tau}(X_{i,t}), M_{t-1}\} \stackrel{def}{=} \tau,$$

- M_{t-1} vector of macro-related variables
- Nonlinear features



Goldman Sachs (Y), Citigroup (X), Conf Bands, Chao et al (2015)

CoVaR and the magic of joint TEs

- CoVaR technique

$$X_{i,t} = \alpha_i + \gamma_i^\top M_{t-1} + \varepsilon_{i,t},$$

$$X_{j,t} = \alpha_{j|i} + \beta_{j|i} X_{i,t} + \gamma_{j|i}^\top M_{t-1} + \varepsilon_{j,t}\,.$$

- $F^{-1}_{\varepsilon_{i,t}}(\tau\,|\,M_{t-1}) = 0$ and $F^{-1}_{\varepsilon_{j,t}}(\tau\,|\,M_{t-1}, X_{i,t}) = 0$

$$\widehat{VaR}^{\tau}_{i,t} = \hat{\alpha}_i + \hat{\gamma}_i^\top M_{t-1},$$

$$\widehat{CoVaR}^{\tau}_{j|i,t} = \hat{\alpha}_{j|i} + \hat{\beta}_{j|i}\,\widehat{VaR}^{\tau}_{i,t} + \hat{\gamma}_{j|i}^\top M_{t-1},$$

CoVaR: First calculate VaRs, then compute the TE given a stressed risk factor.

Linear Quantile Lasso Regression

$$X_{j,t}^{s} = \alpha_{j,t}^{s} + A_{j,t}^{s\top}\beta_{j}^{s} + \varepsilon_{j,t}^{s}, \qquad (1)$$

- Where $A_{j,t}^{s\top} \overset{def}{=} \left[M_{t-1}^{s}, X_{-j,t}^{s}\right]$

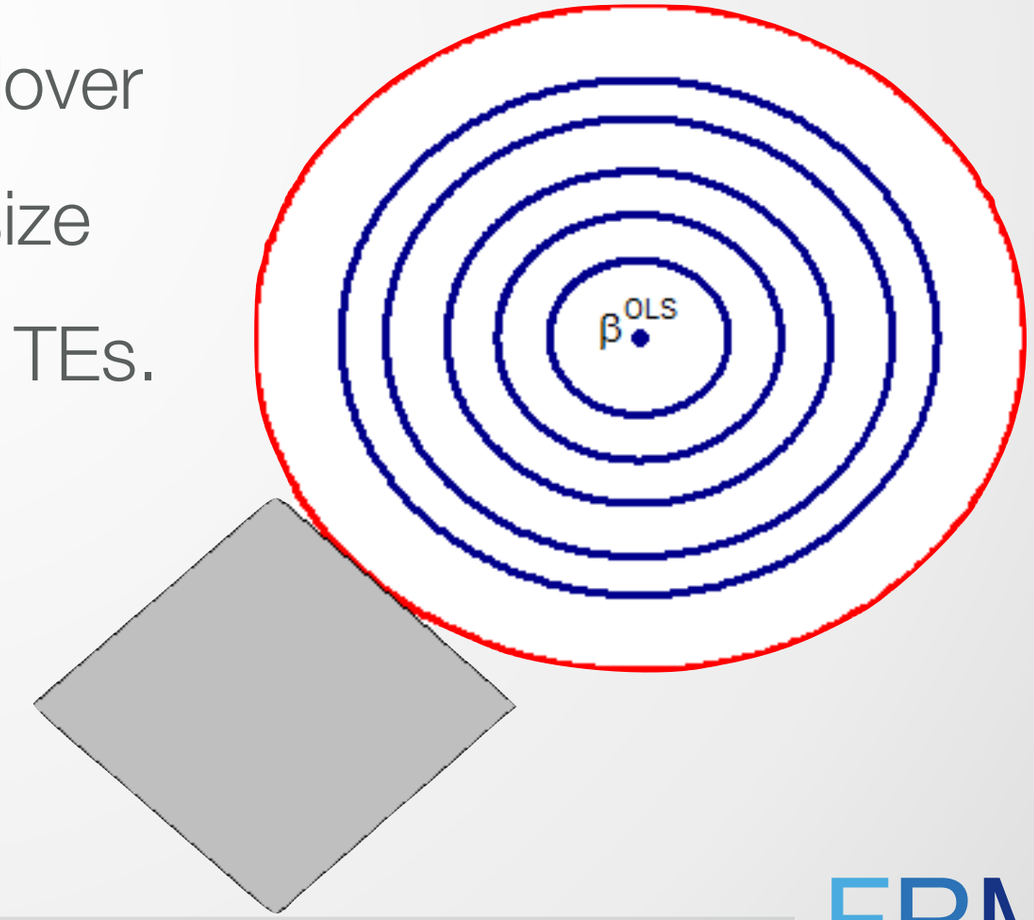
- $X_{-j,t}^{s}$ log returns of all other firms except j at time t
- s length of moving window
- M_{t-1}^{s} log return of macro prudential variable at time $t-1$
- Application $j = 1,\ldots,J,\ t = 2,\ldots,T$
  $J = 100,\ T = 2700,\ s = 63$

Company List | Macroprudentials

Lasso Quantile Regression

$$\min_{\alpha_j^s,\beta_j^s} \left\{ n^{-1} \sum_{t=s}^{s+(n-1)} \rho_\tau(X_{j,t}^s - \alpha_j^s - A_{j,t}^{s\top}\beta_j^s) + \lambda_j^s \parallel \beta_j^s \parallel_1 \right\}, \qquad (2)$$

- Check function $\rho_\tau(u) = \mid u \mid^c \mid 1(u \leq 0) - \tau \mid ,$
- here $c = 1,2$ correspond to quantile, expectile regression
- λ creates size of „active set“, i.e. spillover
- λ is sensitive to residual size, i.e. TE size
- λ reacts to singularity issues, i.e. joint TEs.



λ Role in Linear Lasso Regression

- Penalisation (Lagrange) parameter λ , Osborne et al. (2000)
- Dependence, time-varying, company-specific
- Size of model coefficients depends on

$$\lambda = \frac{\left(Y - X\beta(\lambda)\right)^{\top} X\beta(\lambda)}{\| \beta \|_1}$$

Coeff's depend on λ

- Penalty λ depends on:
- **residual size, condition of design matrix, active set**

λ Role in Linear Quantile Regression

- λ size of estimated LQR coefficients Li Y, Zhu JL (2008)

$$\lambda = \frac{(\alpha - \gamma)^{\top} X\beta(\lambda)}{\| \beta \|_1}$$

Coeff's (λ)

$$(\alpha - \gamma) = \tau\ I(Y - X\beta(\lambda) > 0) + (\tau - 1)\ I(Y - X\beta(\lambda) < 0)$$

- Penalty λ depends on:
- **„residual size“, condition of design matrix, active set**
- Average penalty: an indicator for tail risk

$$FRM_t \overset{def}{=} J^{-1} \sum_{j=1}^{J} \lambda_{jt}$$

- The FRM time series is ONE index for joint TEs!

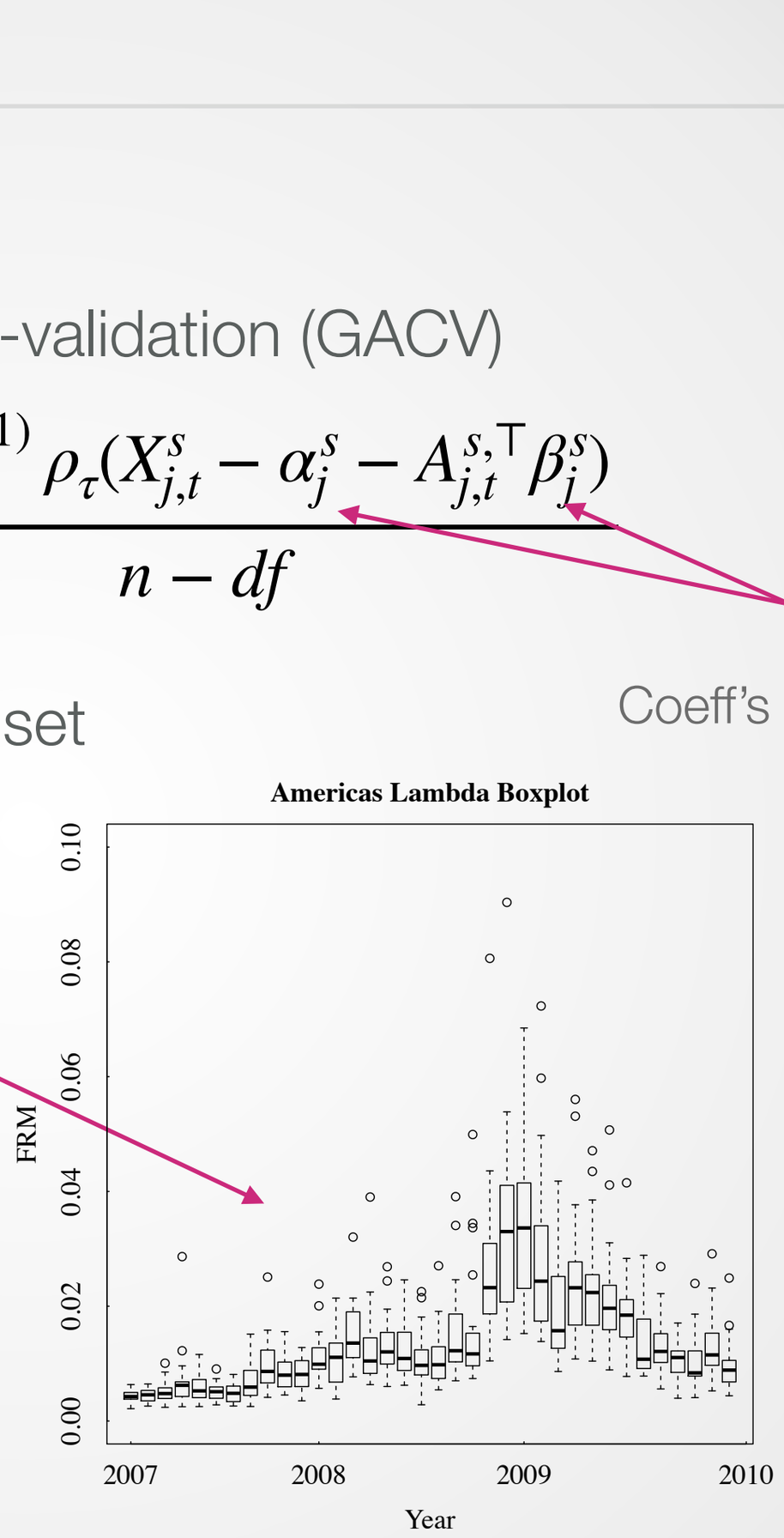
λ Selection

- Generalized approximate cross-validation (GACV)

$$\min GACV(\lambda_j^s) = \min \frac{\sum_{t=s}^{s+(n-1)} \rho_\tau(X_{j,t}^s - \alpha_j^s - A_{j,t}^{s,\top}\beta_j^s)}{n - df}$$

Coeff's depend on λ

- df degrees of freedom #active set
- λ is a function of j,t
- Distribution of $\lambda_{j,t}$
- ID the TE drivers



FRM codes

- hu.berlin/frm

Low Risk	**<20%**
General Risk	**20% - 40%**
Elevated Risk	**40% - 60%**
High Risk	**60% - 80%**
Severe Risk	**>80%**

severe risk of crisis

high risk of crisis

elevated risk of crisis

general risk of crisis

✗ low risk of crisis

Methodology

- Obtain company list of all historically active index members
- Download daily prices and market cap in same currency (USD)
- Sort market cap decreasingly (to select bigger J companies)
- Calculate stock and macro variable returns
- On every trading day,
  - Select $\mathbf{J}$ biggest companies' returns over $\mathbf{s}$ trading days
  - Attach returns of macroeconomic risk factors
  - Calculate λ for all companies
  - Calculate average λ, etc.
  - Store active set

LQ Lasso Regression

Data

- 100 largest U.S. and Canadian publicly traded financial institutions
- 6 macro related variables
- Quantile level $\tau = 0.05, \tau = 0.01, ...$
- Time frame: 2000-2019
- Macroeconomic risk factors:

  CBOE Volatility Index

  S&P 500

  REIT Index

  3M Treasury Constant Maturity Rate

  10Y Treasury Constant Maturity Rate

  Moody's Seasoned Baa Corp Bond Yield Spread

LQ Lasso Regression

European Data

- 100 largest European publicly traded financial institutions
- 7 macro related variables
- Quantile level $\tau = 0.05, \tau = 0.01, ...$
- Time frame: 2000 - 2019
- Macroeconomic risk factors:

  Eurostoxx 50 Volatility Index

  Eurostoxx 600

  MSCI Europe REIT Index

  1Y Germany Treasury Constant Maturity Rate

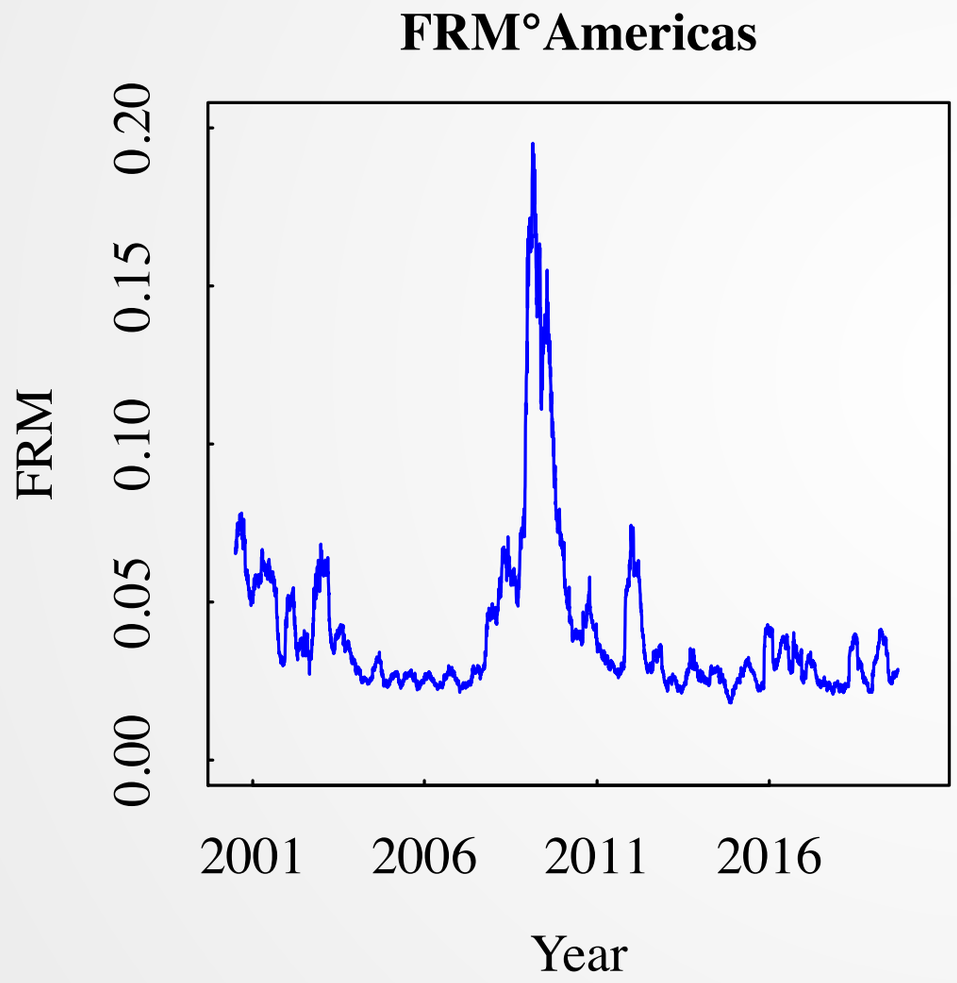
  10Y Germany Treasury Constant Maturity Rate

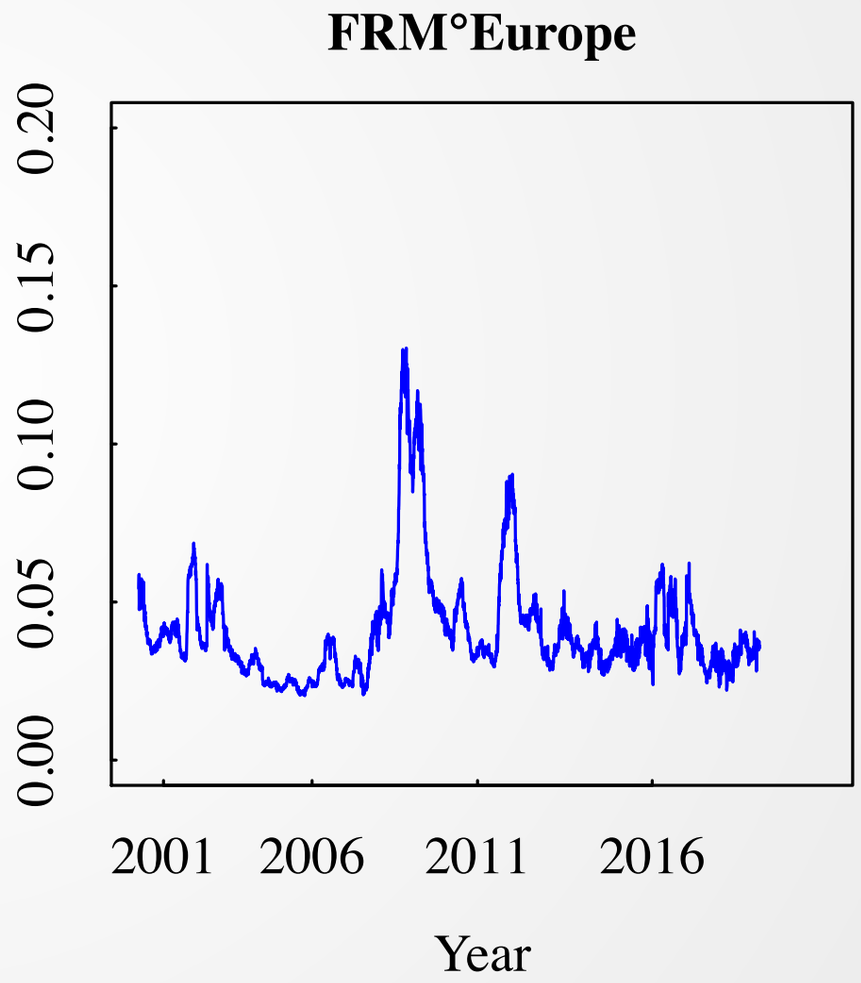
  Barclays Bloomberg EuroAgg Corporate Yield Spread

  10 year Italy Treasury to 10 year German Treasury Constant Maturity Rate Spread

FRM@Americas, FRM@Europe

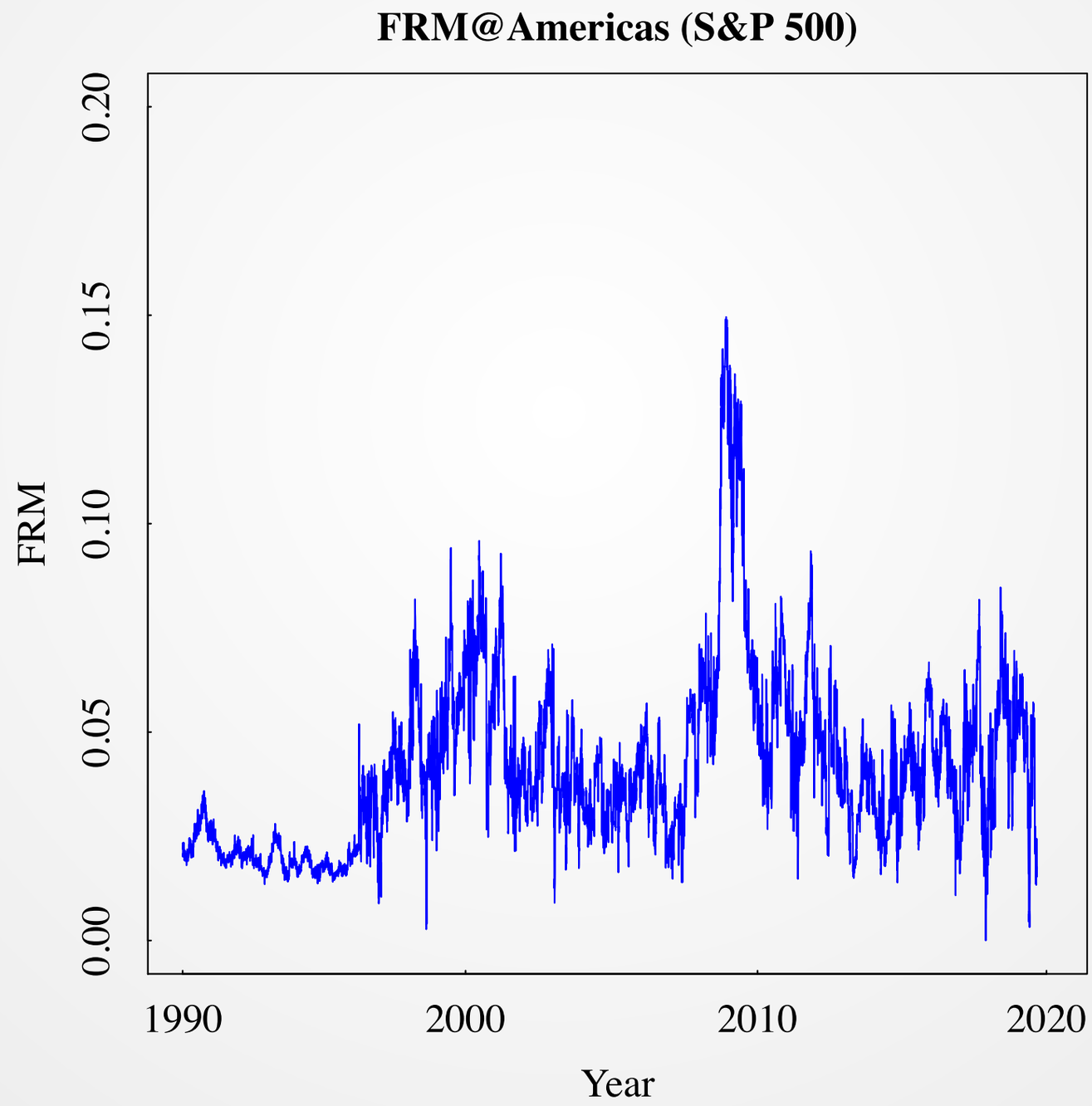
- Based on J=25 Financial Institutions (limited data availability)





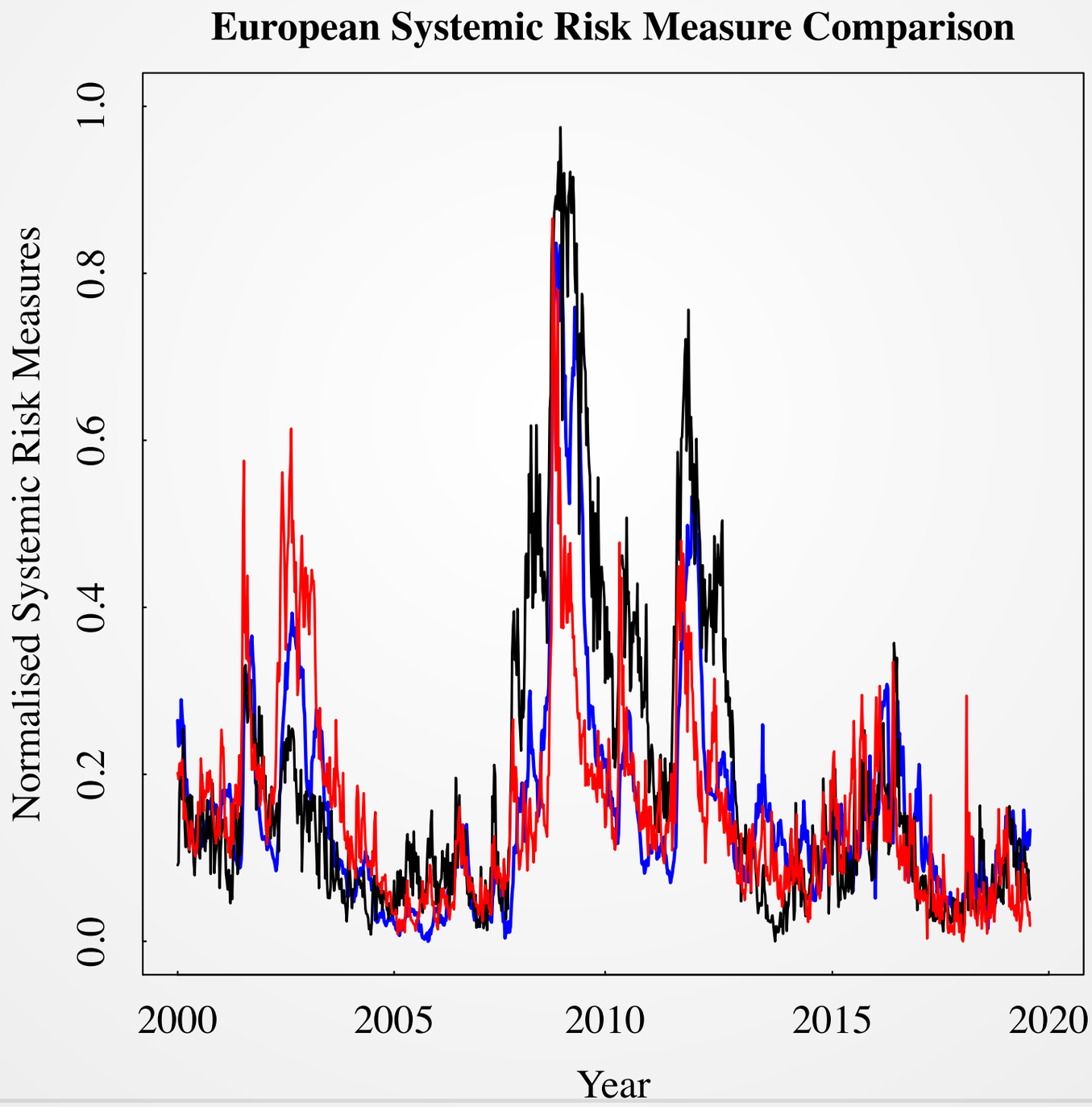
FRM@S&P500

- Based on J=25 Financial Institutions (limited data availability)



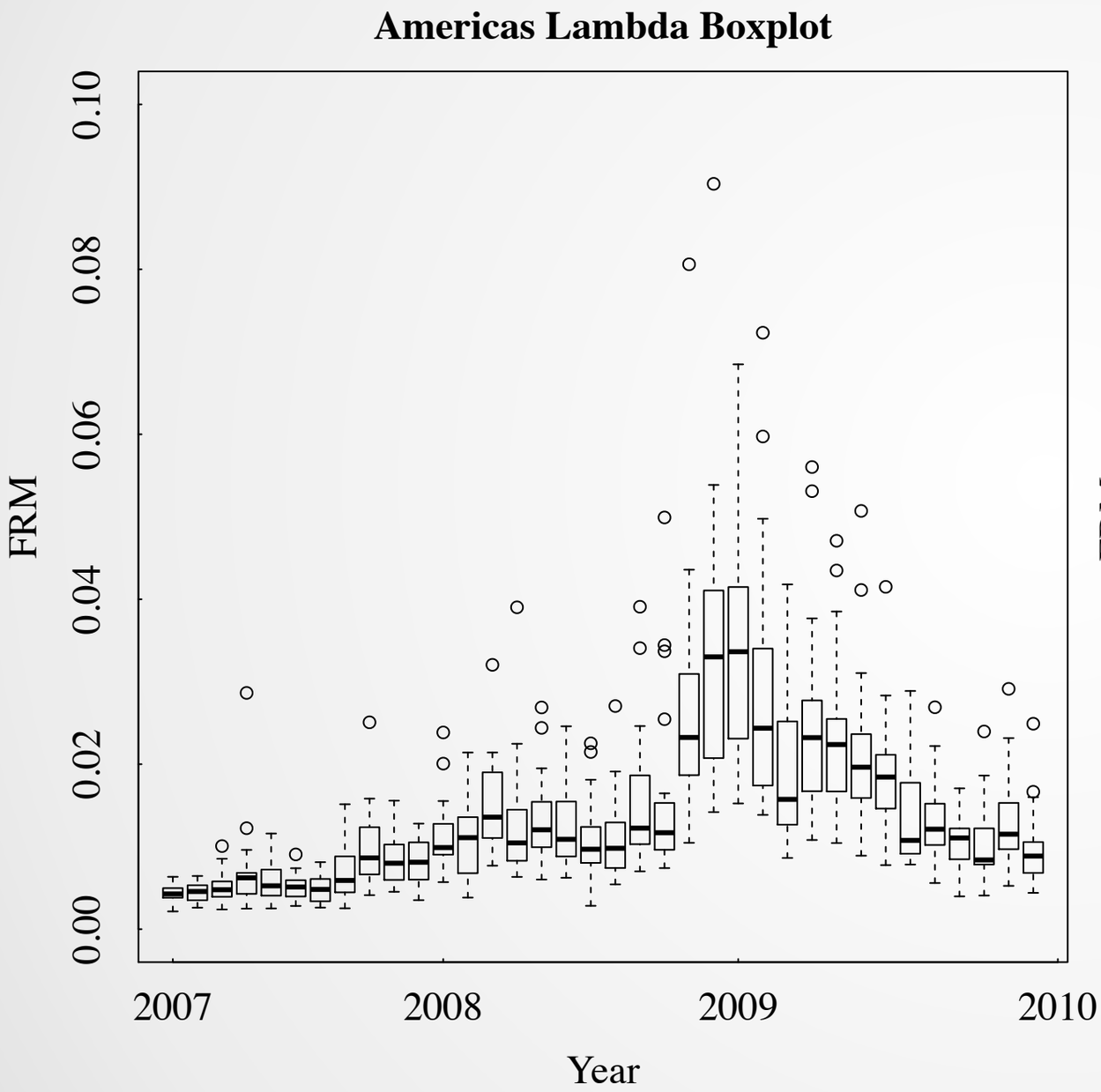
FRM vs Other Risk Measures

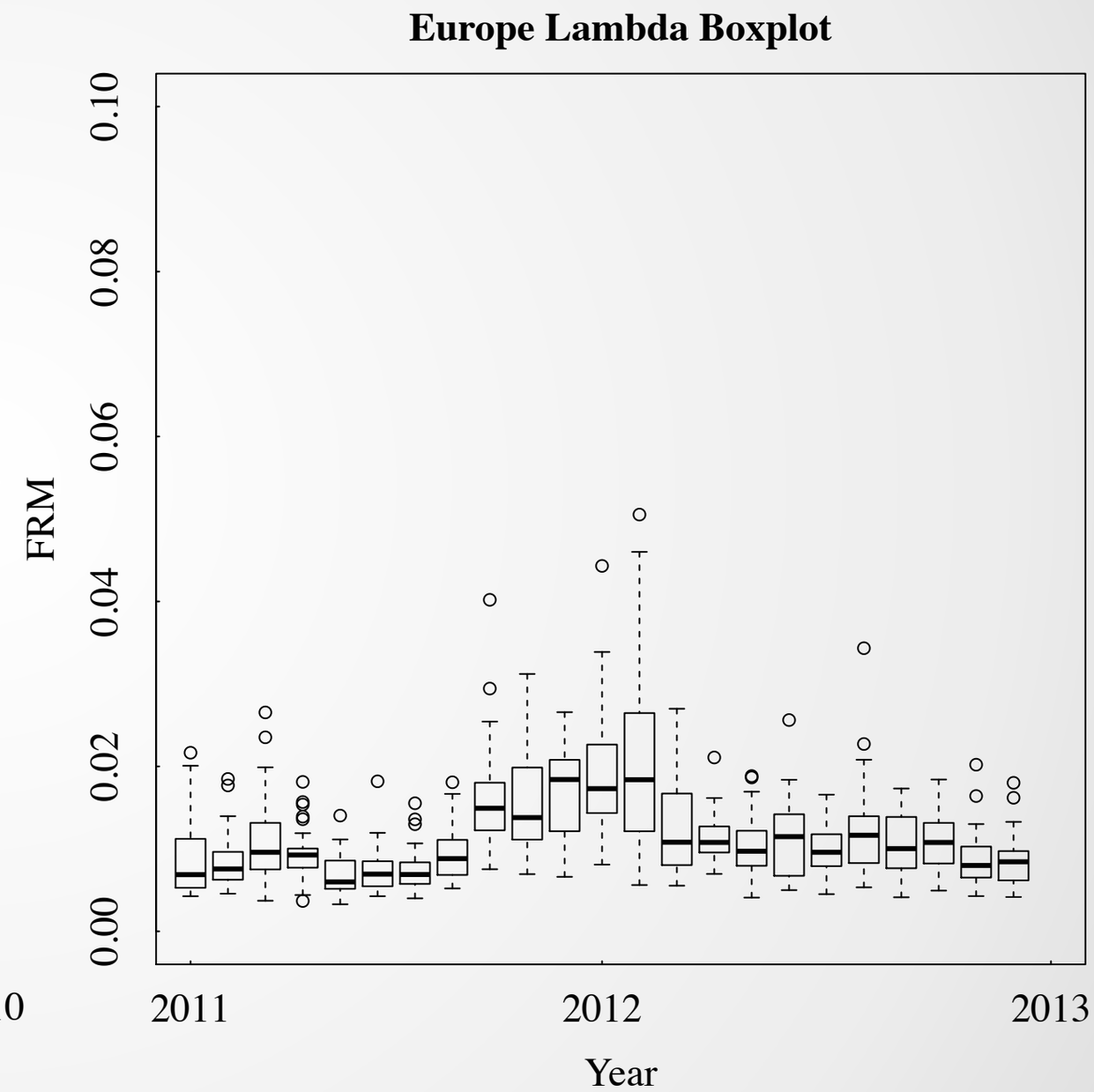
- The evolution of FRM@Europe relative to VSTOXX, ECB's CISS



Distributional characteristics

- Identifying companies CoStress $\tau = 0.05 \;\; \mathrm{J} = 25$





Distributional characteristics of $\lambda_j, j = 1,...J$

Company's CoStress

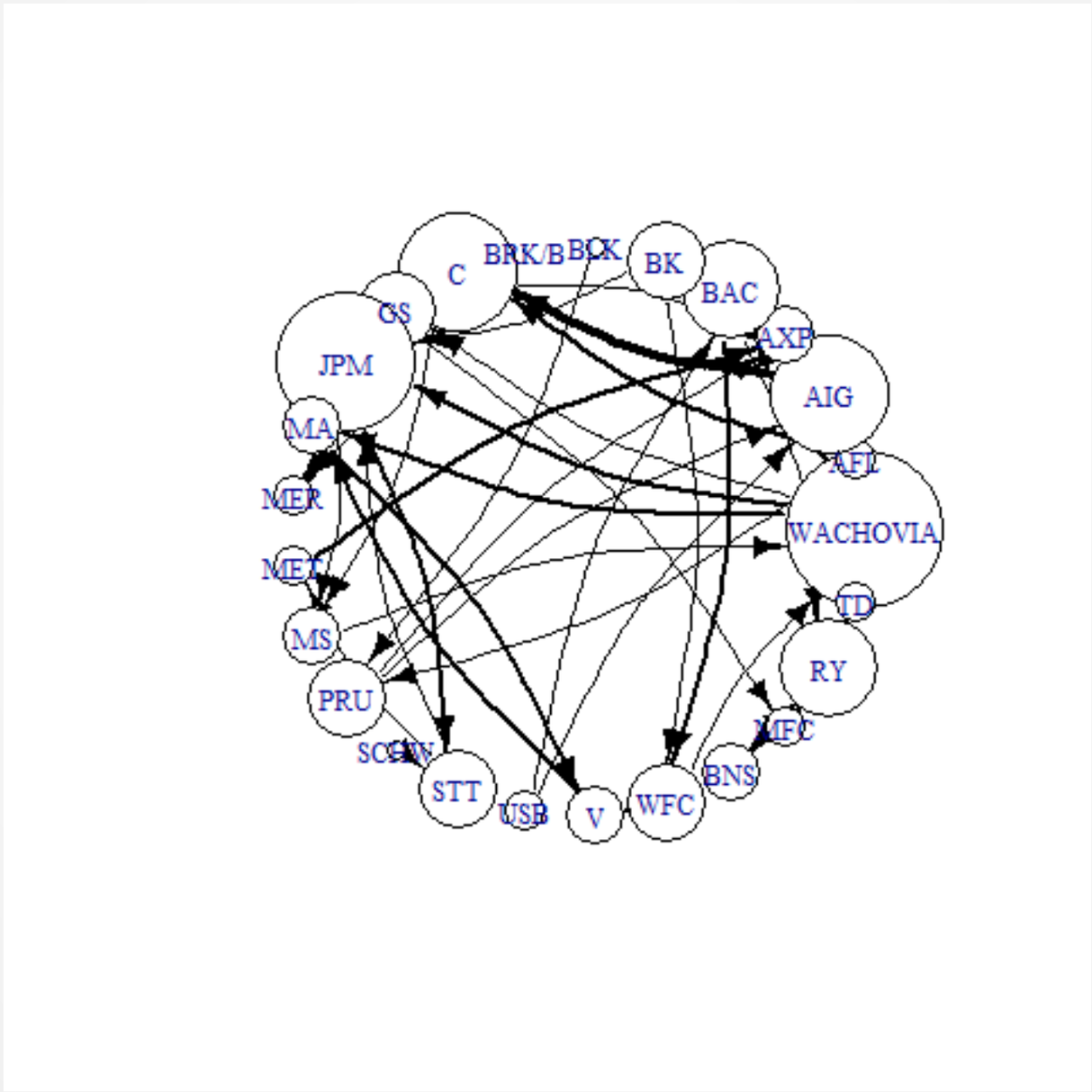
- September 7th, 2008:

  High CoStress: Visa Inc, Toronto Dominion Bank, US Bancorp, American Express Co, and American International Group (AIG) Inc

  Low CoStress: Mastercard Inc, Bank of America Corp, Bank of Nova Scotia, Goldman Sachs Group Inc and Merrill Lynch & Co Inc

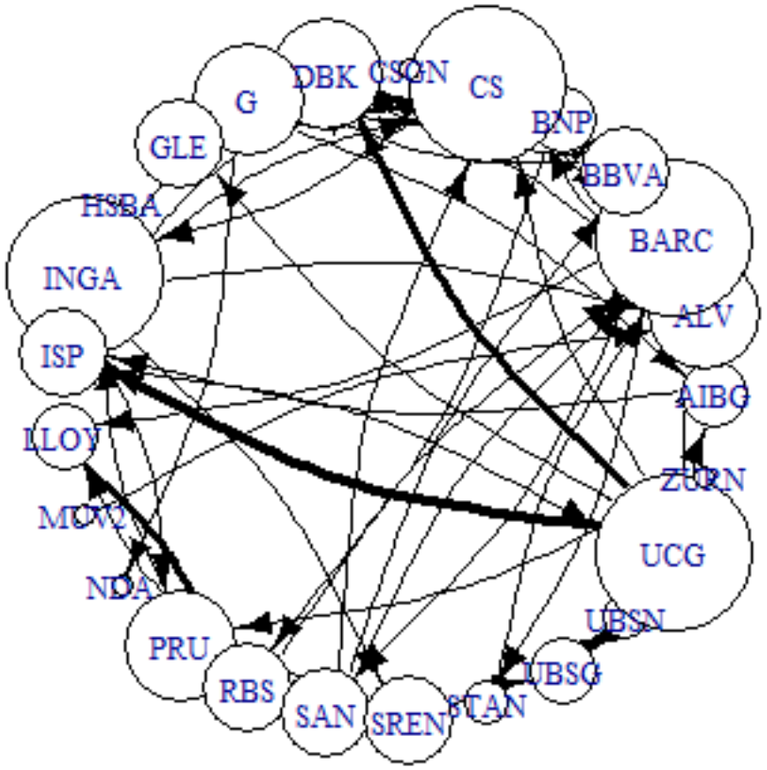
Visualising the Active Set: Total Degree Centrality

- September 7th, 2008, FRM@Americas, J=25



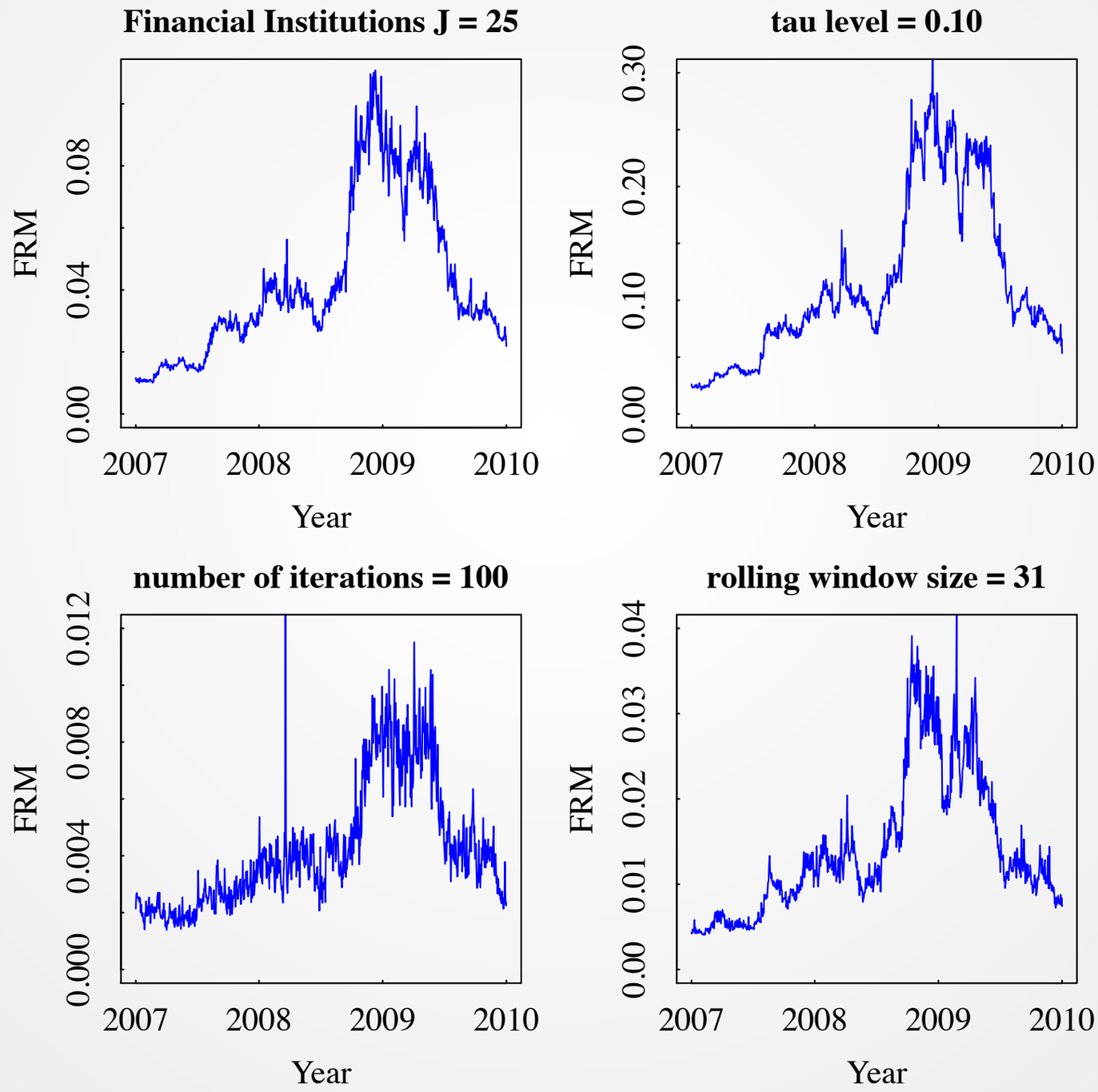
Visualising the Active Set: Total Degree Centrality

- January 20th, 2012, FRM@Europe, J=25



Sensitivity to hyperparameters

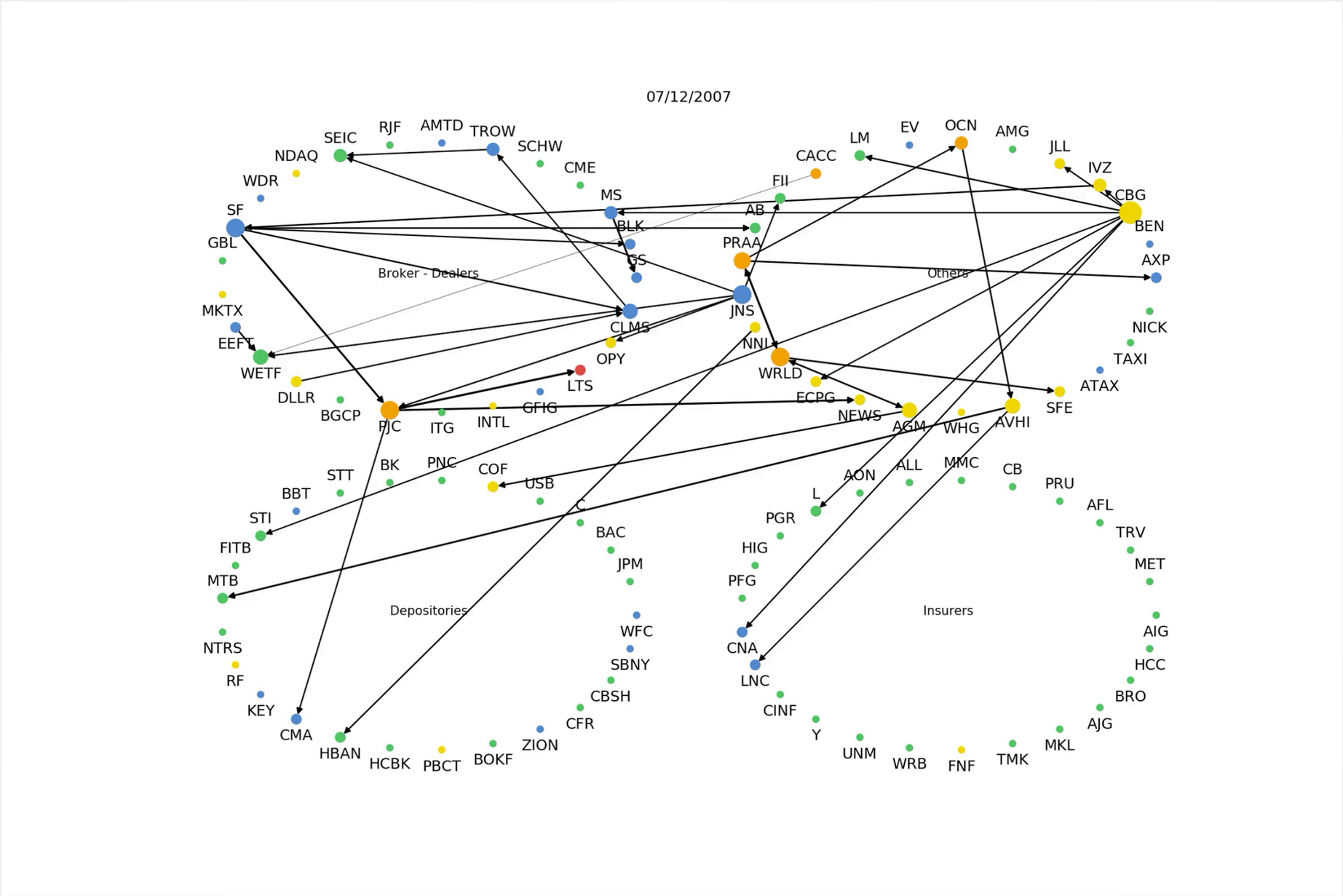
- Identifying companies CoStress, $J = 25$



Network Dynamics

- 100 risk factors

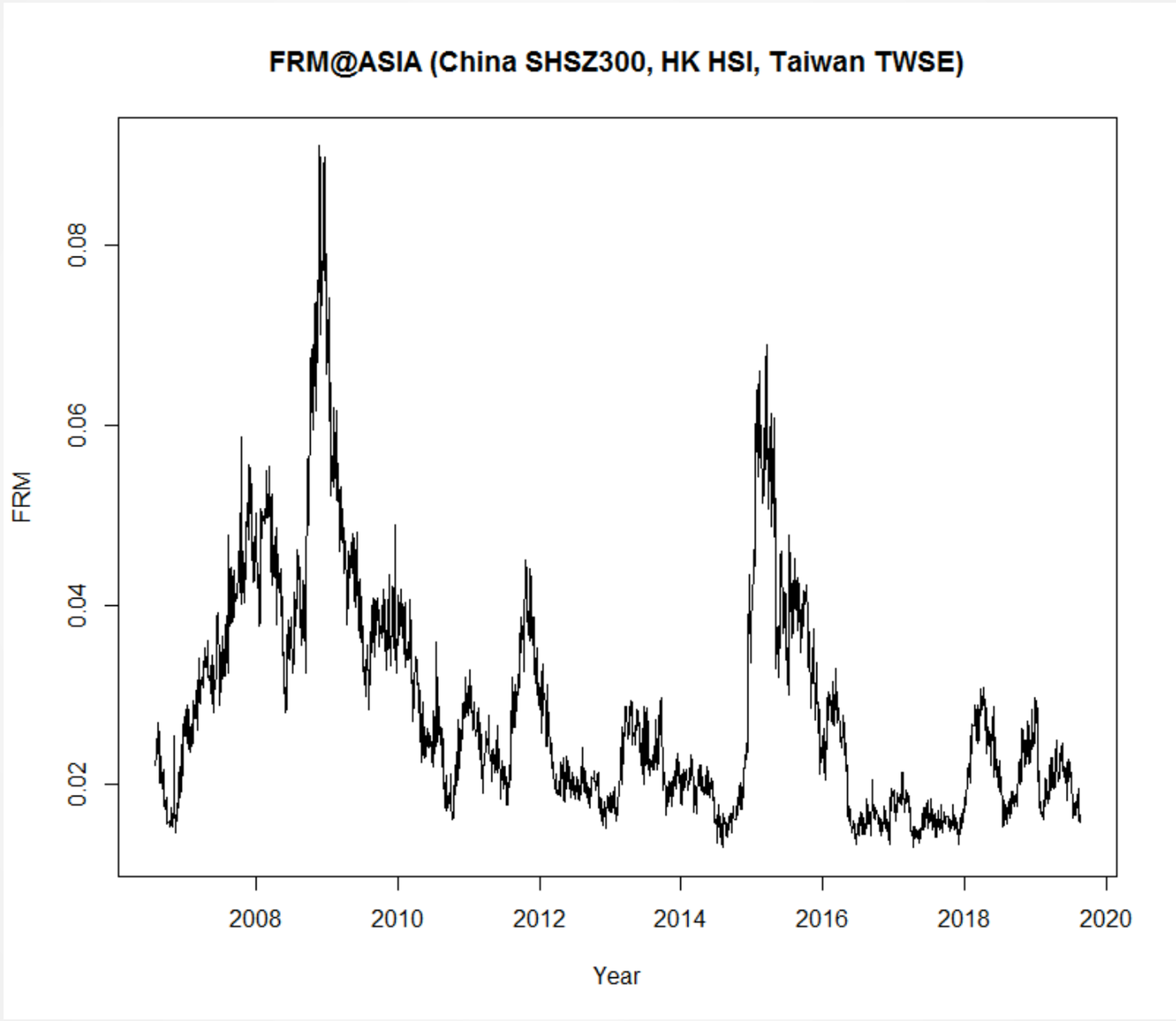
$$\tau = 0.05$$



Coeffs of all companies from 20190417 to 20190426

FRM@Asia

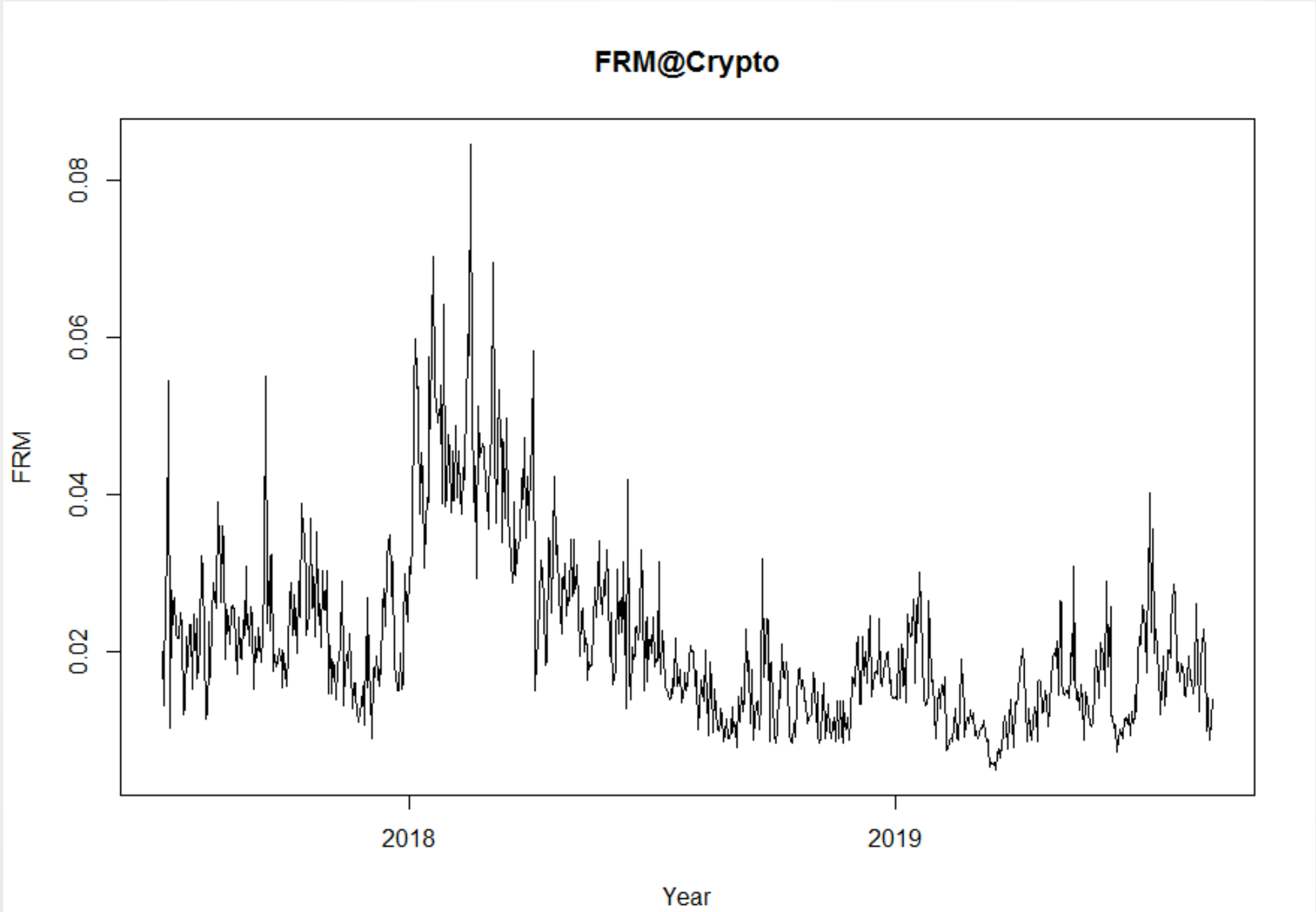
- SHSZ300 and Four Asian Tigers, J = 25



Same macroeconomic risk factors, ex corporate spread

FRM@Crypto

- Scrape Web for Crypto Prices and Amount Outstanding



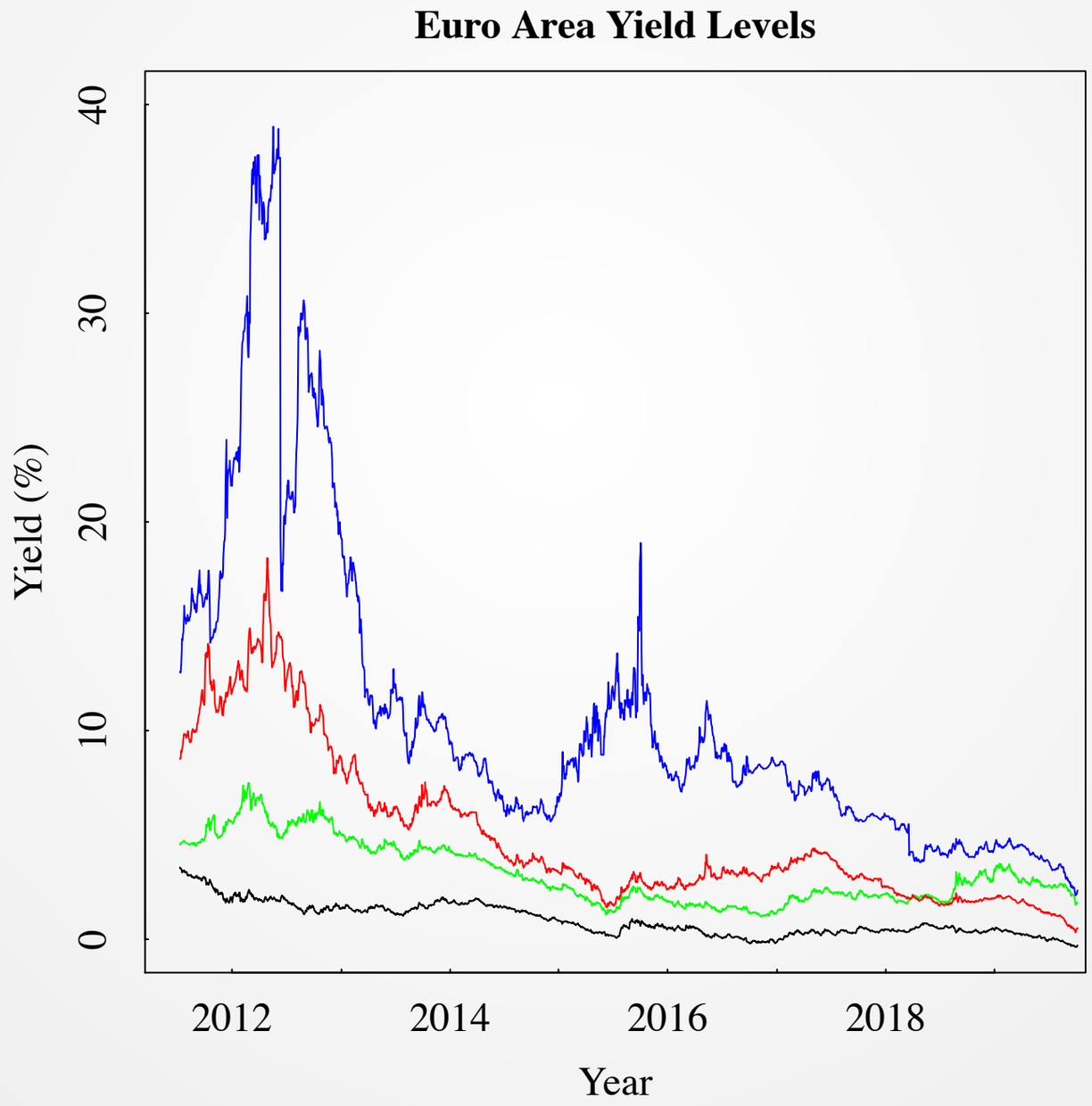
FRM@Crypto

- Macroeconomic risk factors:
  - US dollar index (average of USD vs main non-crypto currencies)
  - yield level in USD (carry component for the drift)
  - VIX
  - CVIX (same as VIX, but on major fiat currencies)
  - S&P500

What are the right macroeconomic risk factors per asset class?

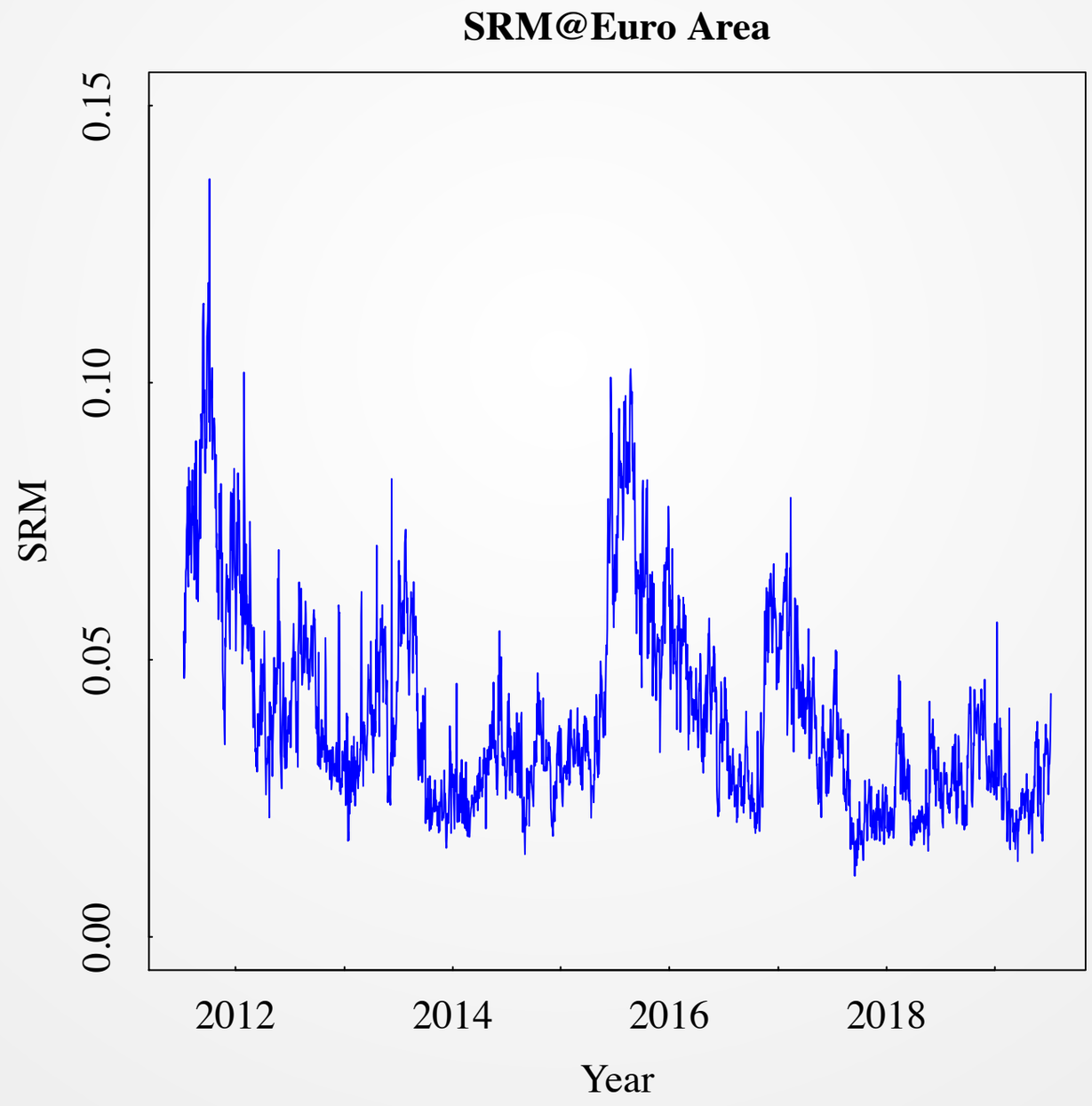
SRM@EuroArea

- EuroArea 10y Yields: Greece, Portugal, Italy, Germany



SRM@EuroArea

- Systemic Risk in Bond Yield Changes: $\tau = 0.05 \;\; \mathrm{J} = 11$



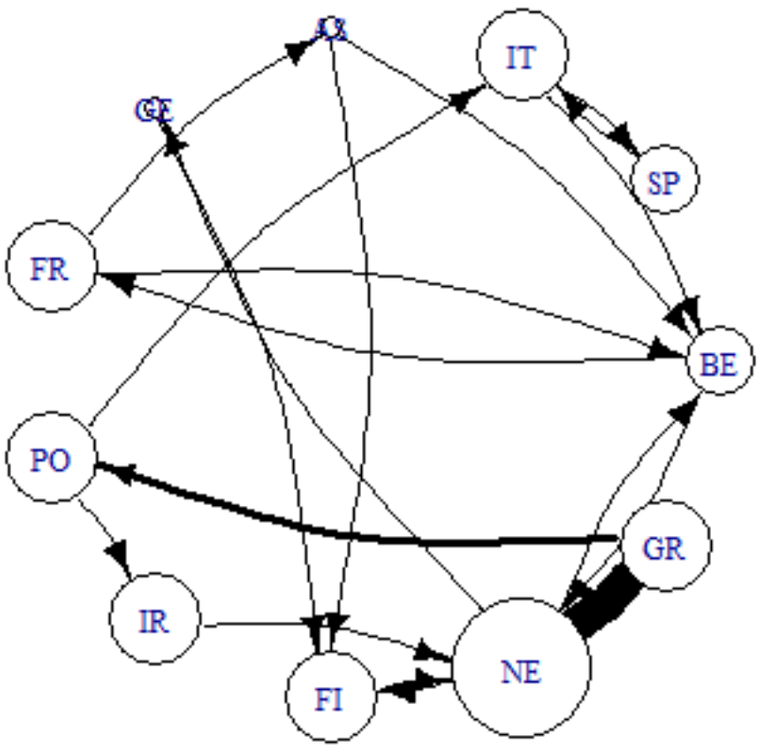
SRM@EuroArea

- Macroeconomic risk factors:
  - Euro Area REIT
  - Euro Stoxx 50
  - Euro Stoxx 50 Volatility Index
  - Germany treasury yield curve slope
  - 10y Kreditanstalt für Wiederaufbau (KfW) yield spread to Germany

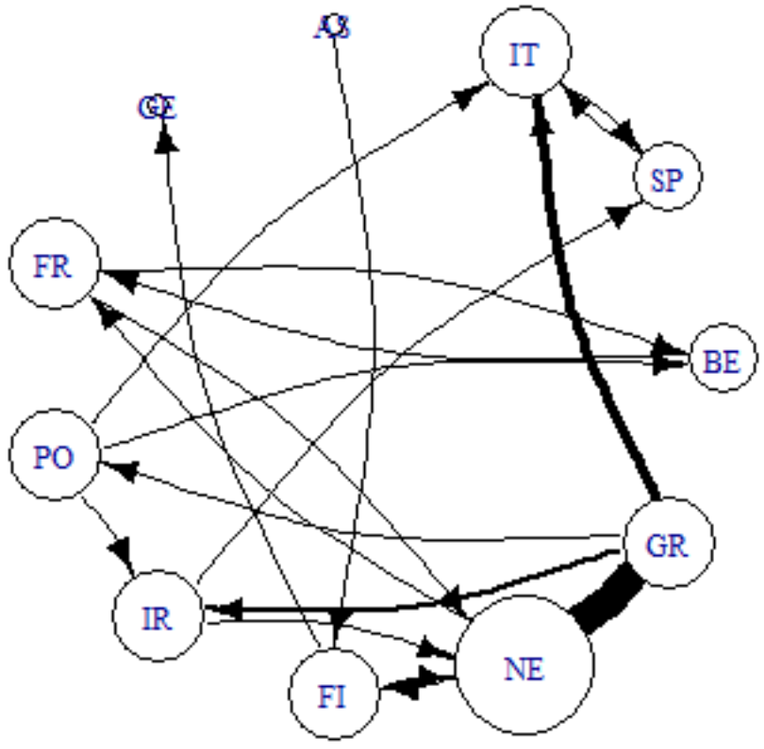
What are the right macroeconomic risk factors per asset class?

SRM@EuroArea: Active Set and CoStress

- May 4th, 2015

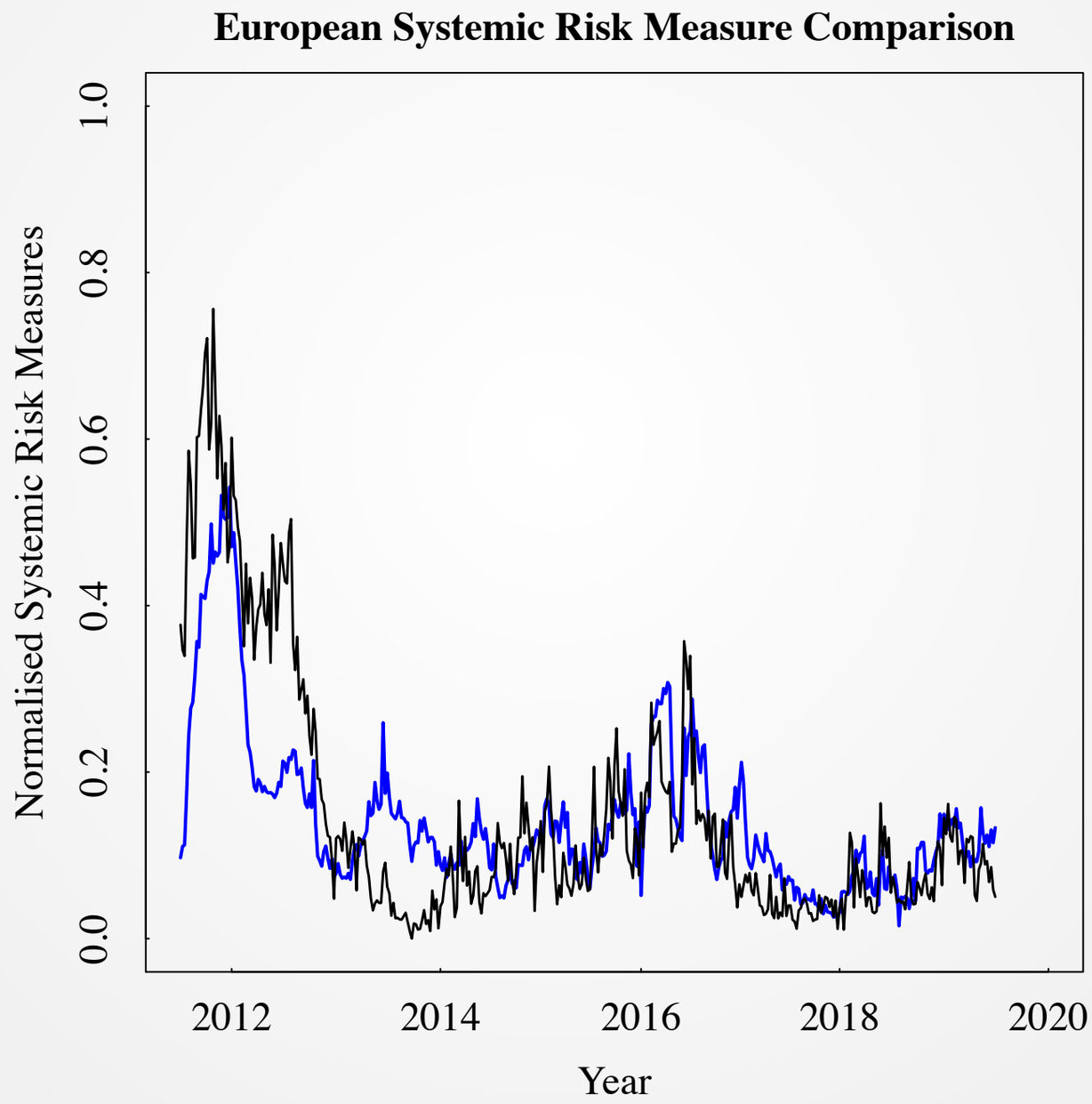


July 3rd, 2015



Combining FRMs

- Average of FRM@Europe, SRM@Euro Area, versus CISS



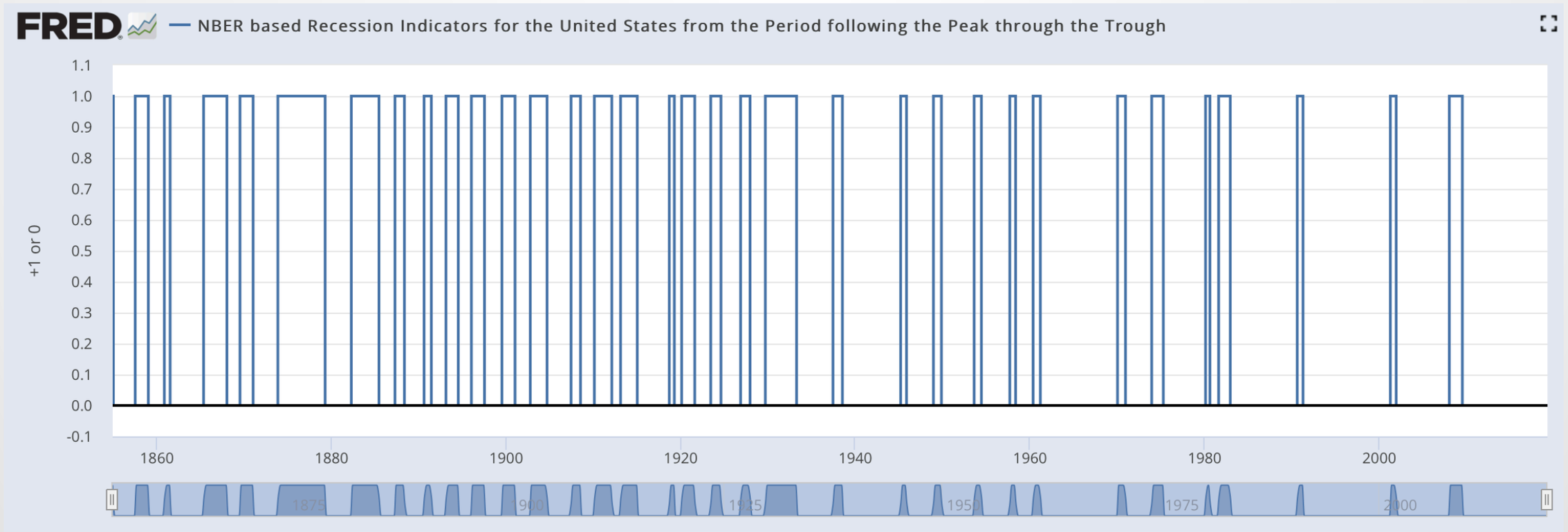
FRED meets FRM

- Logistic linear regression

$$\log \frac{\mathrm{P}(y=1\,|\,x;\beta)}{\mathrm{P}(y=0\,|\,x;\beta)} = \beta_0 + \beta_1 x$$

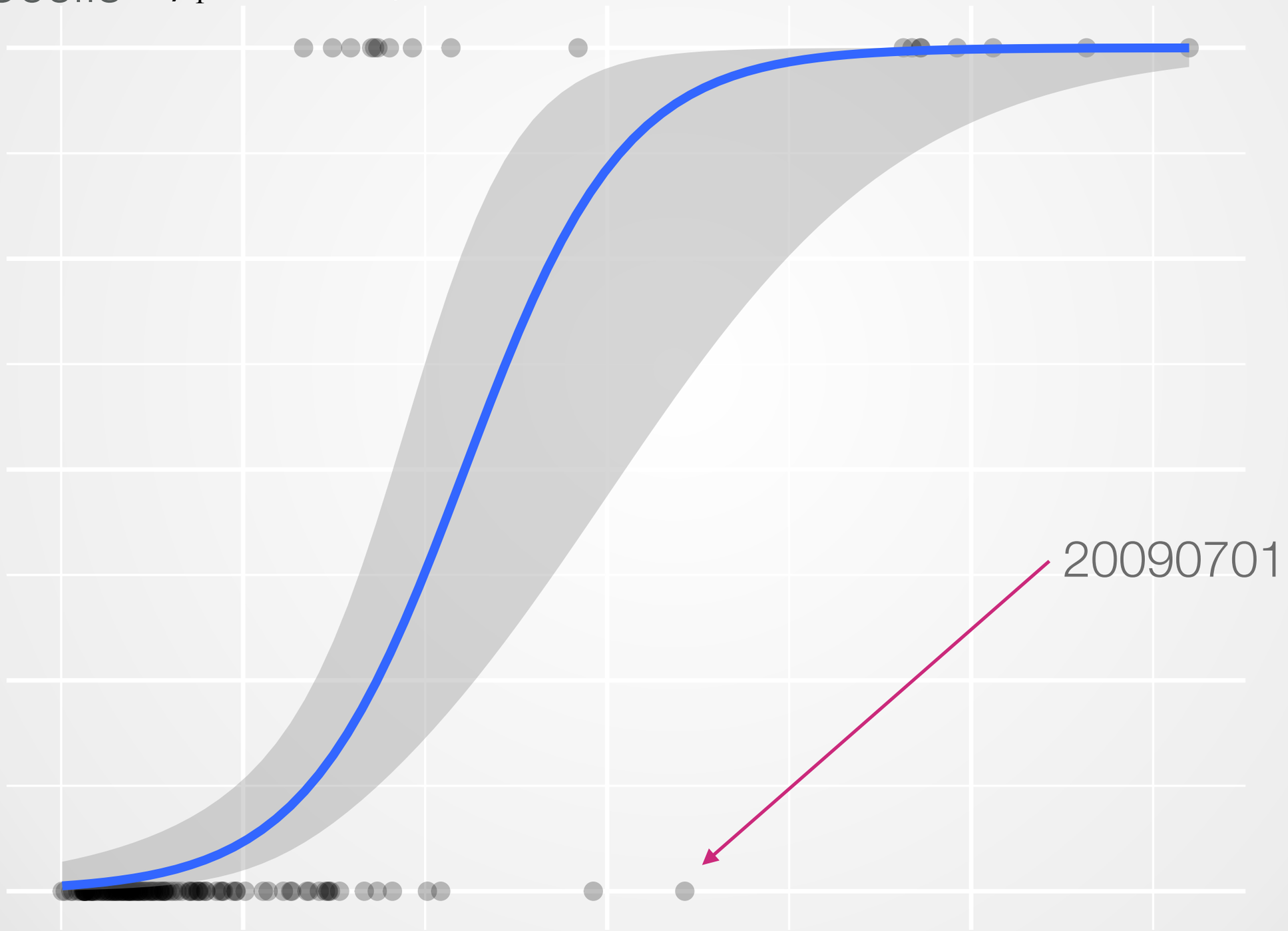
y National Bureau of Economic Research (NBER) recession indicator

x FRM



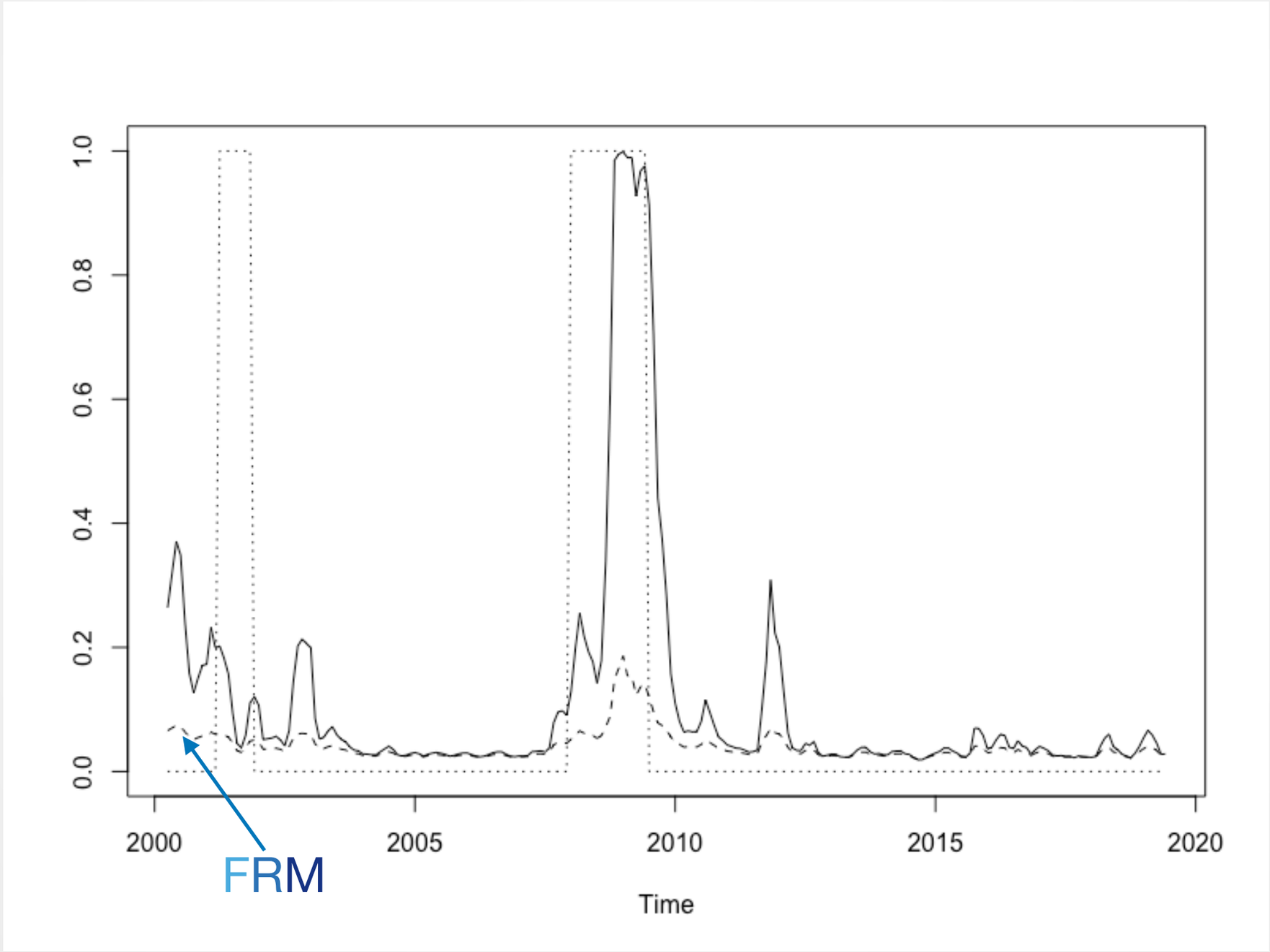
Result

- Coeffs $\beta_1 = 215.5 \;\; \beta_0 = -5.8 \;\; \tau = 0.05$



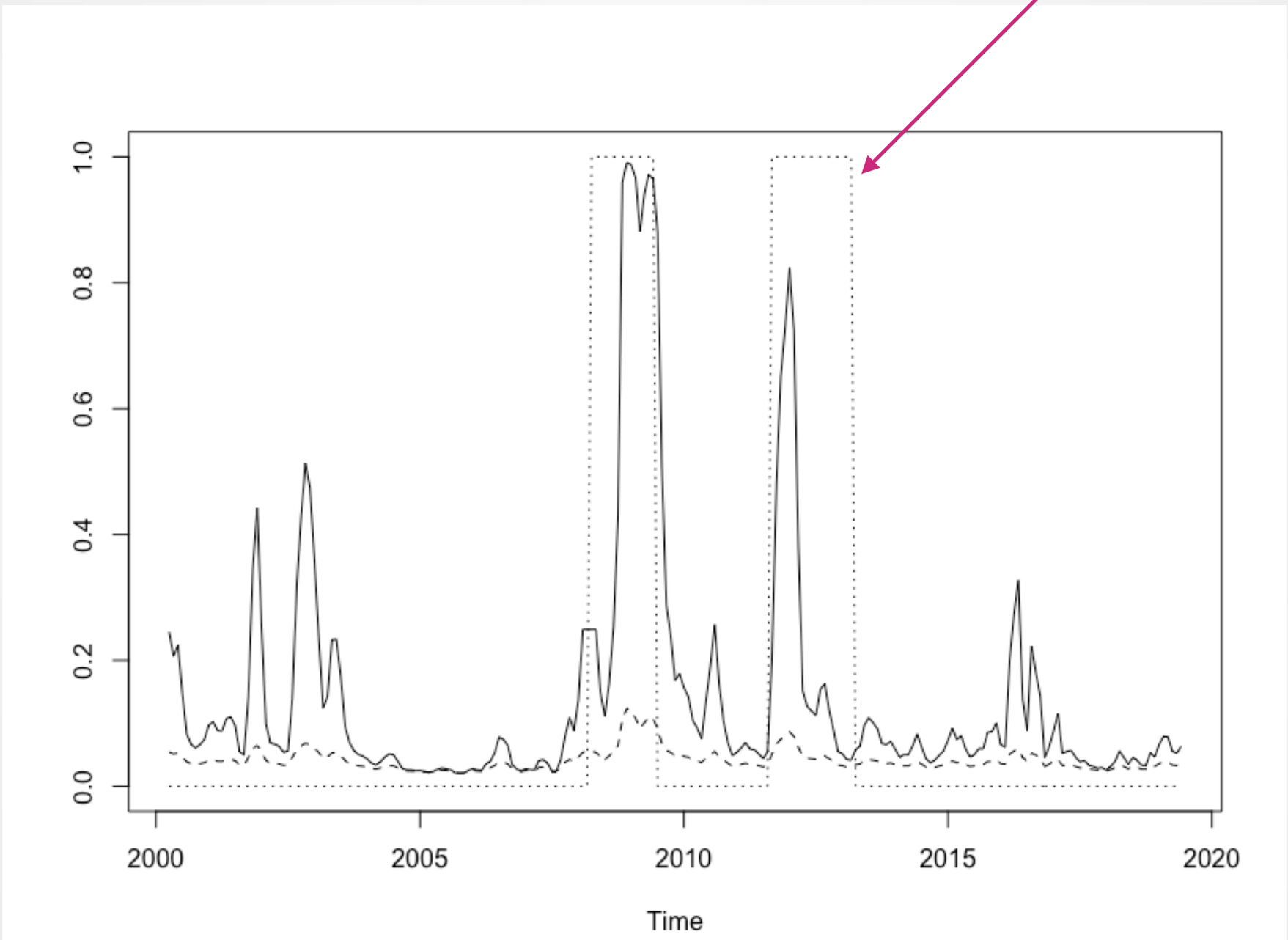
Implied recession probability

- FRM@Americas



Implied recession probability

- FRM@Europa



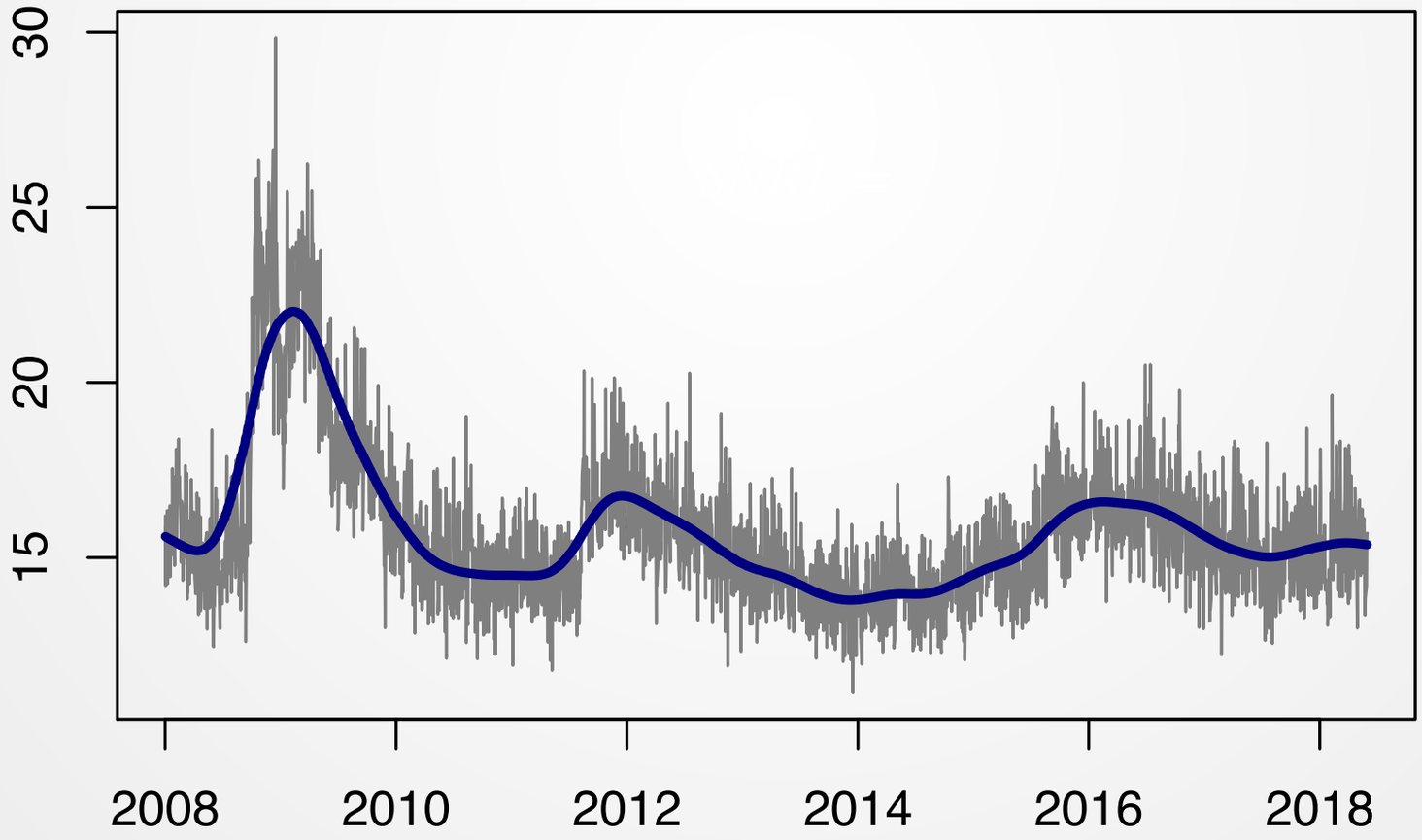
Extensions

- Use national or EU data to construct localised FRM
- Adaptive LASSO
- Global contagion effect of FRMs
- Relate Network Centrality to Max/Min CoStress nodes
- Besides equal weights, weights by degree of centrality
- LASSO in Time and Space
- Aggregate global FRMs, across asset classes
- Price Vectors

Extensions: Neural Network CoVaR (Keilbar, 2018)

- *Systemic Network Risk Index (SNRI)* measures total systemic risk
- Incorporates bivariate risk spillover effects $a_{ji,t}$

$$SNRI_t = \sum_{j=1}^{k} \sum_{i=1}^{k} (1 + |\mathrm{VaR}_{i,t}^{\tau}|)(1 + |\mathrm{CoVaR}_{j,t}^{\tau}|) \cdot a_{ji,t}$$



Extensions: Neural Network CoVaR (Keilbar, 2018)

- *Systemic Hazard Index (SHI)* measures the risk of bank *i* imposes to the financial system

$$SHI_{i,t} = \sum_{j=1}^{k} (1 + |\mathrm{CoVaR}^{\tau}_{j,t}|) \cdot a_{ji,t}$$

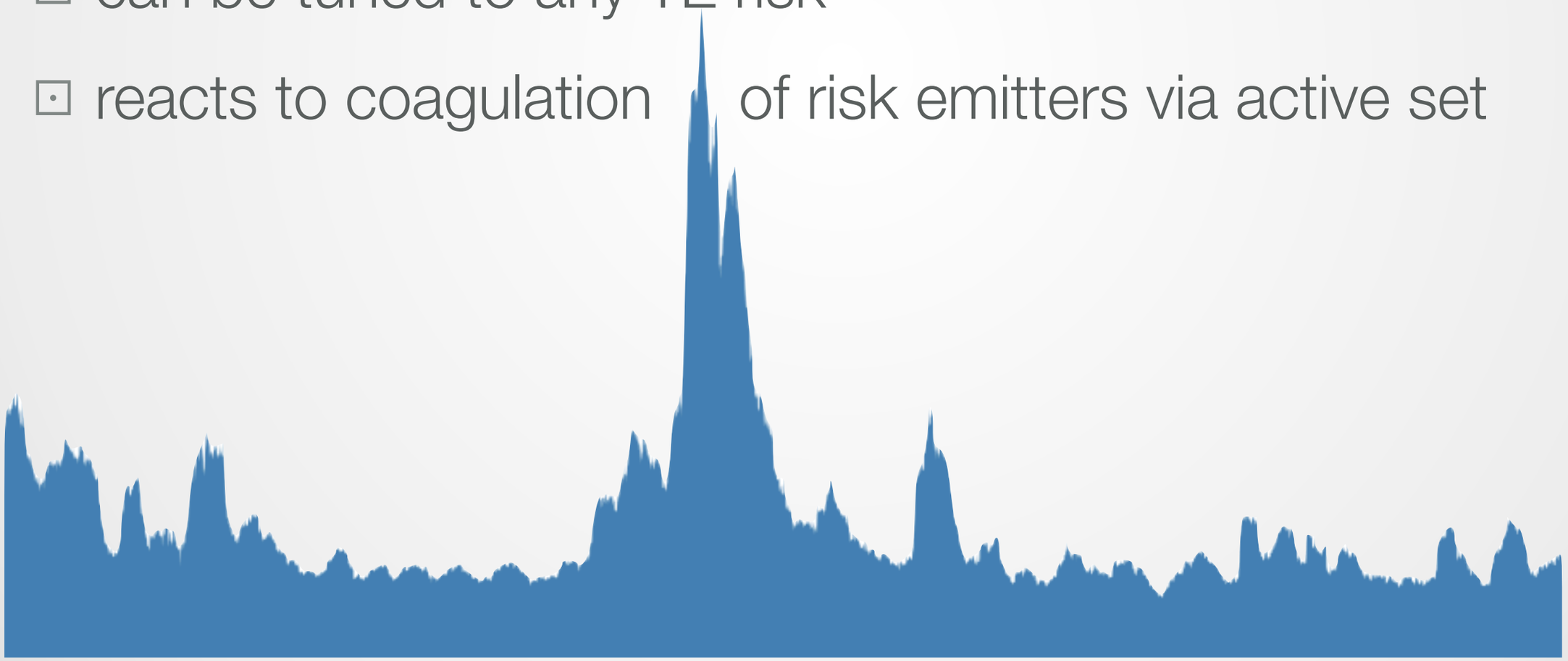
- *Systemic Fragility Index (SFI)* measures the exposure of bank *j* to the financial system

$$SFI_{i,t} = \sum_{i=1}^{k} (1 + |\mathrm{VaR}^{\tau}_{i,t}|) \cdot a_{ji,t}$$

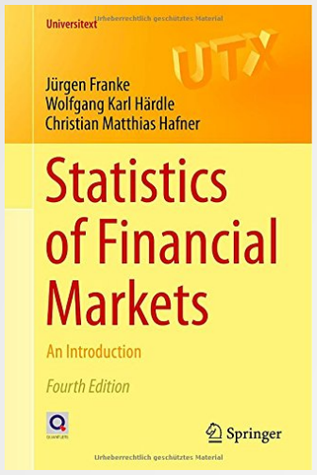
FIRAMIS **https://applications.firamis.de/frei/app/frm_app**

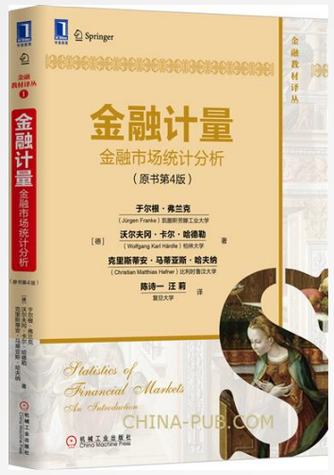
Conclusions

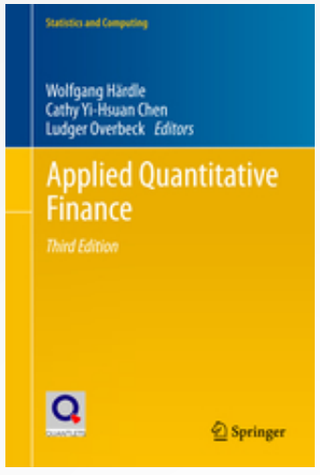
- FRM financialriskmeter = Flexible Risk Meter
- has systemic risk components
- predicts recession periods
- can be tuned to any TE risk
- reacts to coagulation of risk emitters via active set



FRMs in FinTech, Cryptos, …







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Digital Finance

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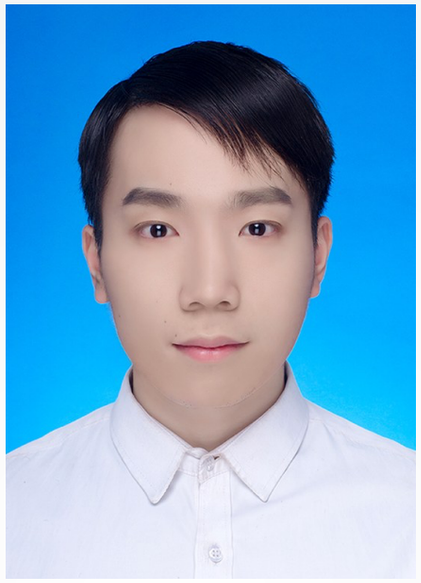

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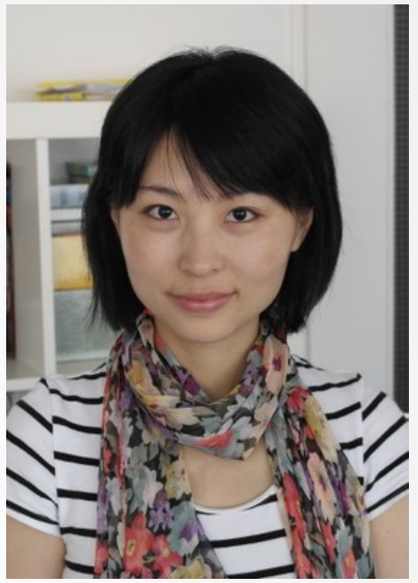

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Expectile as Quantile

$e_\tau(Y)$ is the τ-quantile of the cdf T , where

$$T(y) = \frac{G(y) - xF(y)}{2\{G(y) - yF(y)\} + \{y - \mu_Y\}}$$

and

$$G(y) = \int_{-\infty}^{y} u \, dF(u)$$

Back to Expectiles

Company List

FRM X's

Symbol	Name	LastSale	MarketCap	ADR TSO	IPOyear	Sector	Industry	Summary Quote
WFC	Wells Fargo & Company	51.88	2.65E+11	n/a	n/a	Finance	Major Banks	http://www.nasdaq.com/symbol/wfc
JPM	J P Morgan Chase & Co	62.81	2.31E+11	n/a	n/a	Finance	Major Banks	http://www.nasdaq.com/symbol/jpm
BAC	Bank of America Corporation	16.08	1.67E+11	n/a	n/a	Finance	Major Banks	http://www.nasdaq.com/symbol/bac
C	Citigroup Inc.	50.12	1.49E+11	n/a	n/a	Finance	Major Banks	http://www.nasdaq.com/symbol/c
AIG	American International Group, Inc.	59.75	73911497592	n/a	n/a	Finance	Property-Casualty Insurers	http://www.nasdaq.com/symbol/aig
GS	Goldman Sachs Group, Inc. (The)	169.84	72442901924	n/a	1999	Finance	Investment Bankers/Brokers/Service	http://www.nasdaq.com/symbol/gs
USB	U.S. Bancorp	41.05	71803718395	n/a	n/a	Finance	Major Banks	http://www.nasdaq.com/symbol/usb
AXP	American Express Company	64.42	63405122360	n/a	n/a	Finance	Finance: Consumer Services	http://www.nasdaq.com/symbol/axp
MS	Morgan Stanley	30.5	59054830750	n/a	n/a	Finance	Investment Bankers/Brokers/Service	http://www.nasdaq.com/symbol/ms
BLK	BlackRock, Inc.	330.16	54848693699	n/a	1999	Finance	Investment Bankers/Brokers/Service	http://www.nasdaq.com/symbol/blk
MET	MetLife, Inc.	44.37	49322866962	n/a	2000	Finance	Life Insurance	http://www.nasdaq.com/symbol/met
PNC	PNC Financial Services Group, Inc. (The)	91.6	46515010272	n/a	n/a	Finance	Major Banks	http://www.nasdaq.com/symbol/pnc
BK	Bank Of New York Mellon Corporation (The)	38.82	42428419621	n/a	n/a	Finance	Major Banks	http://www.nasdaq.com/symbol/bk
SCHW	The Charles Schwab Corporation	30.79	40535754347	n/a	n/a	Finance	Investment Bankers/Brokers/Service	http://www.nasdaq.com/symbol/schw
COF	Capital One Financial Corporation	68.55	36471702025	n/a	1994	Finance	Major Banks	http://www.nasdaq.com/symbol/cof
PRU	Prudential Financial, Inc.	76.92	34537080000	n/a	2001	Finance	Life Insurance	http://www.nasdaq.com/symbol/pru
TRV	The Travelers Companies, Inc.	109.04	33172017516	n/a	n/a	Finance	Property-Casualty Insurers	http://www.nasdaq.com/symbol/trv
BX	The Blackstone Group L.P.	27.29	32092061544	n/a	2007	Finance	Investment Managers	http://www.nasdaq.com/symbol/bx
CME	CME Group Inc.	88.93	30079362252	n/a	2002	Finance	Investment Bankers/Brokers/Service	http://www.nasdaq.com/symbol/cme

Predicting Future Recessions

- Predictions up to 6mth ahead

	US recession			**EU recession**		
k-month ahead	coefficient	std	R^2	coefficient	std	R^2
1	69.43∗	14.44	0.36	77.07∗	13.95	0.27
2	54.87∗	11.55	0.29	65.12∗	12.30	0.22
3	47.12∗	9.84	0.23	56.65∗	11.18	0.18
4	42.12∗	8.77	0.19	50.83∗	10.45	0.14
5	35.83∗	7.59	0.14	45.68∗	9.86	0.12
6	29.77∗	6.70	0.10	38.56∗	9.16	0.09