FRM financialriskmeter for Cryptos

Ladislaus von Bortkiewicz Professor of Statistics
Humboldt-Universität zu Berlin
BRC Blockchain Research Center
lvb.wiwi.hu-berlin.de
Charles University, WISE XMU, NCTU 玉山学者

Money

- Groucho Marx: „Money frees you from doing things you dislike. Since I dislike doing nearly everything, money is handy."
- David Hume: „Money is () the instrument () to facilitate the exchange of one commodity for another. It is () the oil which renders the motion of the wheels more smooth and easy.
- Friedrich Hayek: „Instead of a national government issuing a specific currency () private businesses should be allowed to issue their own forms of money, deciding how to do so on their own."

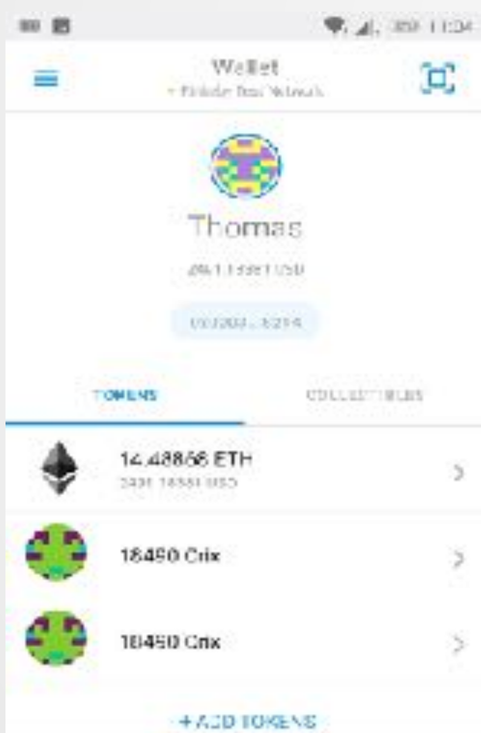


ideas: Michael Burda, CCC 2017

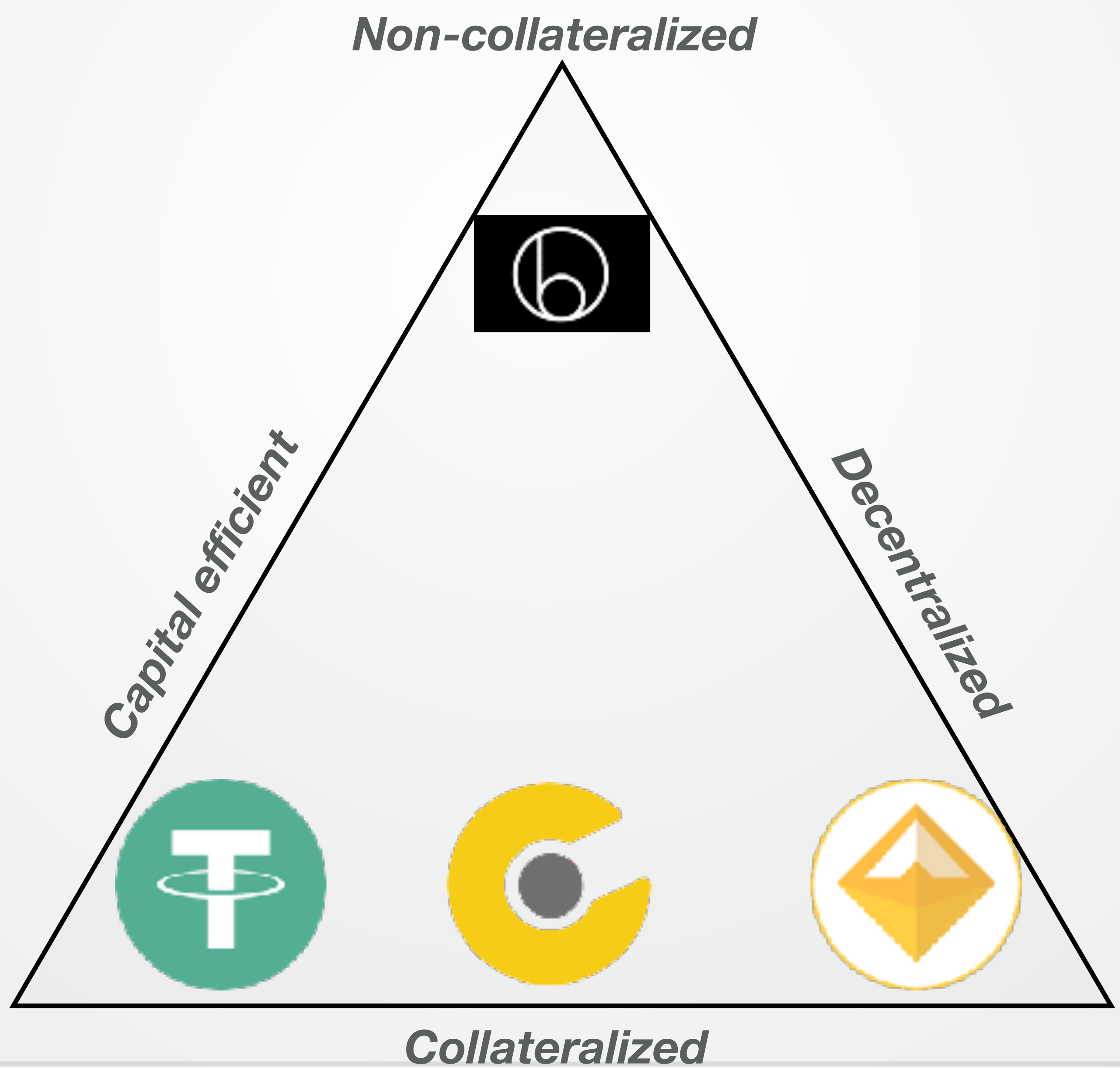
CRIX - the Coin

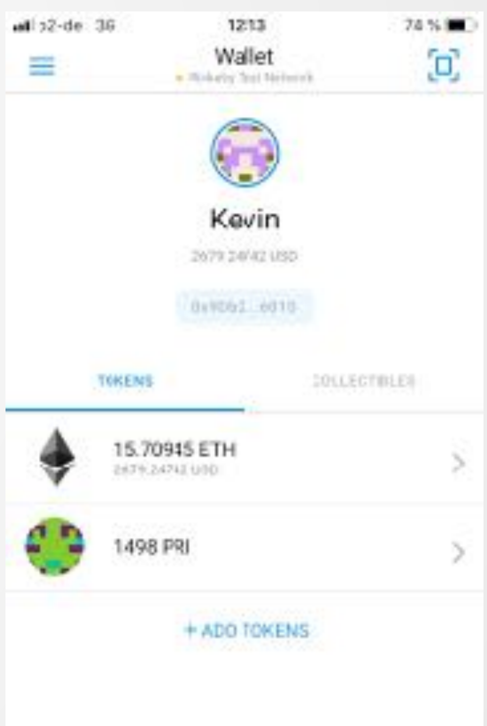
- Smart Contract: Solidity
- EVM Ethereum Virtual Machine (gas)
- Safemath library

Create you own wallet!



Fiat-collateralized



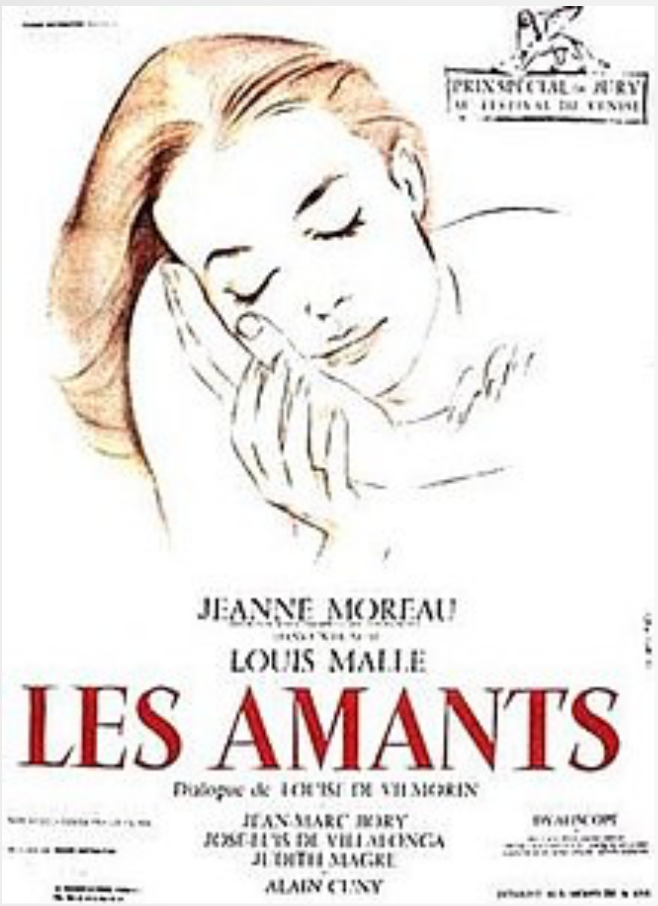


Crypto-collateralized

Tail Events (TE)

- TEs across Cryptos 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

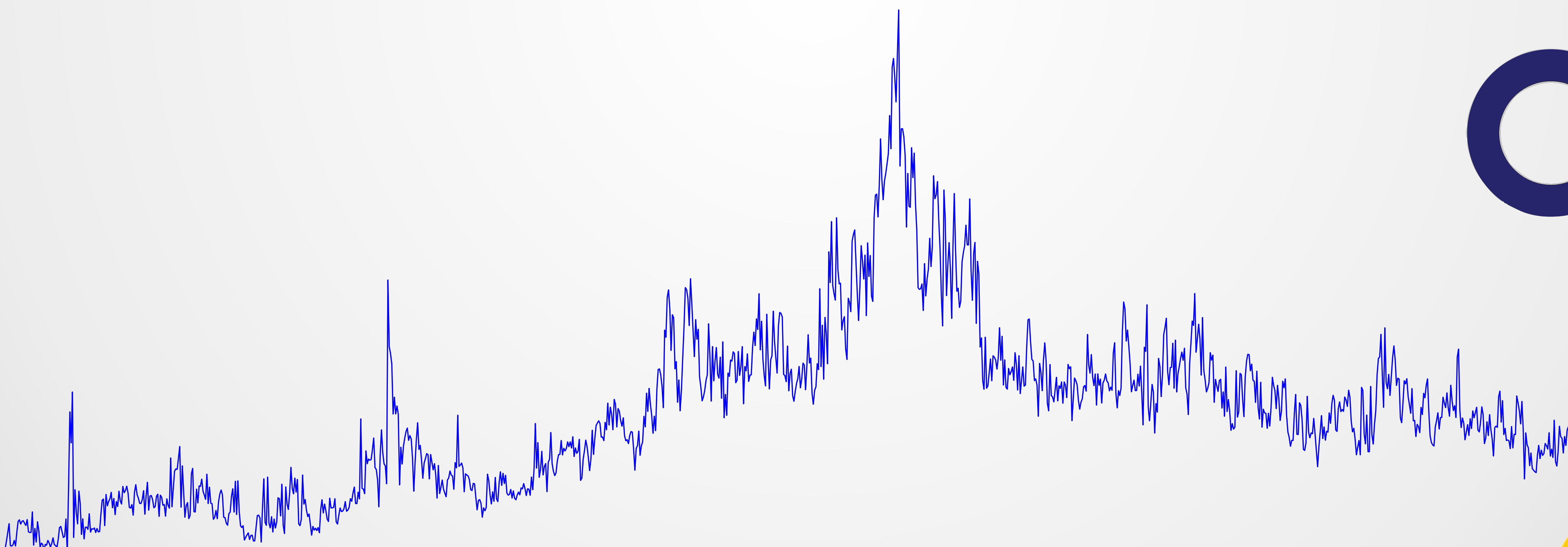
"Broadly speaking, model risk can be attributed to either an incorrect model or to an incorrect implementation of a model" , Buraschi and Corielle (2005)

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

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

Risk Measures

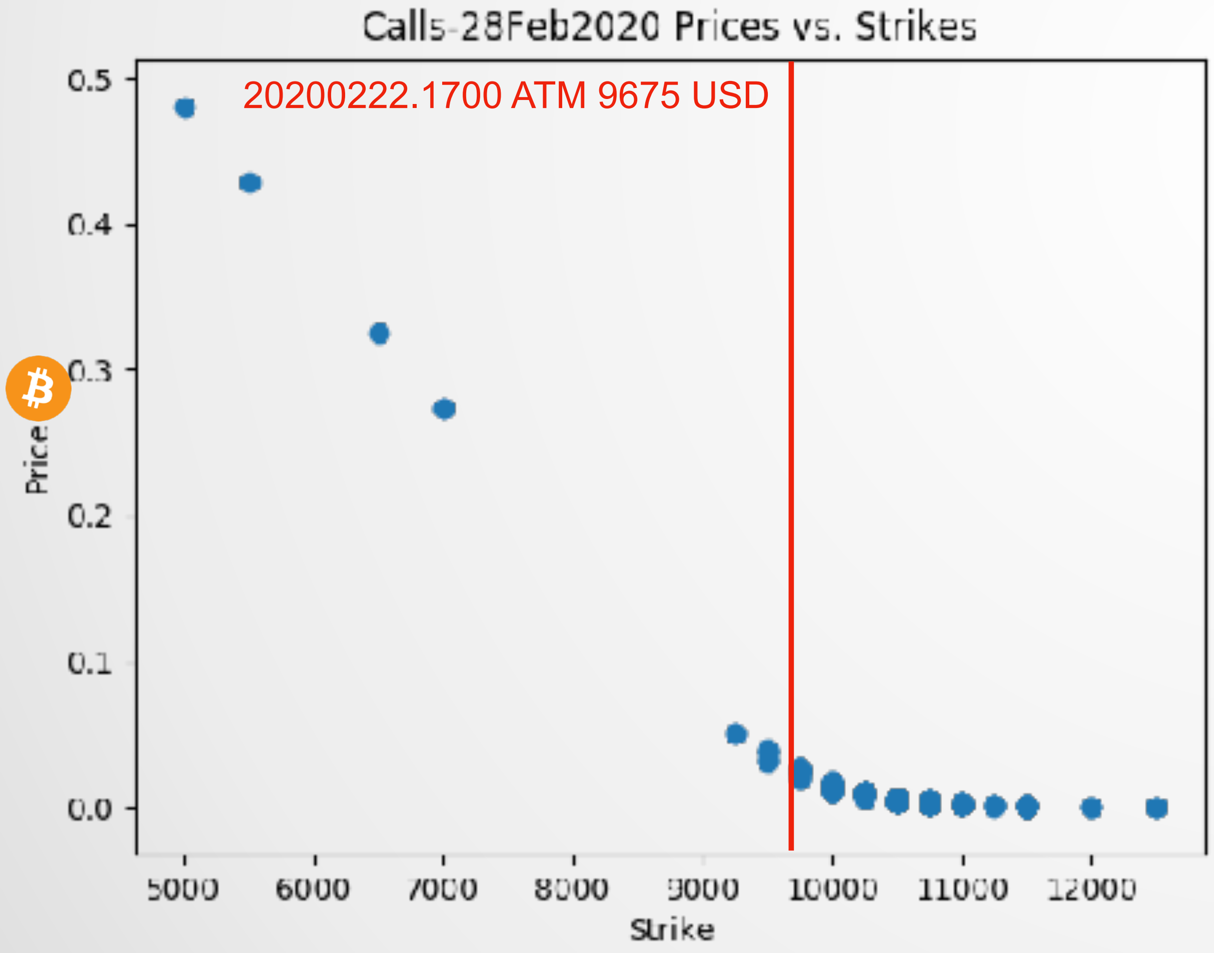
- VIX: IV based, does not reflect joint TEs
- CoVaR concentrates on a pair of risk factors
- CISS, Google trends, SRISK, …
- FRM displays the full picture of TE dependencies
- Firamis.de/FRM financialriskmeter

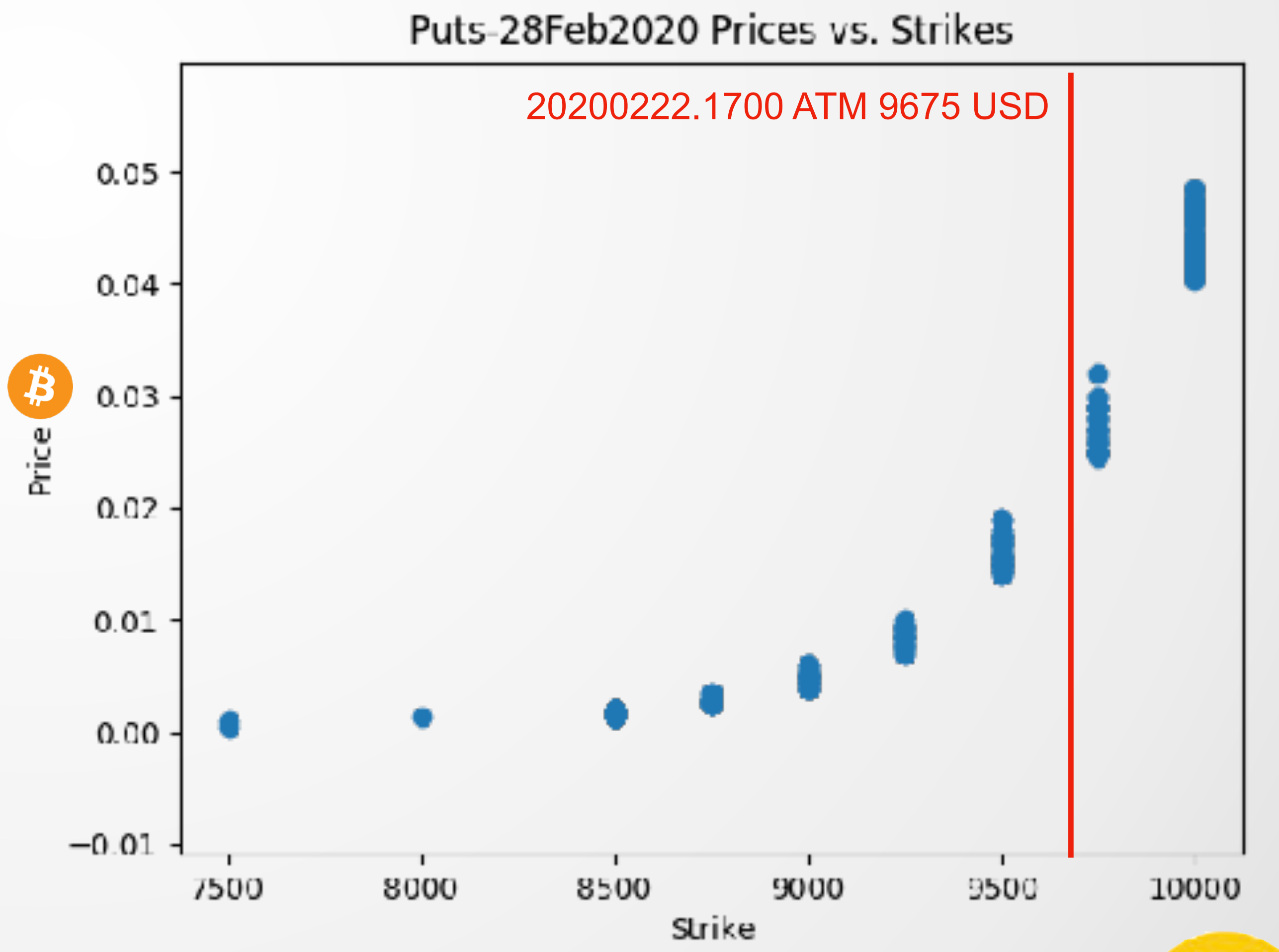


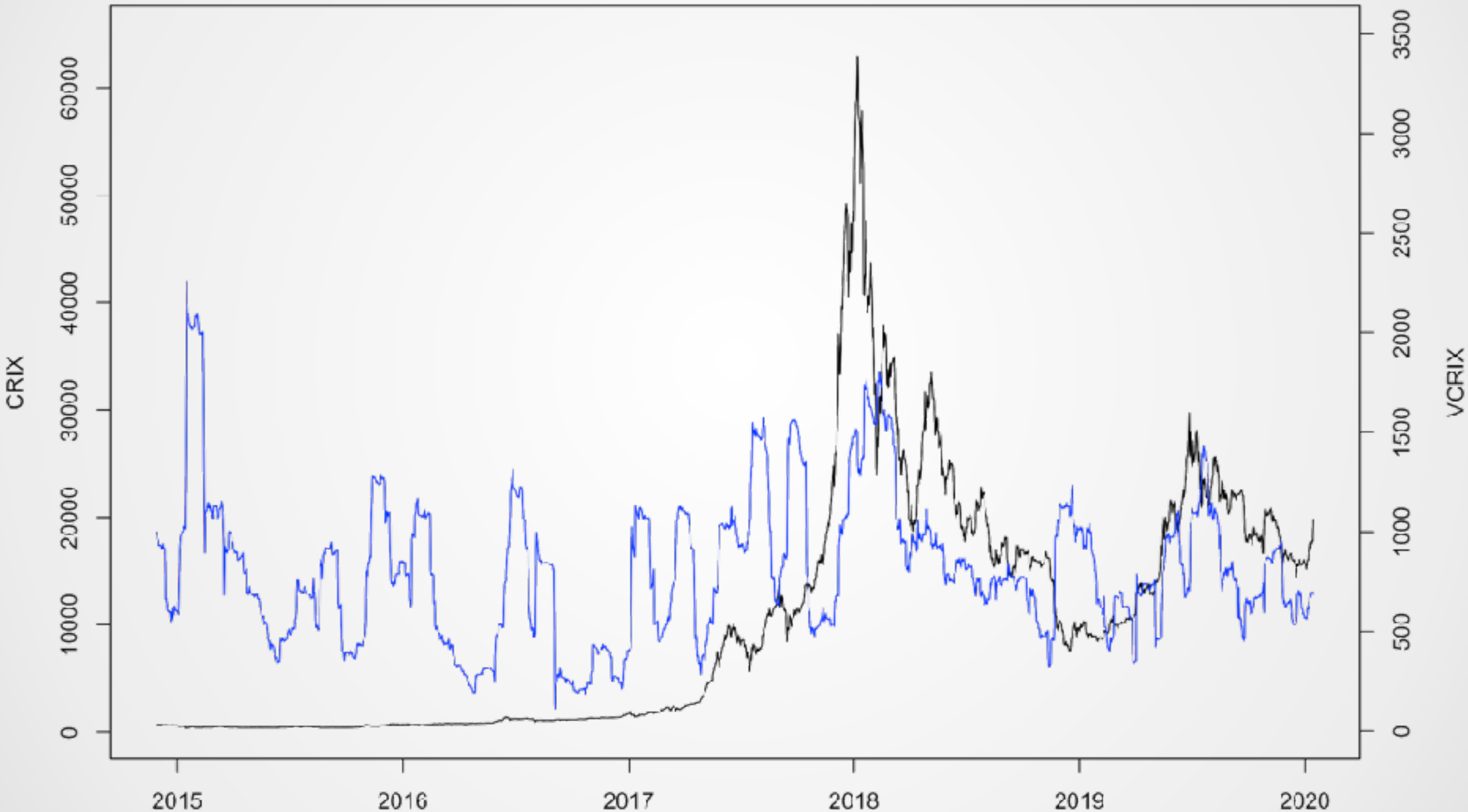
Call and Puts on BTCs

- Listed at Bloomberg since 20200113

Prices from 20200221.1600 - 20200222.1100
Timestamps precise in the range 1E-3 sec.
Calls, Puts with maturity 20200228






CRIX
VCRIX
0
10000
20000
30000
40000
50000
60000
0
500
1000
1500
2000
2500
3000
3500
2015
2016
2017
2018
2019
2020

Outline

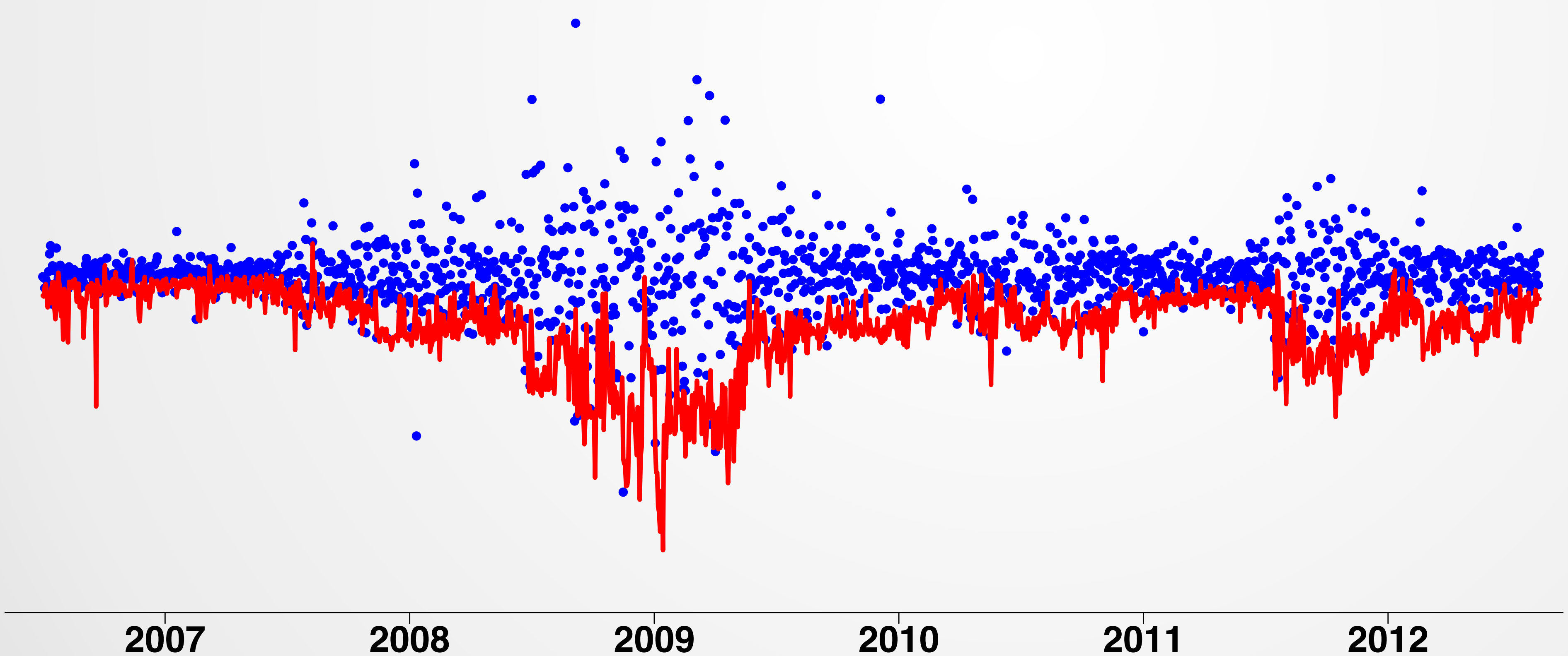
1. Motivation ✔
2. Genesis
3. FRM Framework
4. CoStress ID, Active Set
5. Extension to other asset classes
6. FRM a predictor for recession
7. Conclusions

VaR Value at Risk

- Probability measure based

$$P(X_{i,t} \leq VaR^{\tau}_{i,t}) \overset{def}{=} \tau,\ \tau \in (0,1)$$

- $X_{i,t}$ 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:

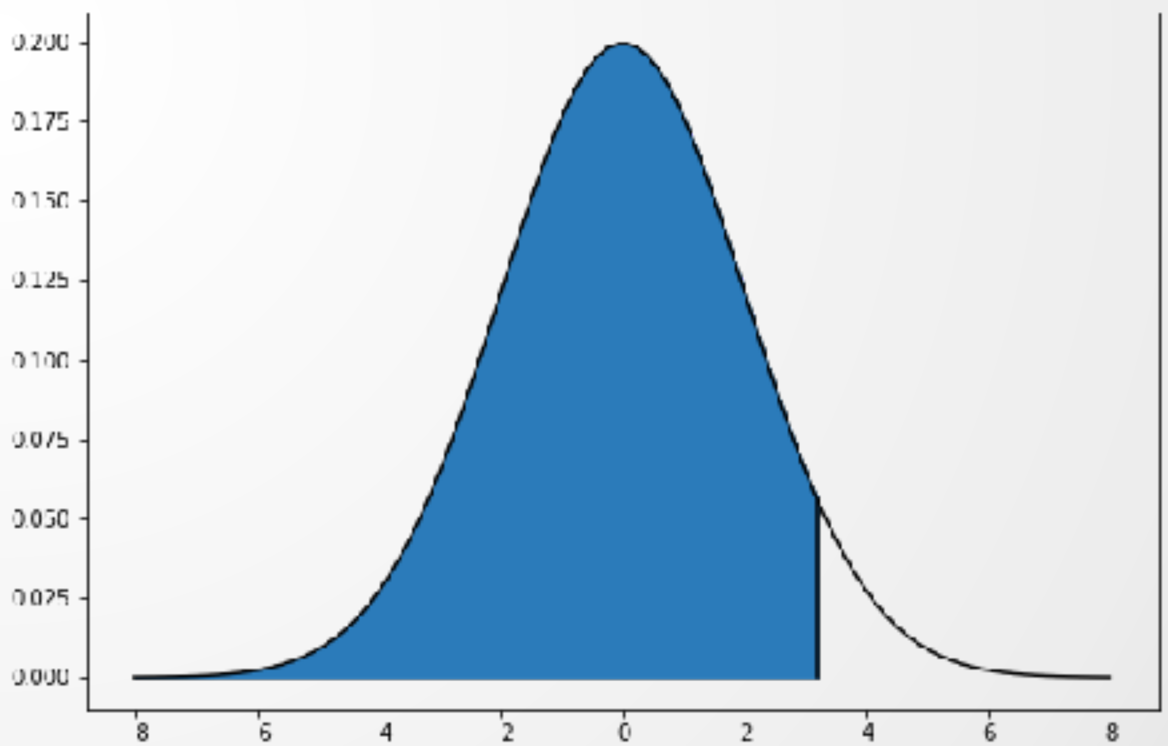
log returns

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

asymmetric loss function

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

α = 1 for quantiles,
α = 2 for expectiles

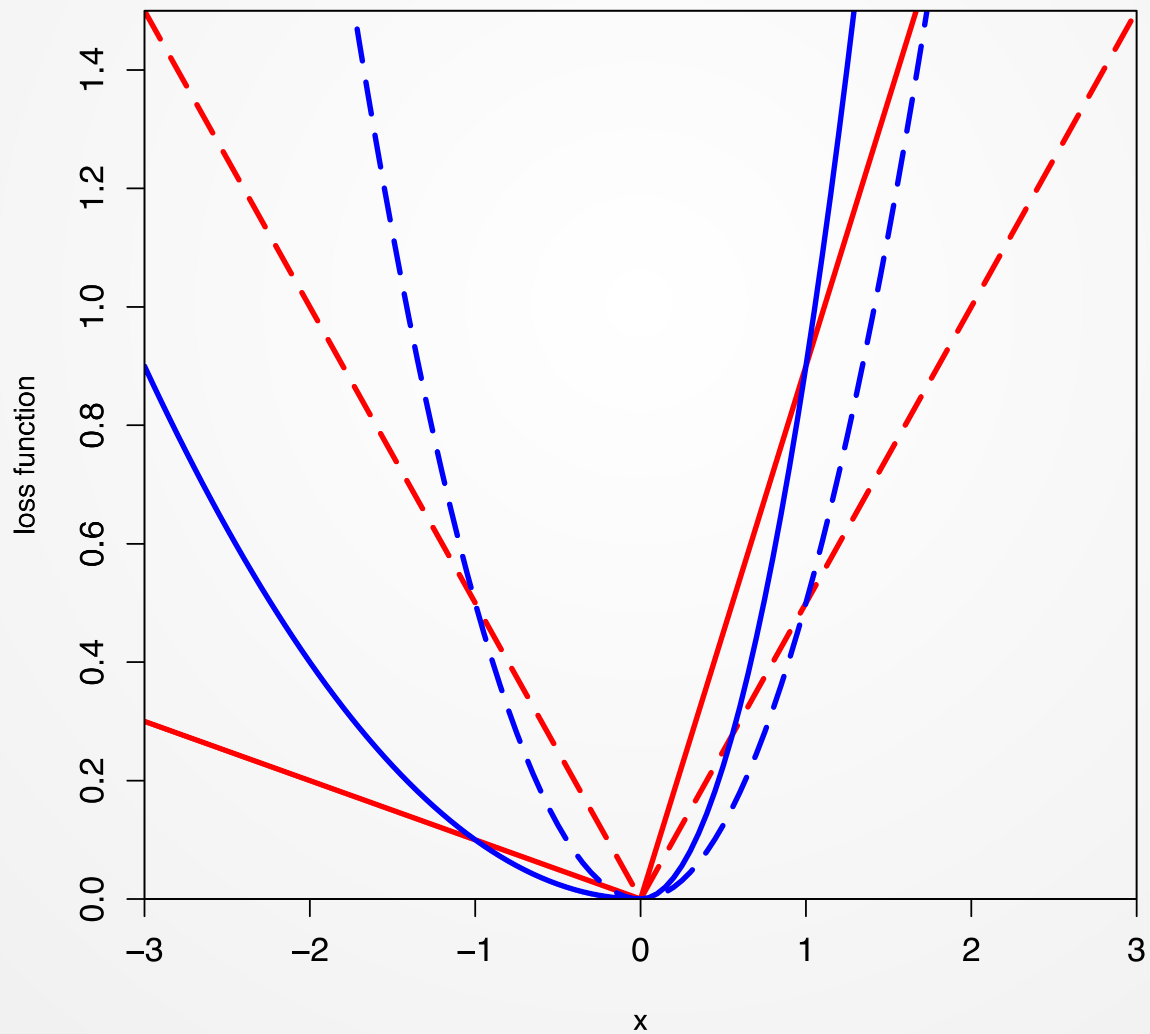


τ = 0.7, $N(0,2)$ Quantile = 3.2

Expectile as Quantile

Quantiles and Expectiles

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



LQRcheck

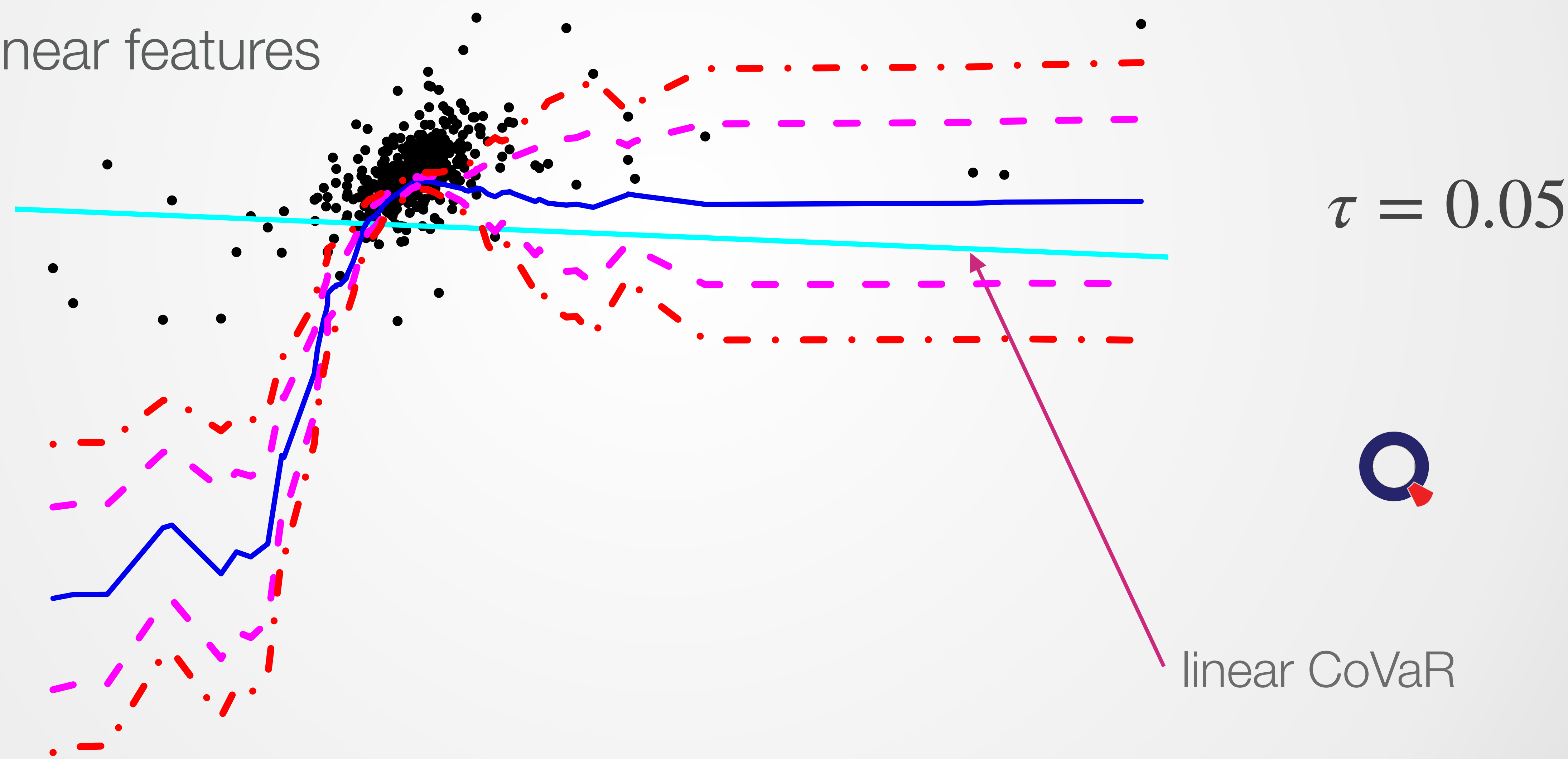
Figure: Loss function of expectiles and quantiles for $\tau = 0.5$ (dashed) and $\tau = 0.9$ (solid)

Conditional Value at Risk

- Adrian and Brunnermeier (2016) introduced CoVaR

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

- 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

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

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

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

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

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

Linear Quantile Lasso Regression

$$X^s_{j,t} = \alpha^s_{j,t} + A^{s\top}_{j,t}\beta^s_j + \varepsilon^s_{j,t}, \qquad (1)$$

- Where $A^{s\top}_{j,t} \stackrel{def}{=} \left[M^s_{t-1}, X^s_{-j,t}\right]$

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

3M

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 $\rho_\tau(u) = | u |^c | 1(u \leq 0) - \tau |$,
- 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

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

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

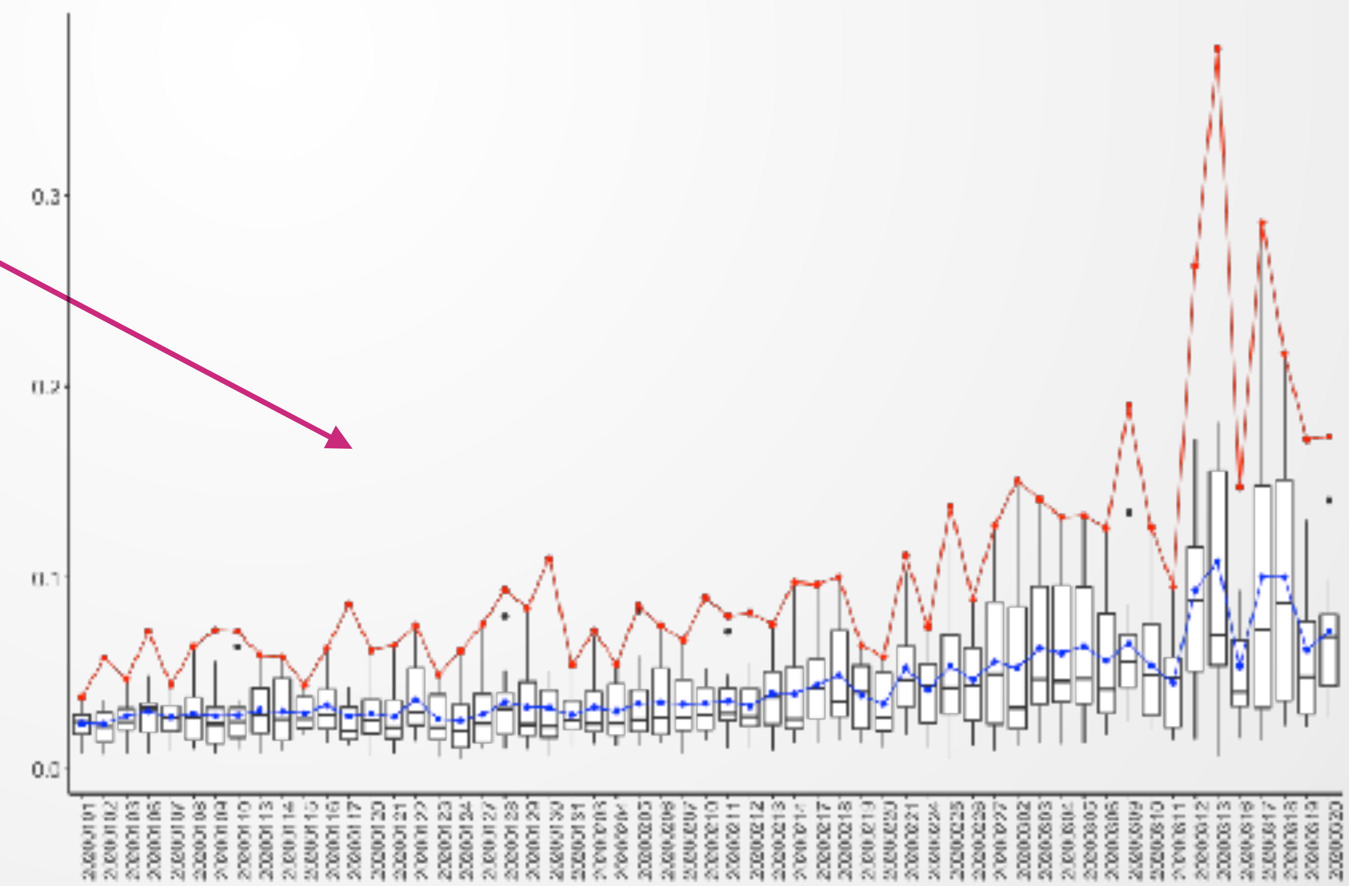
λ Selection

- 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

FIRAMIS app HU Berlin app

FRM@Americas

FRM@Asia

FRM@Crypto

FRM@Europe

FRM@iTraxx

Methodology

- Obtain risk driver list of all historically active index members
- Download daily rates in same currency (USD)
- Sort market cap decreasingly (to select J biggest risk drivers)
- Calculate returns
- On every trading day,
  - Select J biggest risk driver's returns over 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 $\tau = 0.05, \tau = 0.01, \ldots$
- Time frame: 2000-2019
- Macroeconomic risk factors:

  CBOE Volatility Index

  S&P 500

  REIT Index

  3M Treasury Constant Maturity Rate

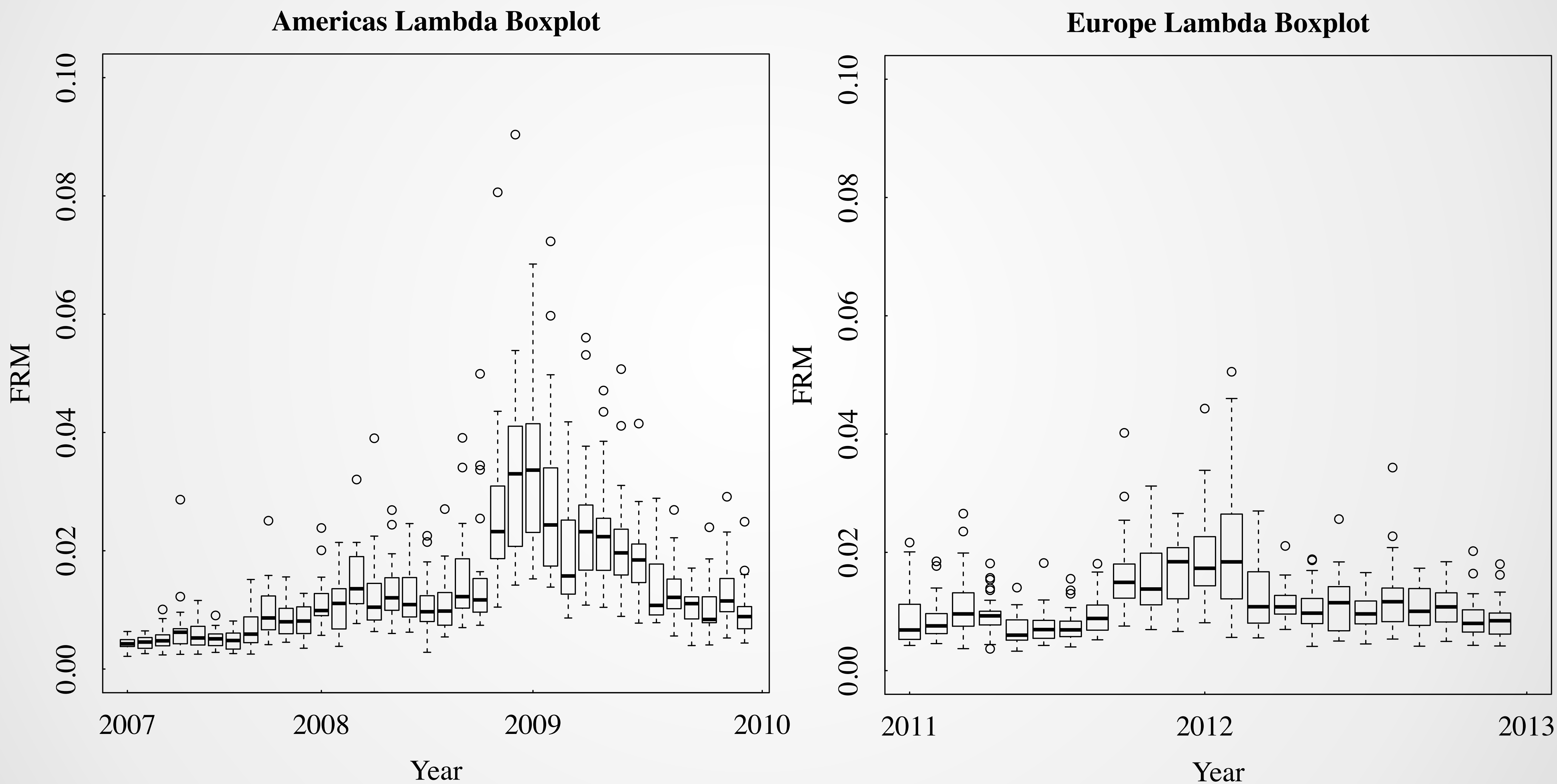
  10Y Treasury Constant Maturity Rate

  Moody's Seasoned Baa Corp Bond Yield Spread

LQ Lasso Regression

Distributional characteristics

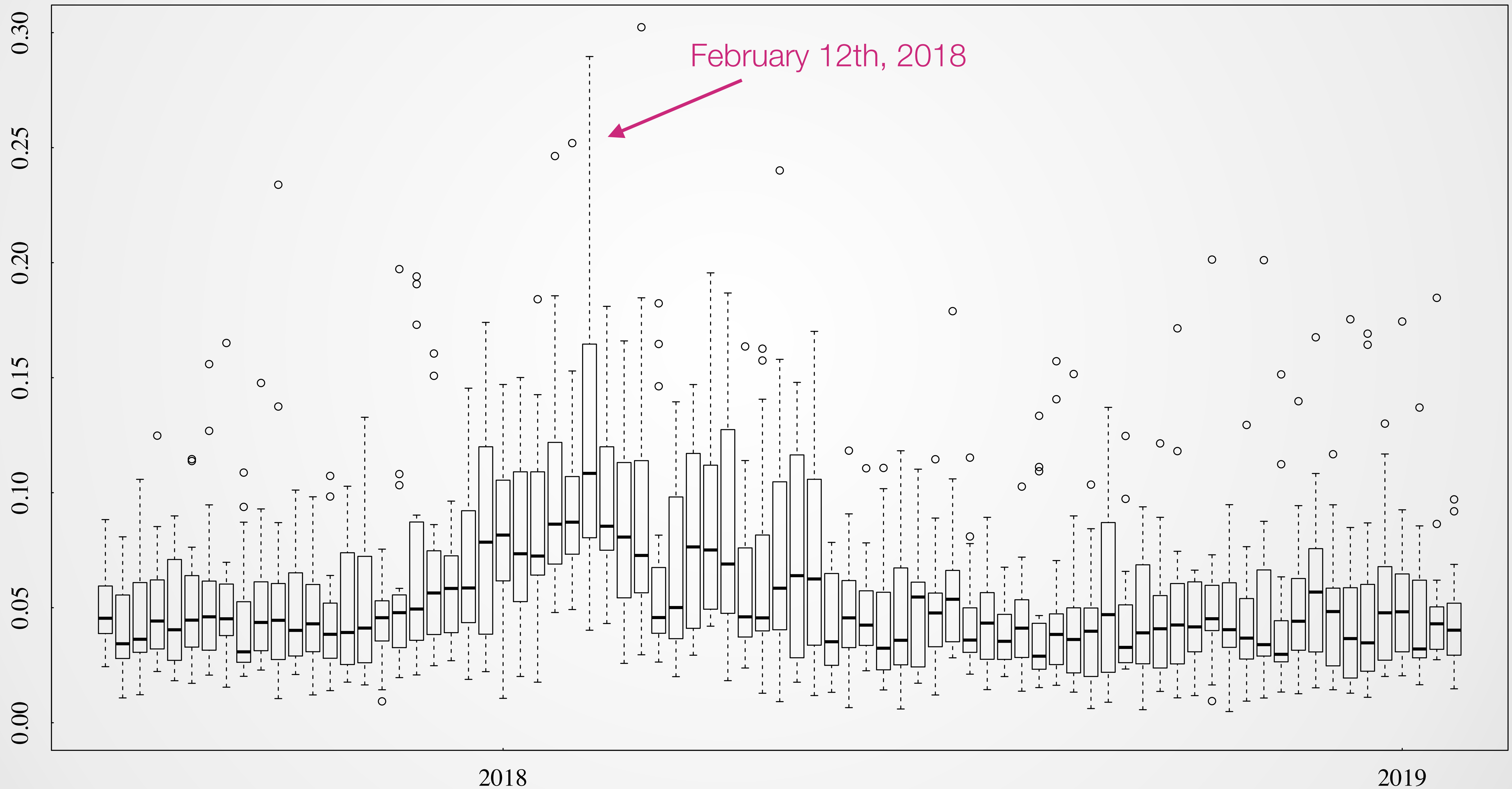
- Identifying companies CoStress $\tau = 0.05 \;\; J = 25$



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

Distributional characteristics

- Identifying Crypto Currency CoStress $\tau = 0.05$ $J = 15$



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

Crypto’s CoStress

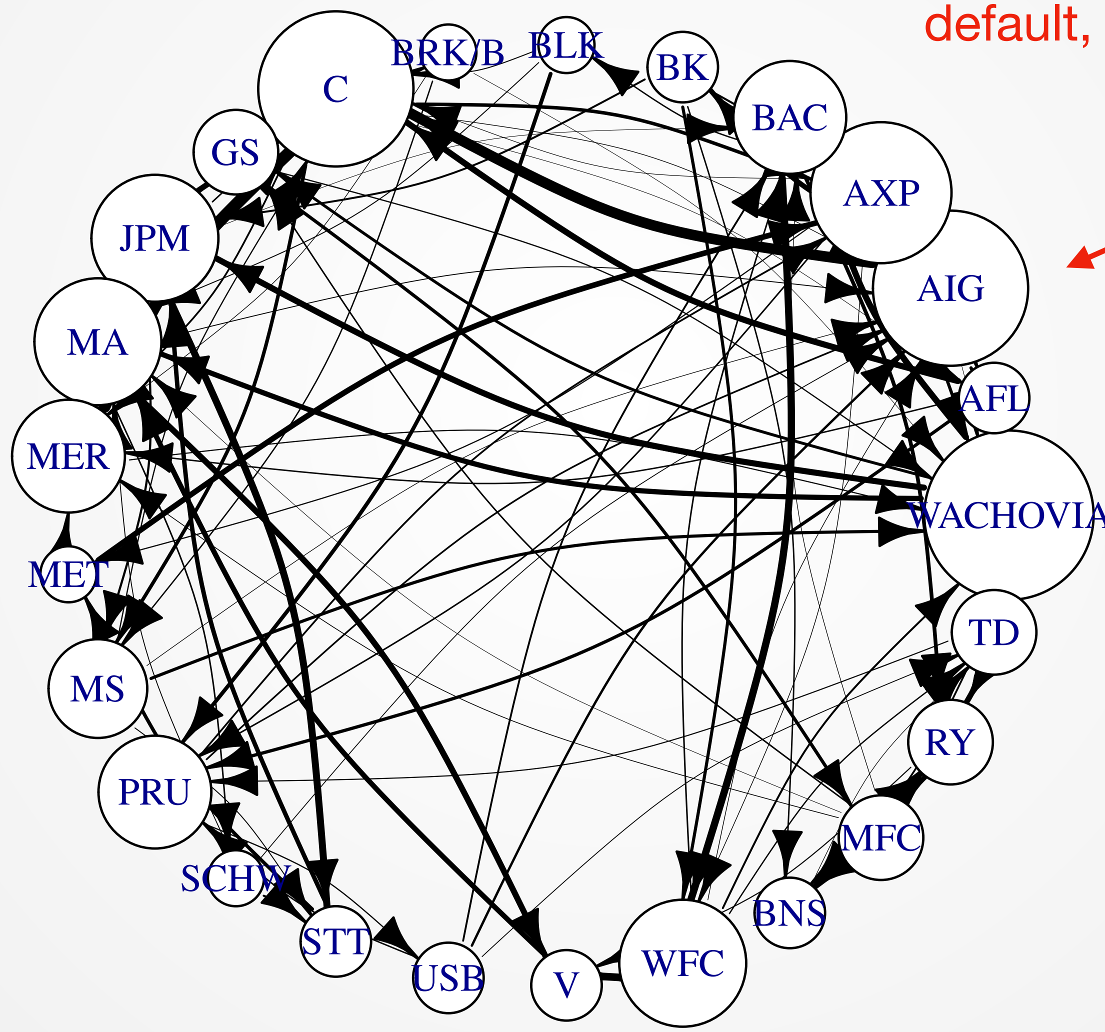
- February 12th, 2018:

  High CoStress: XMR, XML, DASH, EOS, ETH, LTC

  Low CoStress: XEM, NEO, LSK, BTC, BCH

Visualising the Active Set: Total Degree Centrality

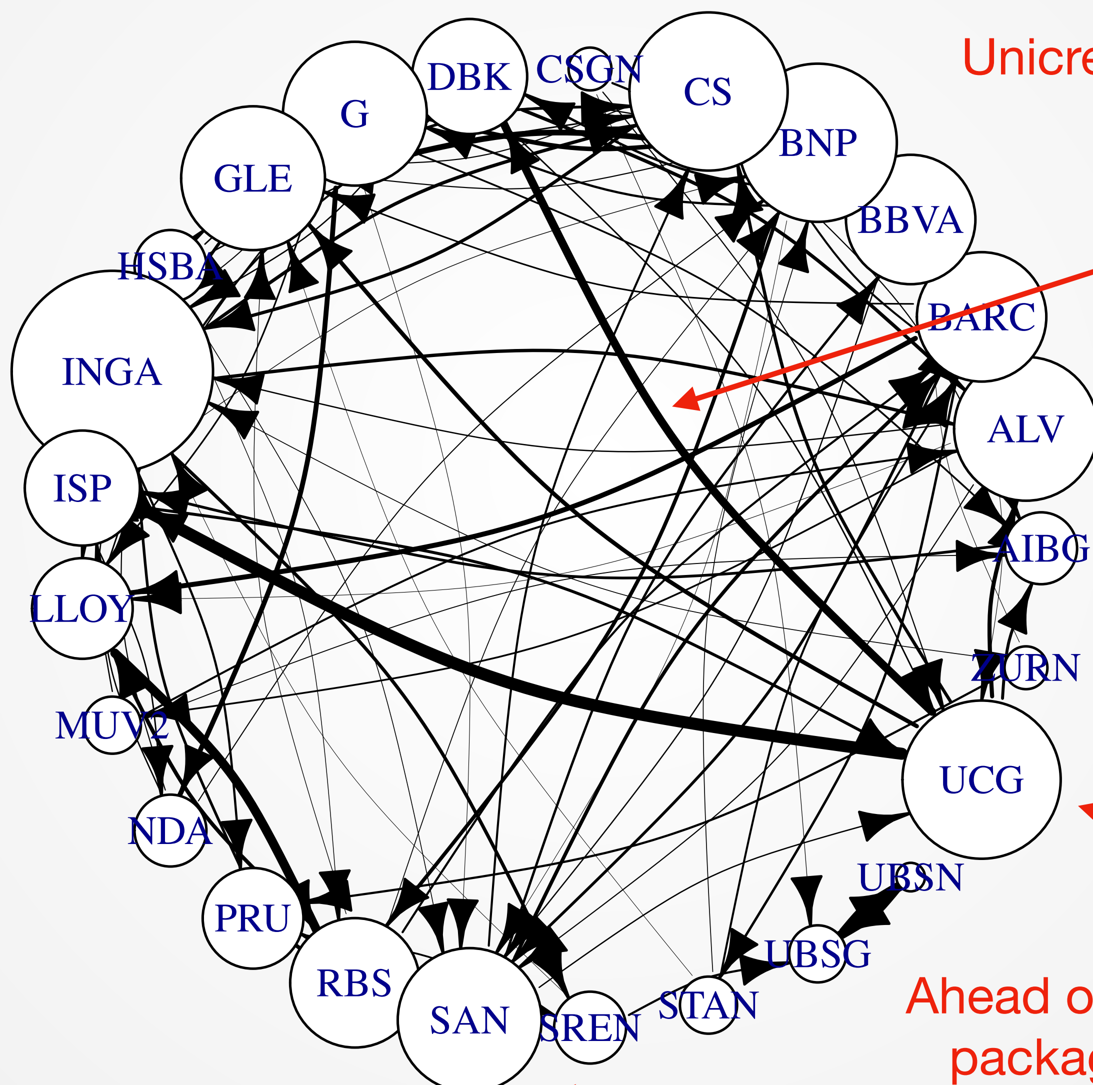
- September 5th, 2008, FRM@Americas, *J*=25



One day ahead of the Lehman Brother default, AIG and Wachovia are captured as systemic

Visualising the Active Set: Total Degree Centrality

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

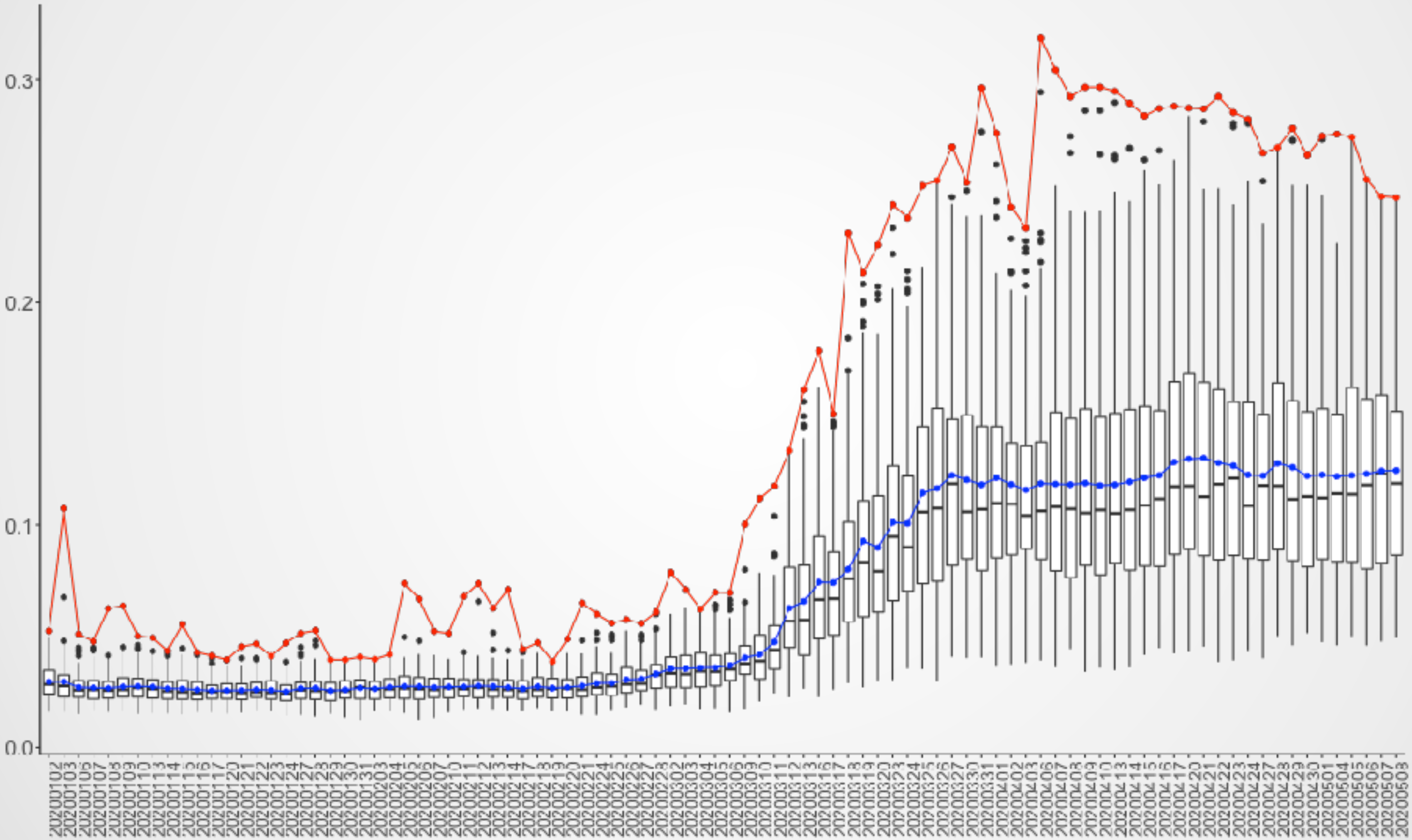


Unicredit (UCG) strongly influences DBK (Deutsche Bank)

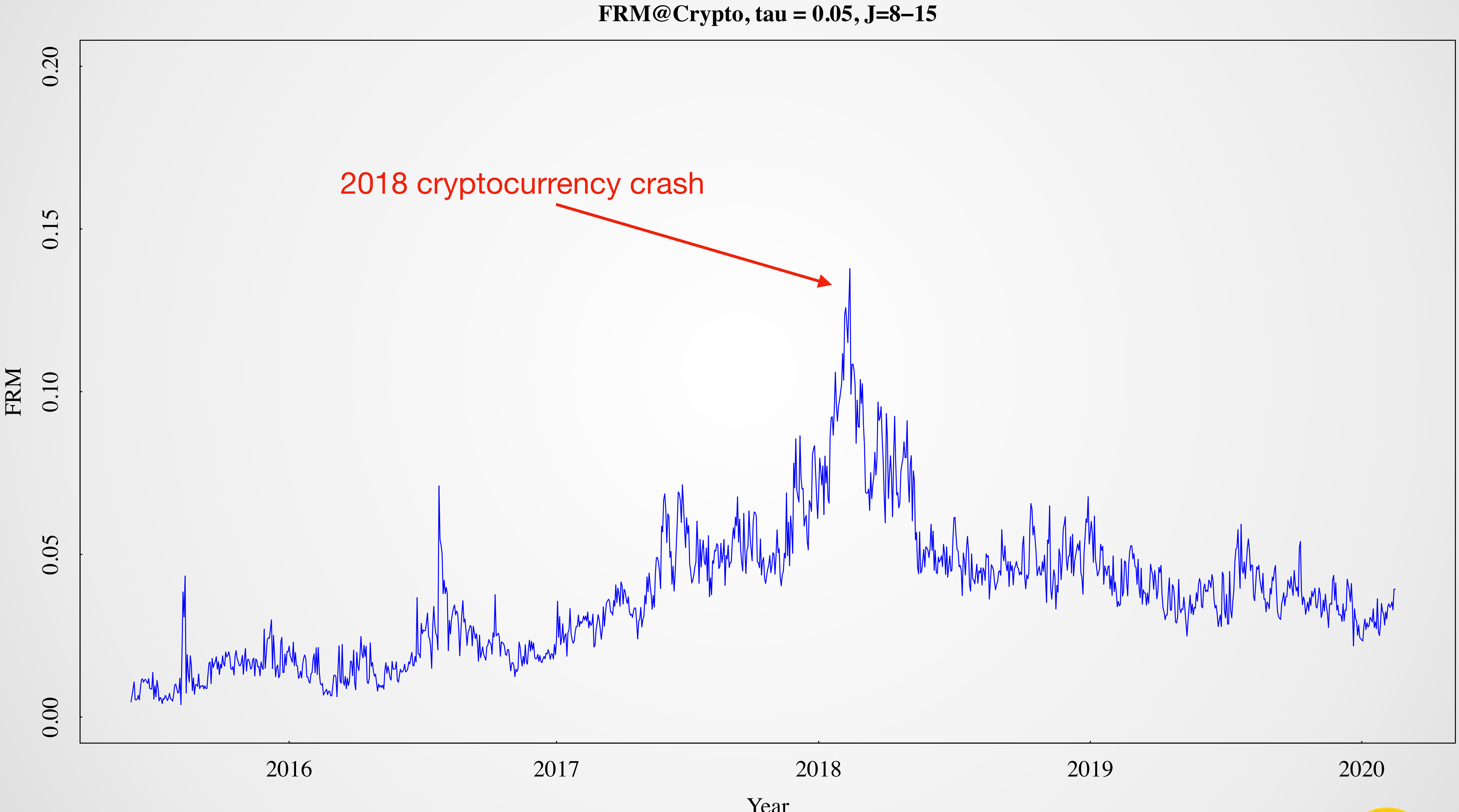
Ahead of the February 2012 Greece bailout package, Italian and Spanish banks are central nodes.

Visualising the Trend: FRM the Boxplot

- January 2020 to May 2020, FRM@Europe



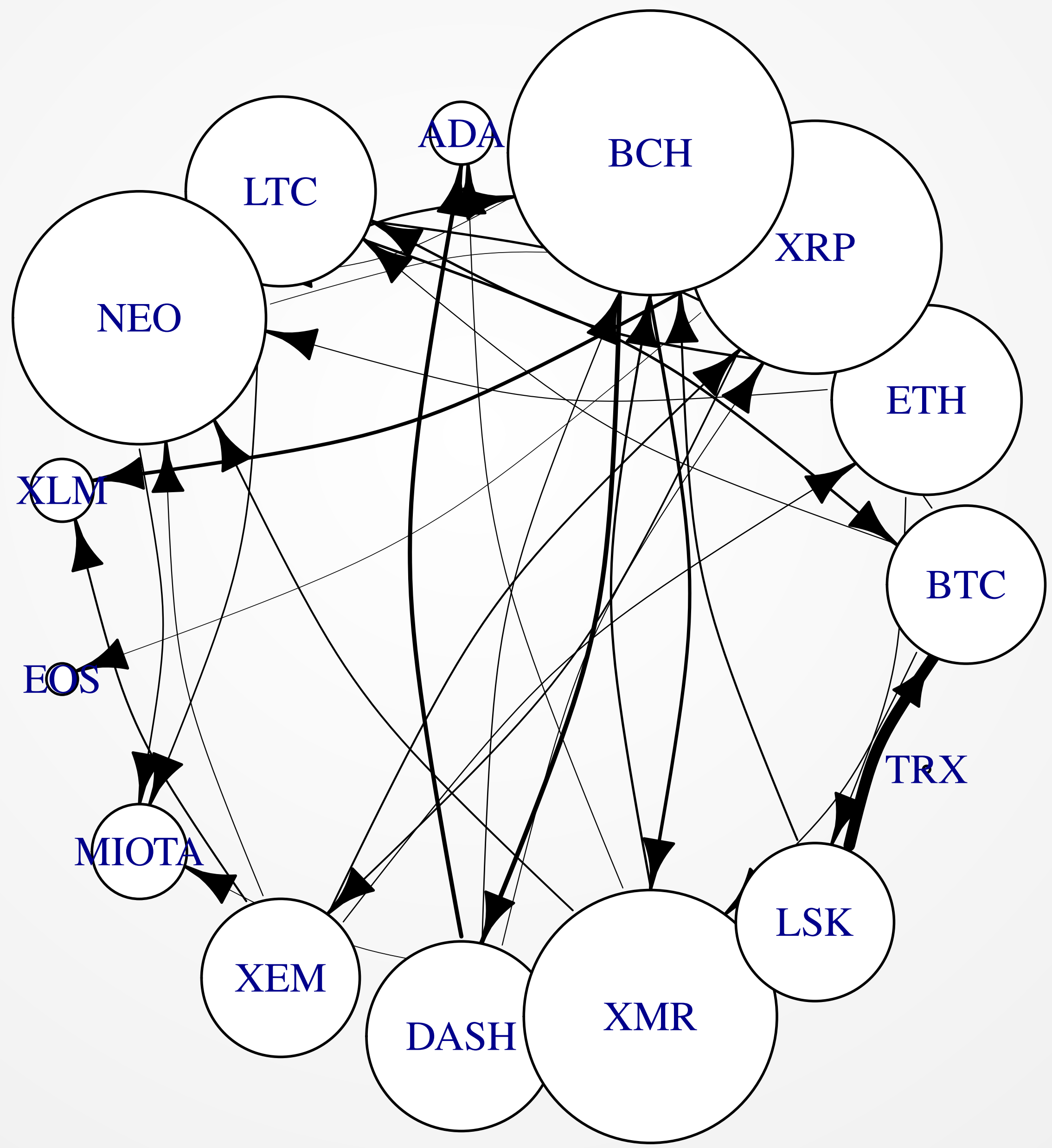
FRM@Crypto



http://frm.wiwi.hu-berlin.de

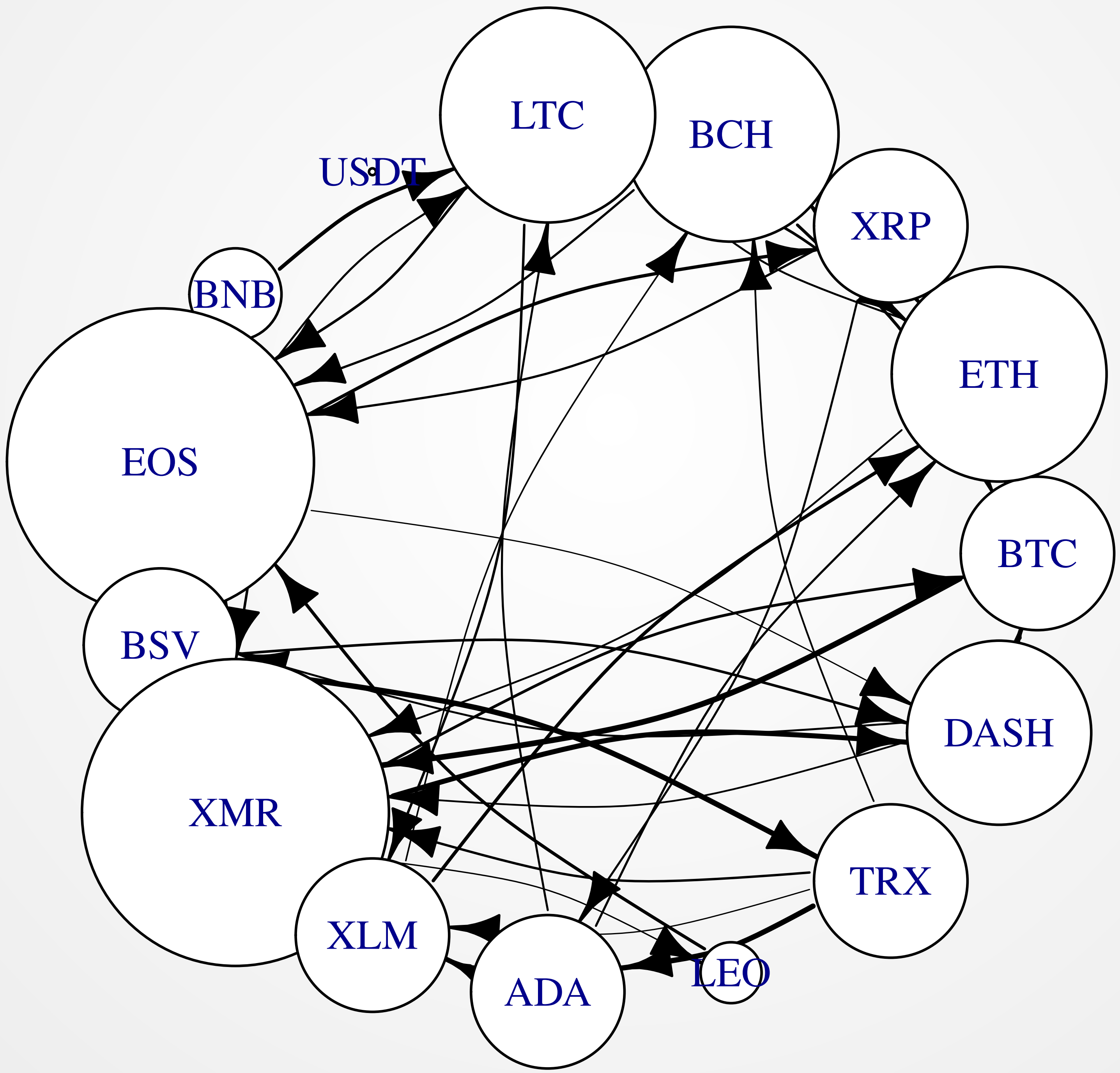
FRM@Crypto - Network Total Degree Centrality

- τ = 0.05, 12 February 2018

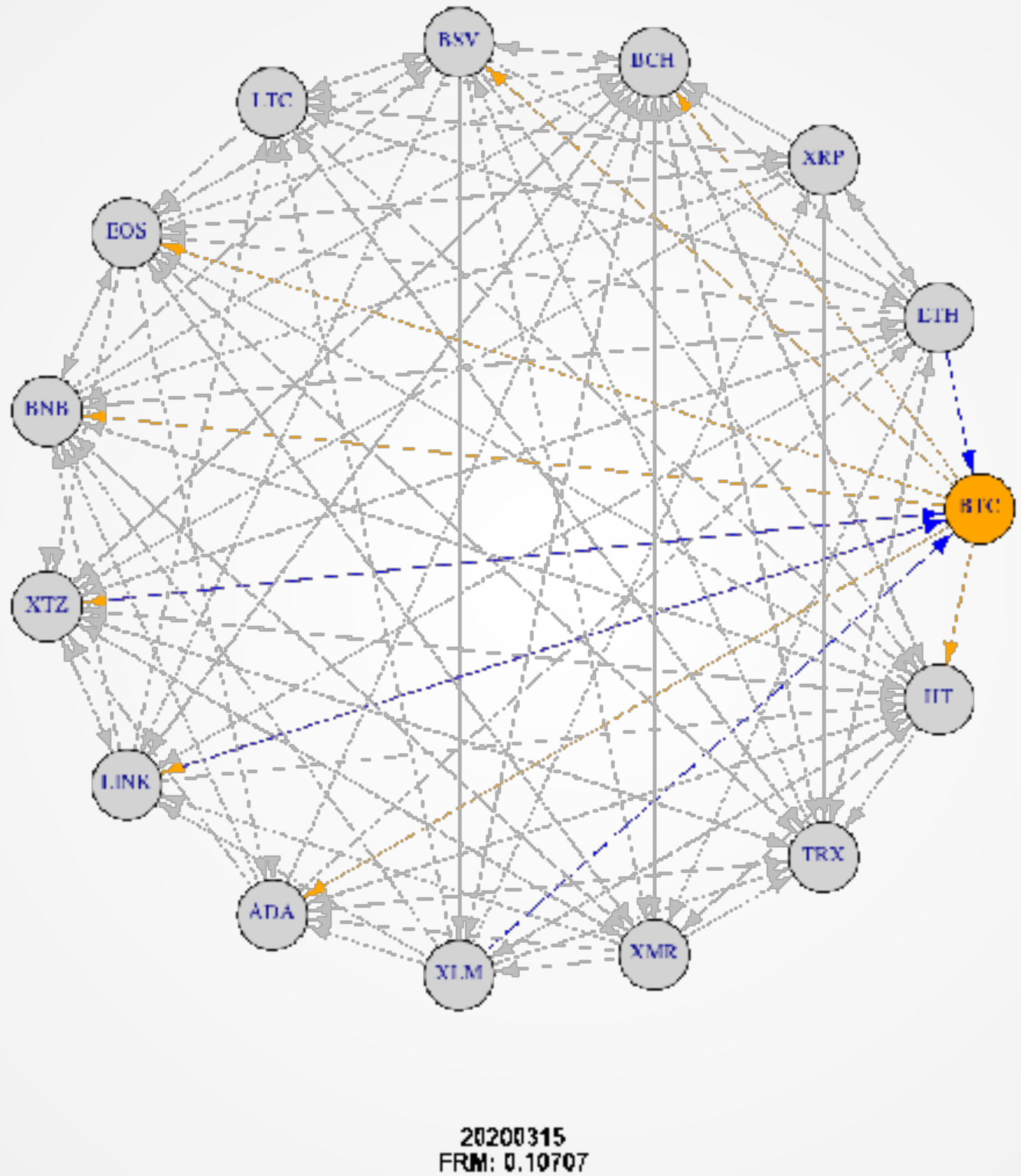


FRM@Crypto - Network Total Degree Centrality

- τ = 0.05, 27 August 2019



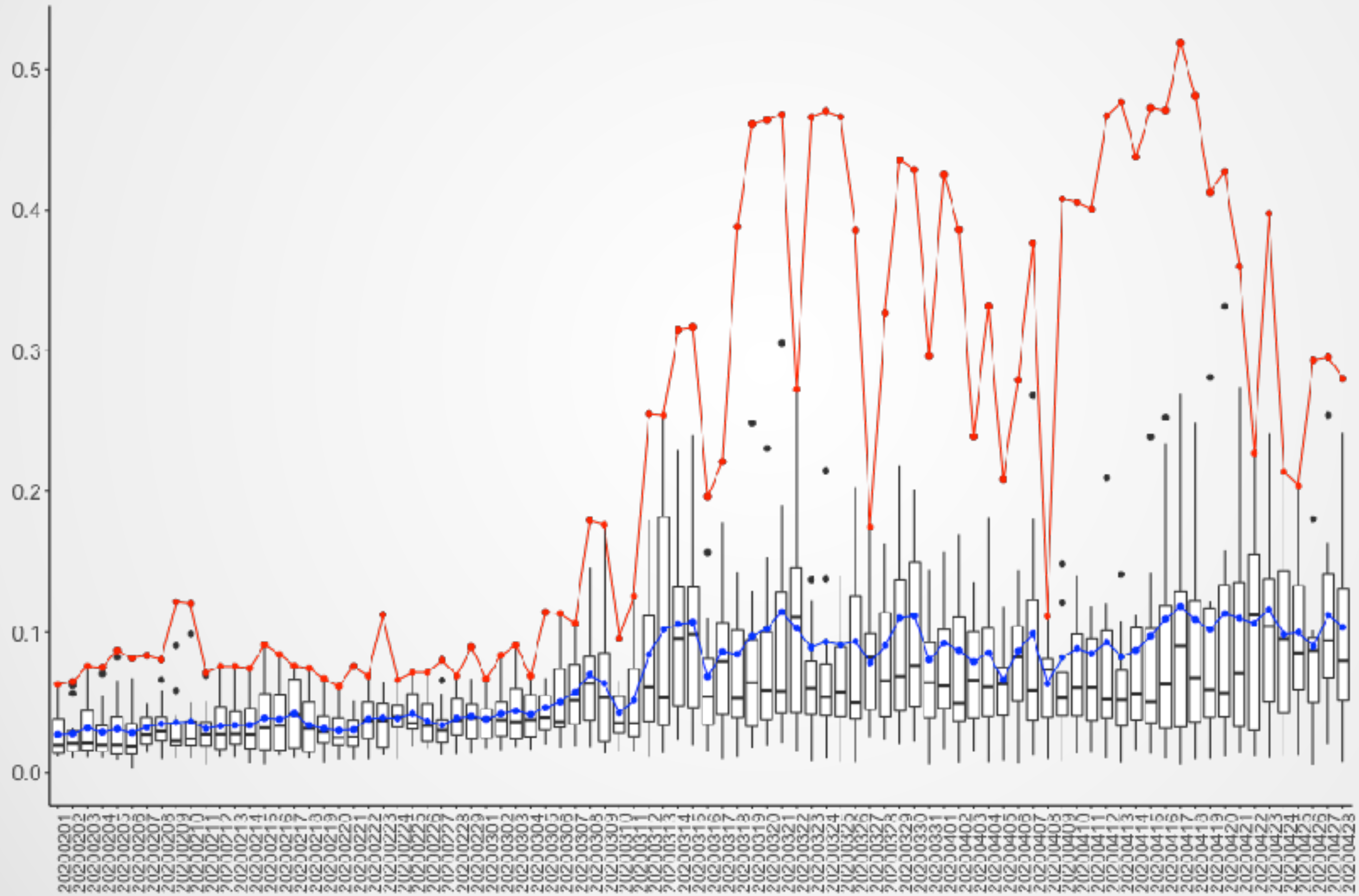
Visualising the Active Set: FRM@Crypto the Movie



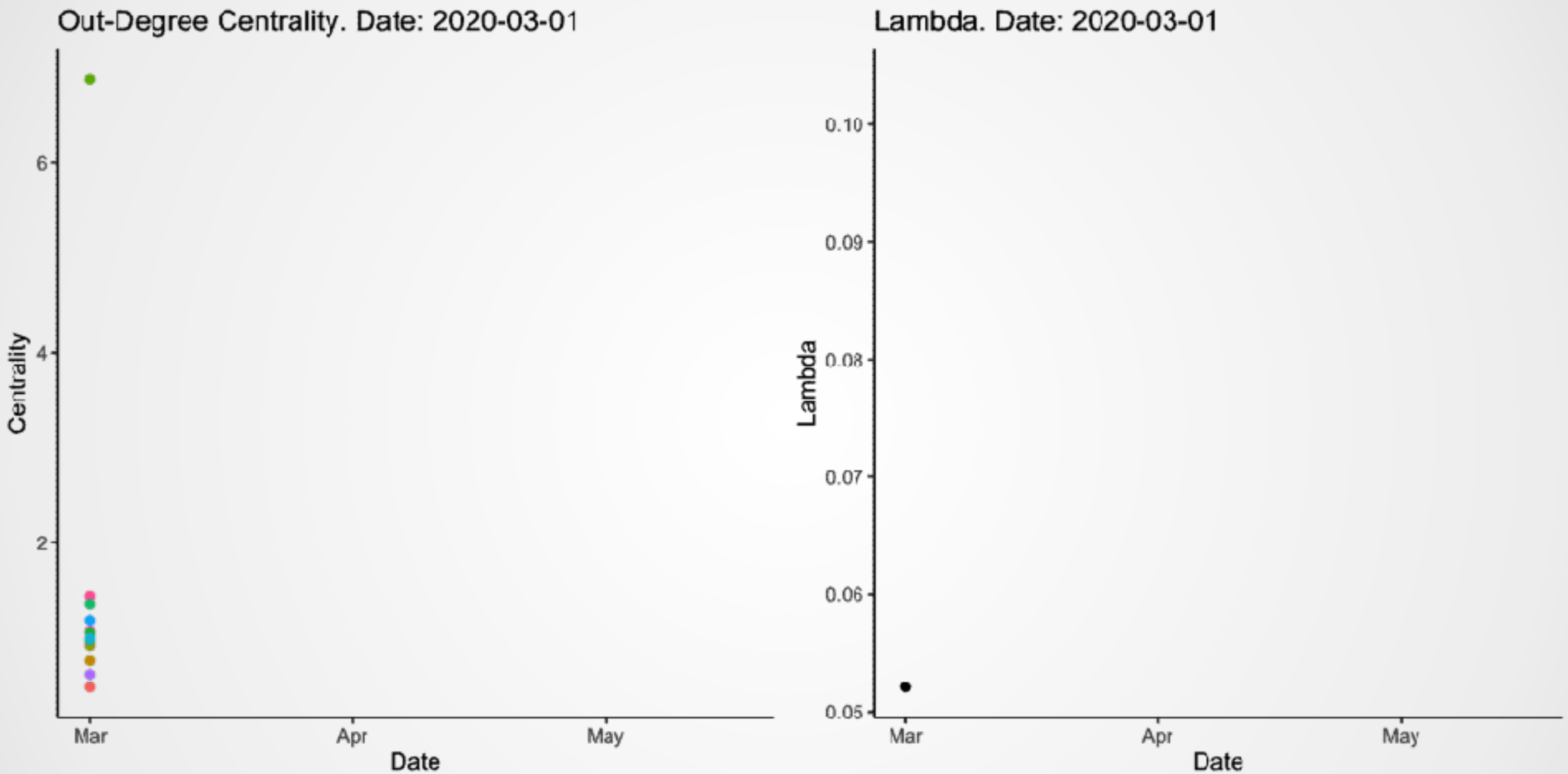
Network analysis of FRM from 03 March 2020 to 17 May 2020

FRM scaled to risk

- February 2020 to May 2020, FRM@Crypto

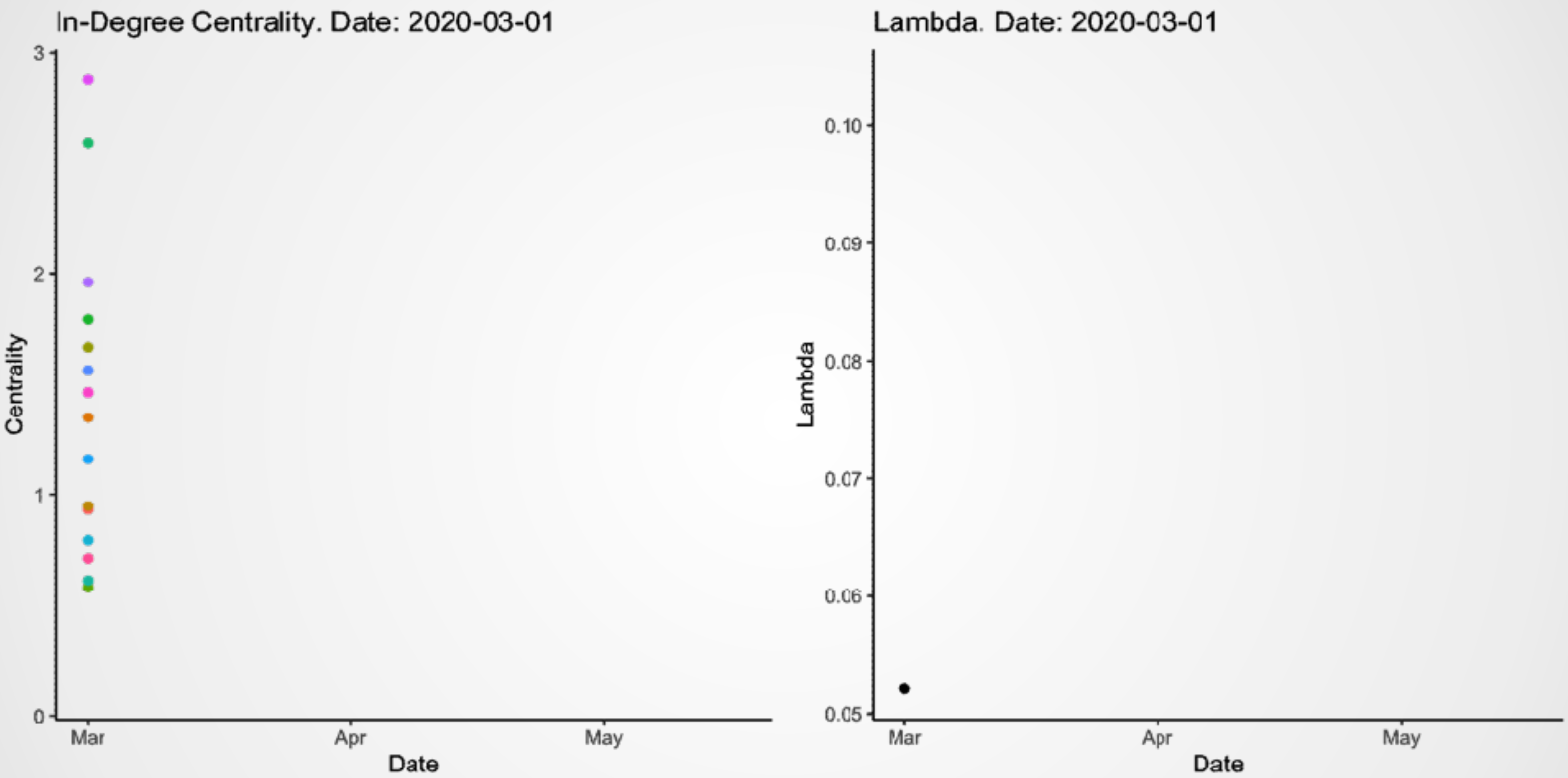


FRM@Crypto Out-Degree Centrality



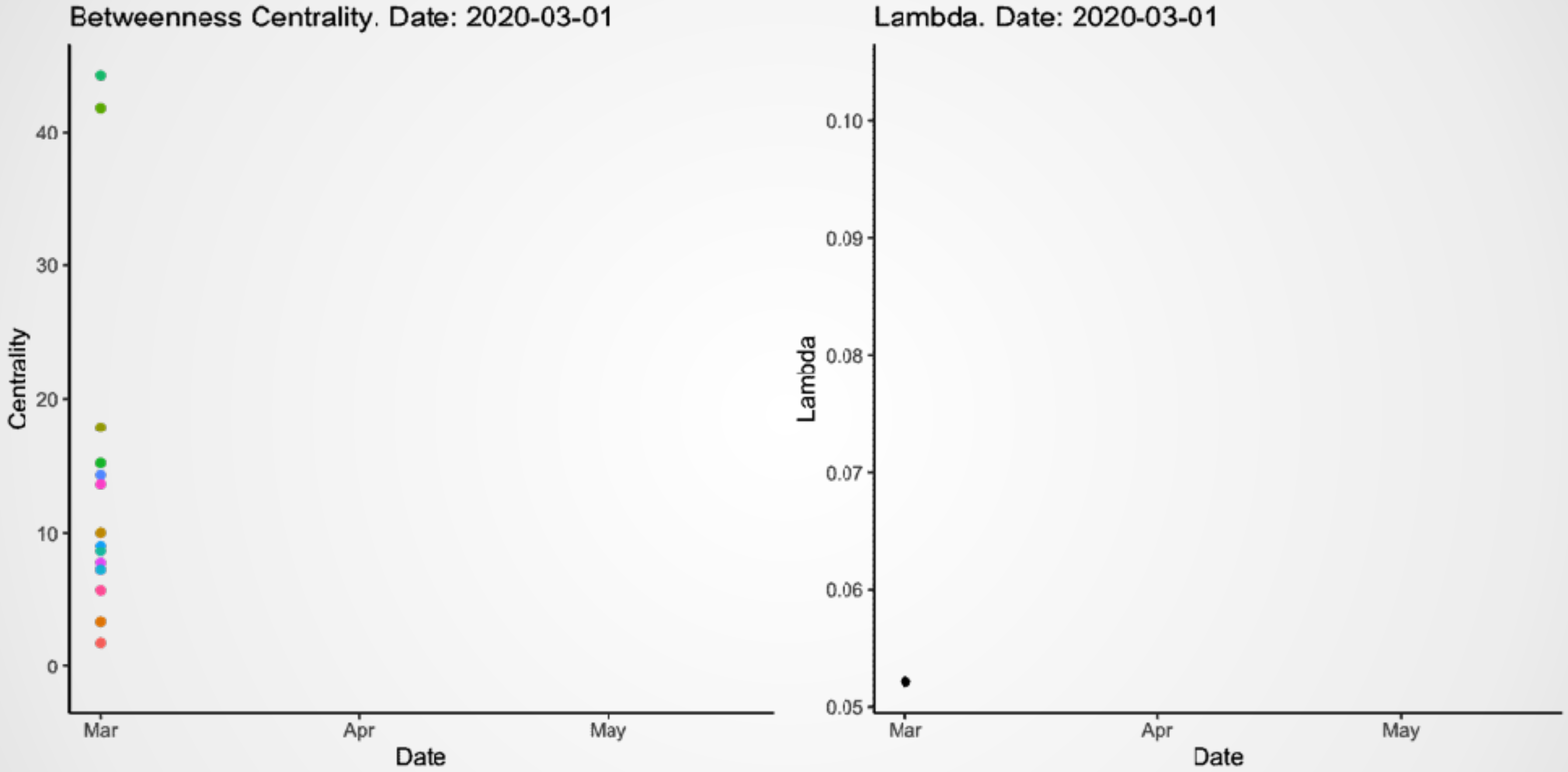
Left-hand side panel: # of outbounds links of BTC, ETH, XRP, BCH, BSV, LTC, EOS, BNB, XTZ, LIN, ADA, XLM, XMR, TRX, HT. Right-hand side panel: FRM index over time. Data from 01 March 2020 to 17 May 2020

FRM@Crypto In-Degree Centrality



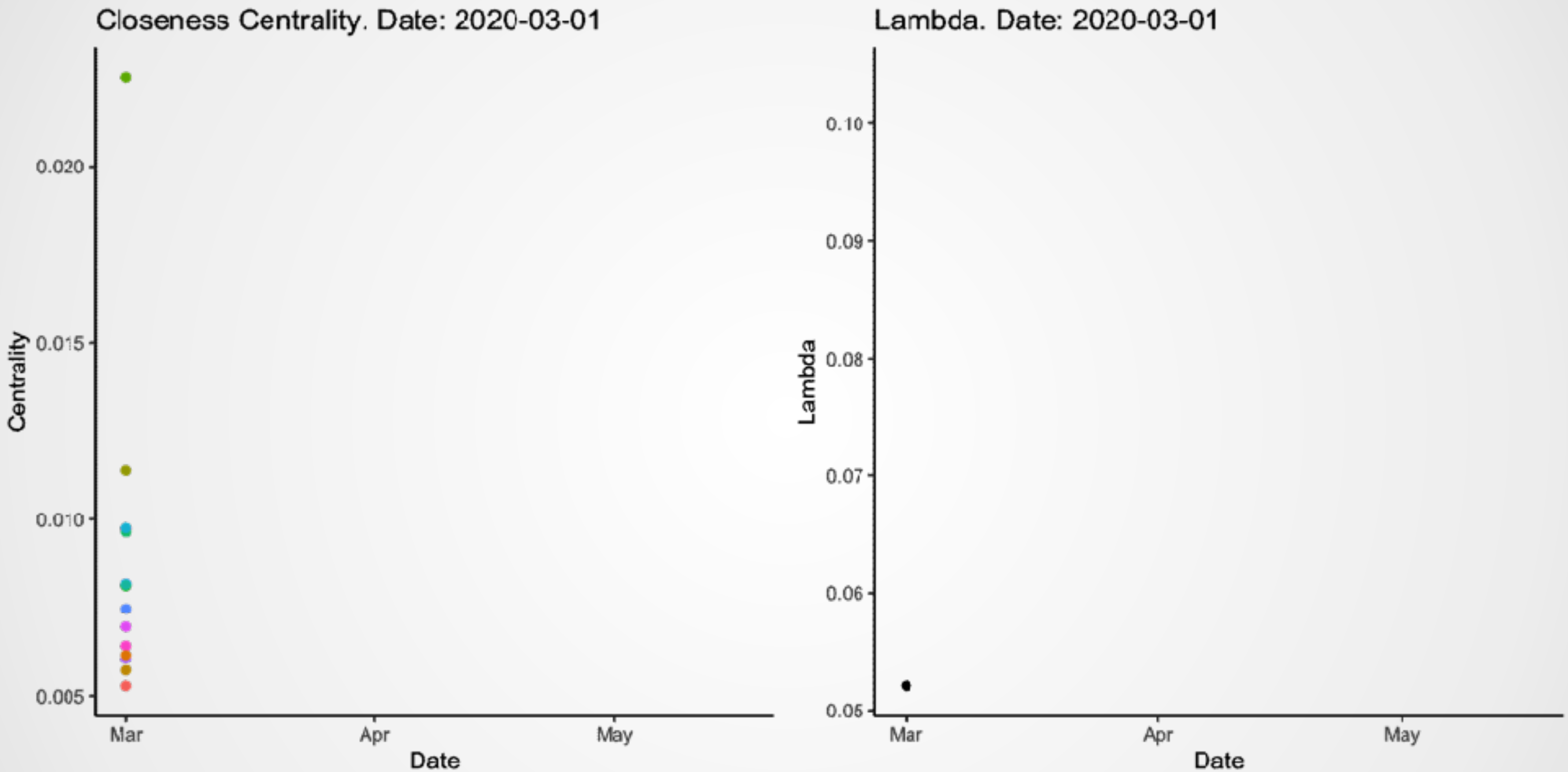
Left-hand side panel: # of inbound links of BTC, ETH, XRP, BCH, BSV, LTC, EOS, BNB, XTZ, LIN, ADA, XLM, XMR, TRX, HT. Right-hand side panel: FRM index over time. Data from 01 March 2020 to 17 May 2020

FRM@Crypto Betweenness Centrality



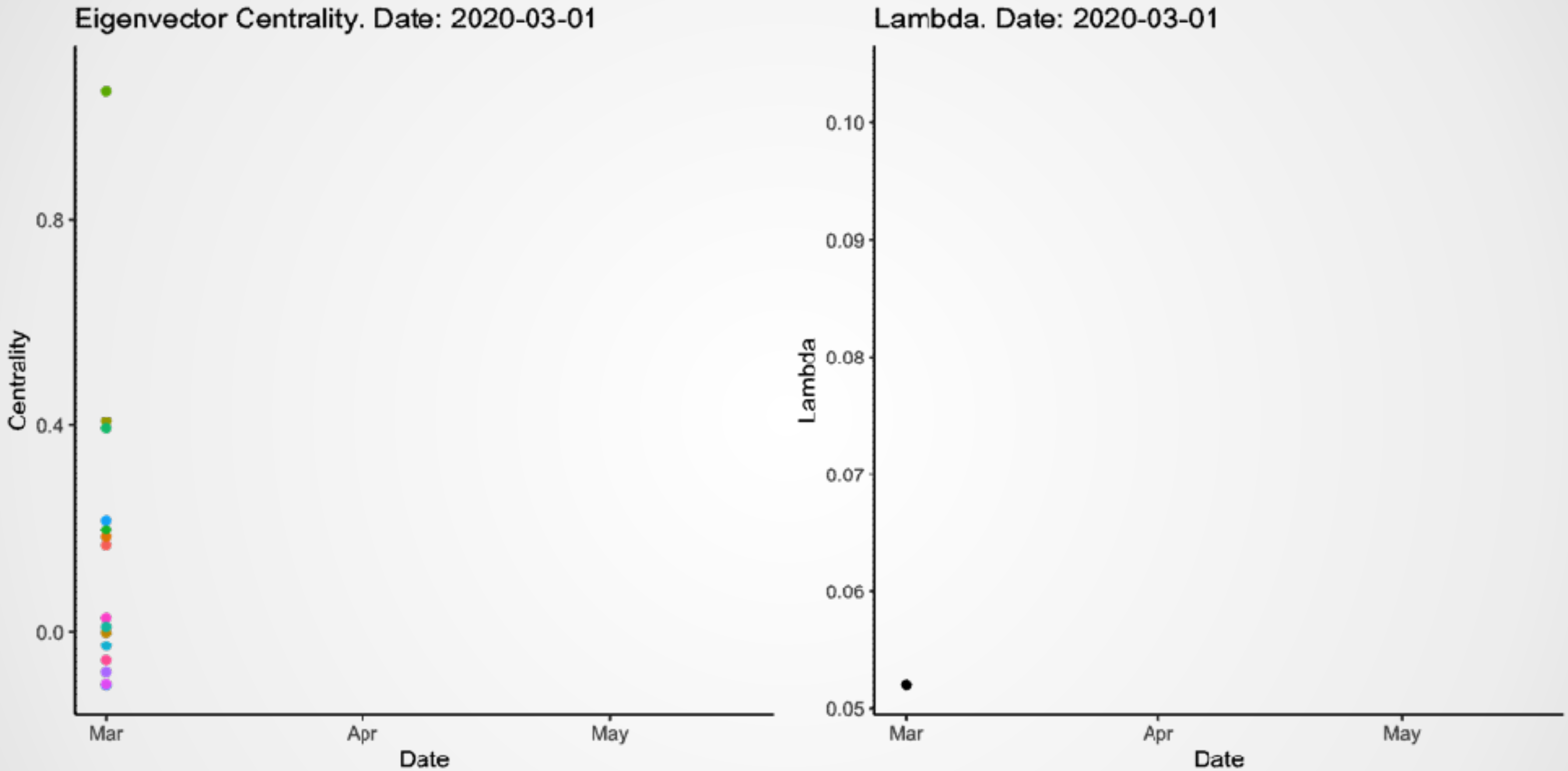
Left-hand side panel: „bridge" behaviour measure for BTC, ETH, XRP, BCH, BSV, LTC, EOS, BNB, XTZ, LIN, ADA, XLM, XMR, TRX, HT. Right-hand side panel: FRM index over time. Data from 01 March 2020 to 17 May 2020

FRM@Crypto Closeness Centrality



Left-hand side panel: fastness in influencing of BTC, ETH, XRP, BCH, BSV, LTC, EOS, BNB, XTZ, LIN, ADA, XLM, XMR, TRX, HT. Right-hand side panel: FRM index over time. Data from 01 March 2020 to 17 May 2020

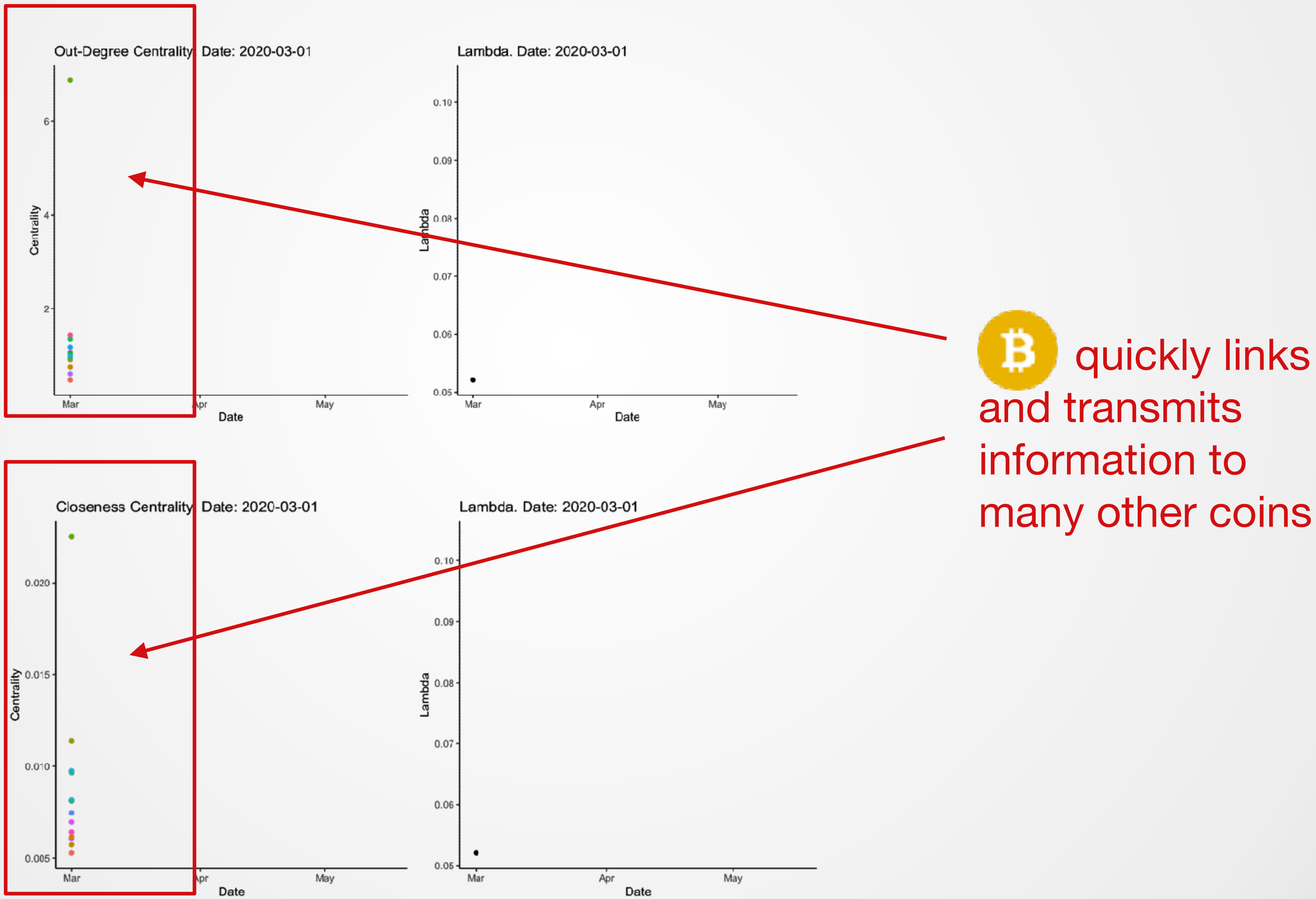
FRM@Crypto Eigenvector Centrality



Left-hand side panel: normalised eigenvector centrality of BTC, ETH, XRP, BCH, BSV, LTC, EOS, BNB, XTZ, LIN, ADA, XLM, XMR, TRX, HT. Right-hand side panel: FRM index over time. Data from 01 March 2020 to 17 May 2020

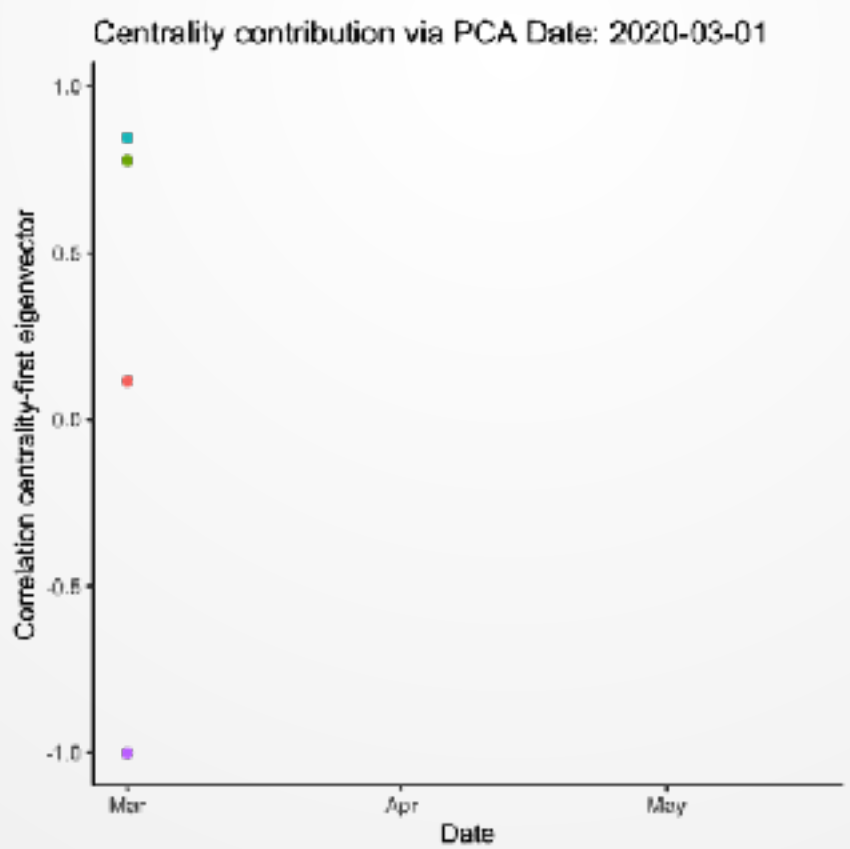
FRM@Crypto Centrality contribution

- Does cointegration hold for periods of financial distress?



FRM@Crypto Centrality contribution criterion

- 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)
  - VCRIX
  - S&P500



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)
  - VCRIX
  - S&P500

What are the right macroeconomic risk factors per asset class?

FRM@Crypto Adjacency Matrix

- $\tau = 0.05$, 12 February 2018

	BTC	ETH	XRP	BCH	ADA	LTC	NEO	XLM	EOS	MIOTA	XEM	DASH	XMR	LSK	TRX	
BTC			0.13		0.04	0.10	0.00		0.04	0.07	-0.12		0.13		0.00	9
ETH			0.03	0.07		0.24	0.10			0.01		0.04		0.13	0.02	8
XRP				0.33	-0.03		-0.03	0.35	0.07		0.17			-0.13		7
BCH		0.18	-0.03				0.08			-0.05	0.00	0.45	0.32		0.01	8
ADA																0
LTC	0.26	0.23							0.02	0.16	0.00		-0.01			6
NEO			0.07	0.24	0.00	0.18	0.23	0.02		0.15	0.01				0.02	9
XLM																0
EOS																0
MIOTA																0
XEM		0.12	0.19	0.04		0.06	0.10	0.19			0.13				0.06	8
DASH			0.10	0.12	0.40					0.04	0.07		0.25		-0.14	7
XMR			0.01	0.23	0.10		0.18			0.08				0.05	0.02	7
LSK	1.12		0.06	0.20			-0.52	-0.03				0.11	0.16			7
TRX																0
	2	3	8	7	5	4	8	4	3	7	7	3	5	3	7	

influences only two other crypto currencies

FRM@Crypto Adjacency Matrix with Macro Variables

- τ = 0.05, 12 February 2018

	BTC	ETH	XRP	BCH	ADA	LTC	NEO	XLM	EOS	MIOTA	XEM	DASH	XMR	LSK	TRX	1Y	CVIX	DXY	SPX	VIX	VCRIX
BTC			0.13		0.04	0.10	0.00		0.04	0.07	-0.12		0.13		0.00					-0.11	0.17
ETH			0.03	0.07		0.24	0.10			0.01		0.04		0.13	0.02					-0.14	
XRP				0.33	-0.03		-0.03	0.35	0.07		0.17			-0.13						0.04	0.14
BCH		0.18	-0.03				0.08			-0.05	0.00	0.45	0.32		0.01					0.08	
ADA																					
LTC	0.26	0.23							0.02	0.16	0.00		-0.01								
NEO			0.07	0.24	0.00	0.18	0.23	0.02		0.15	0.01				0.02						
XLM																					
EOS																					
MIOTA																					
XEM		0.12	0.19	0.04		0.06	0.10	0.19			0.13				0.06						
DASH			0.10	0.12	0.40					0.04	0.07		0.25		-0.14						
XMR			0.01	0.23	0.10		0.18			0.08				0.05	0.02						
LSK	1.12		0.06	0.20			-0.52	-0.03				0.11	0.16								0.26
TRX																					

Few traditional macro variables explain crypto currency tail behaviour

FRM@Crypto

- Adjacency Matrix 12 February 2018

XRP	0.33
NEO	0.24
XMR	0.23
LSK	0.20
DASH	0.12
ETH	0.07
XEM	0.04

BCH	0.23
NEO	0.18
ADA	0.10
MIOTA	0.08
LSK	0.05
TRX	0.02
XRP	0.01

XMR

BCH	0.32
DASH	0.25
LSK	0.16
BTC	0.13
LTC	-0.01

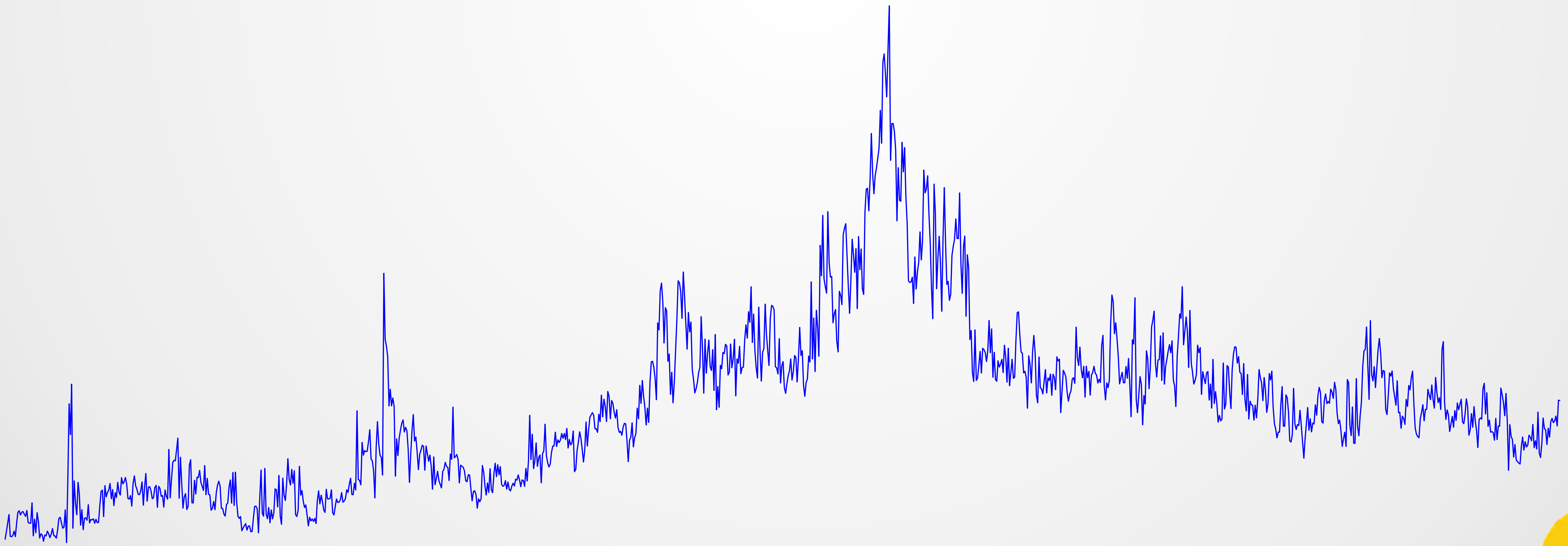
XMR in high Co-Stress

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

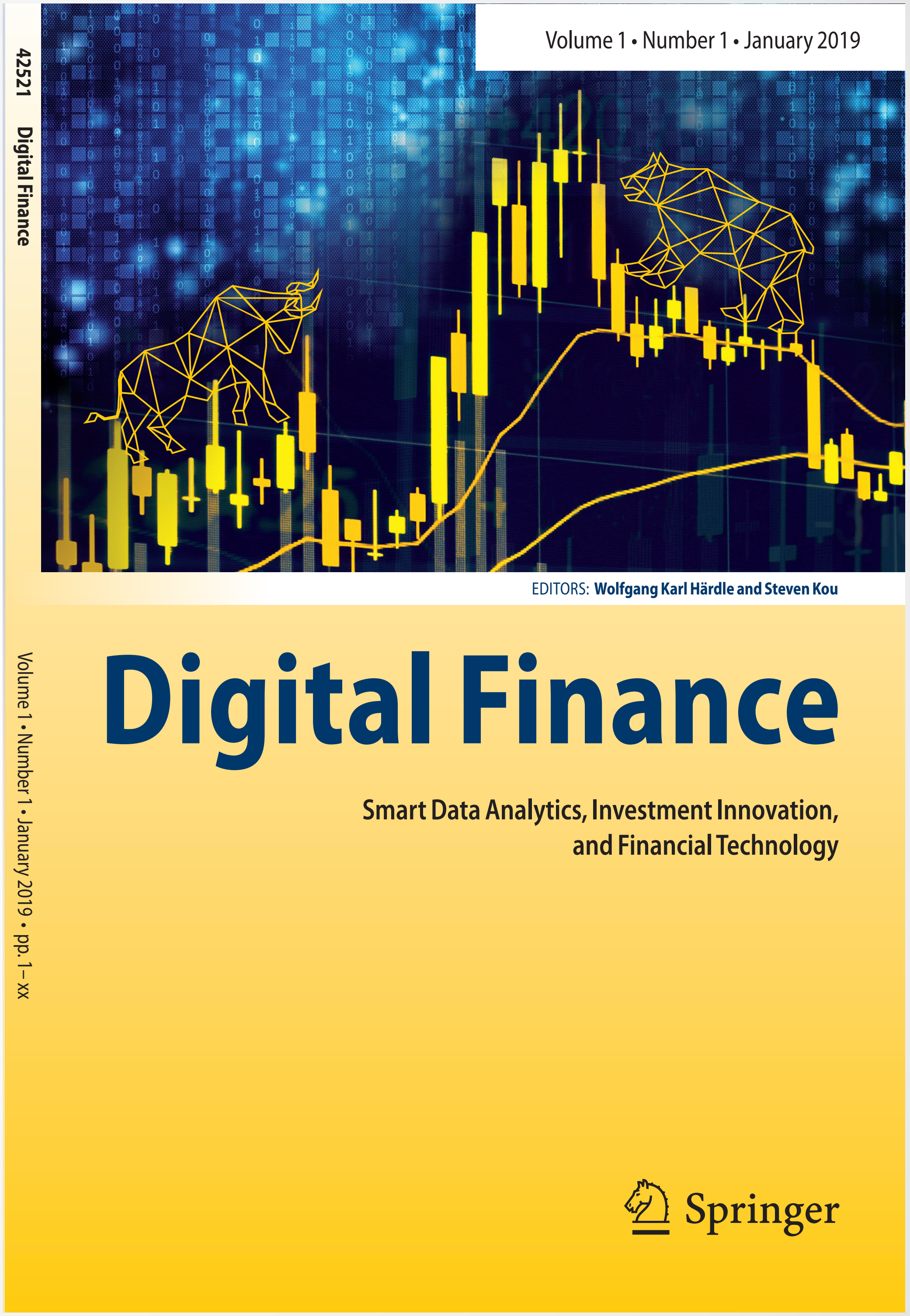
Conclusions

- FRM financialriskmeter = Flexible Risk Meter
- can be tuned to any asset class and to any TE risk
- reacts to coagulation of risk emitters via active set



FRM in FinTech, Cryptos, …

Vol 1. 2019 on Crypto Currencies



Michael Althof

Vanessa Guarino

Wolfgang K Härdle

Rui REN

Anna Shchekina

Alla Petukhina

Ang LI

Souhir Ben Amor

AlexTruesdale

Ilyas Agakishiev

References

- Adrian J, Brunnermeier M (2016) CoVaR, American Economic Review, 106 (7): 1705-41, DOI: 10.1257/aer.20120555
- Buraschi A, Corielle F (2005). Risk management of time-inconsistency: Model updating and recalibration of no-arbitrage models. J Banking and Finance 29: 2883–907
- Chao SK, Härdle WK, Wang W (2015) Quantile Regression in Risk Calibration. in Handbook for Financial Econometrics and Statistics, Cheng-Few Lee, ed., Springer Verlag, DOI: 10.1007/978-1-4614-7750-1_54.
- Härdle WK, Wang W, Zbonakova L (2018) Time Varying Lasso, in Applied Quantitative Finance 3rd ed, (Chen, Härdle, Overbeck eds.) Springer Verlag, ISBN 978-3-662-54486-0
- Keilbar G (2018) Modeling systemic risk using Neural Network Quantile Regression, MSc thesis
- Li Y, Zhu JL (2008) L1 Norm Quantile Regression, J Comp Graphical Statistics 17(1): 1-23
- Osborne MR, Presnell B, Turlach BA (200) J Comp Graphical Statistics Vol. 9, 319-337

FRM financialriskmeter for Cryptos

Ladislaus von Bortkiewicz Professor of Statistics
Humboldt-Universität zu Berlin
BRC Blockchain Research Center
lvb.wiwi.hu-berlin.de
Charles University, WISE XMU, NCTU 玉山学者

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 (as of 20180701)

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

FRM equations