FRM@China
FinancialRiskMeter for China

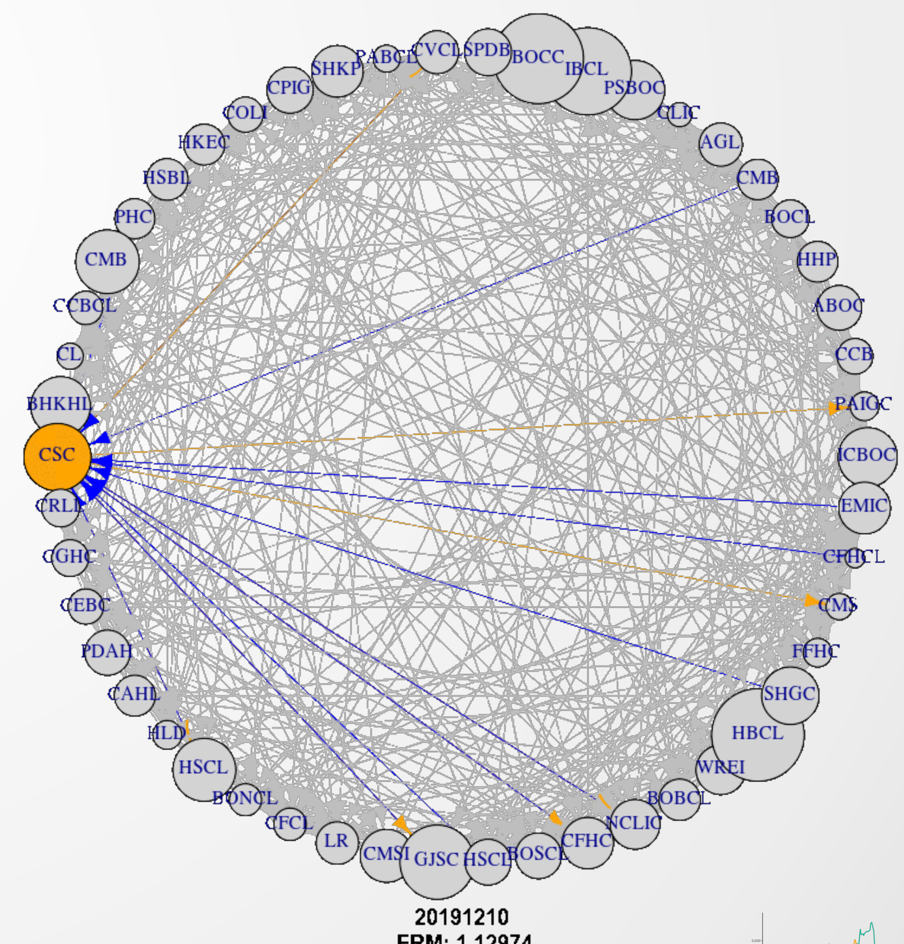
Ruting Wang
Michael Althof
Wolfgang Karl Härdle

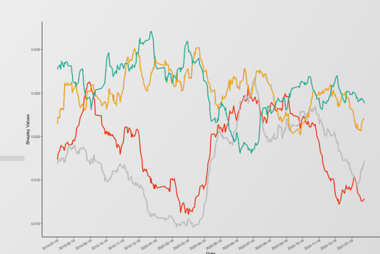
Ladislaus von Bortkiewicz Professor of Statistics
Humboldt-Universität zu Berlin
BRC Blockchain Research Center
lvb.wiwi.hu-berlin.de
Charles University, WISE XMU, NCTU 玉山學者

Systemic Risk

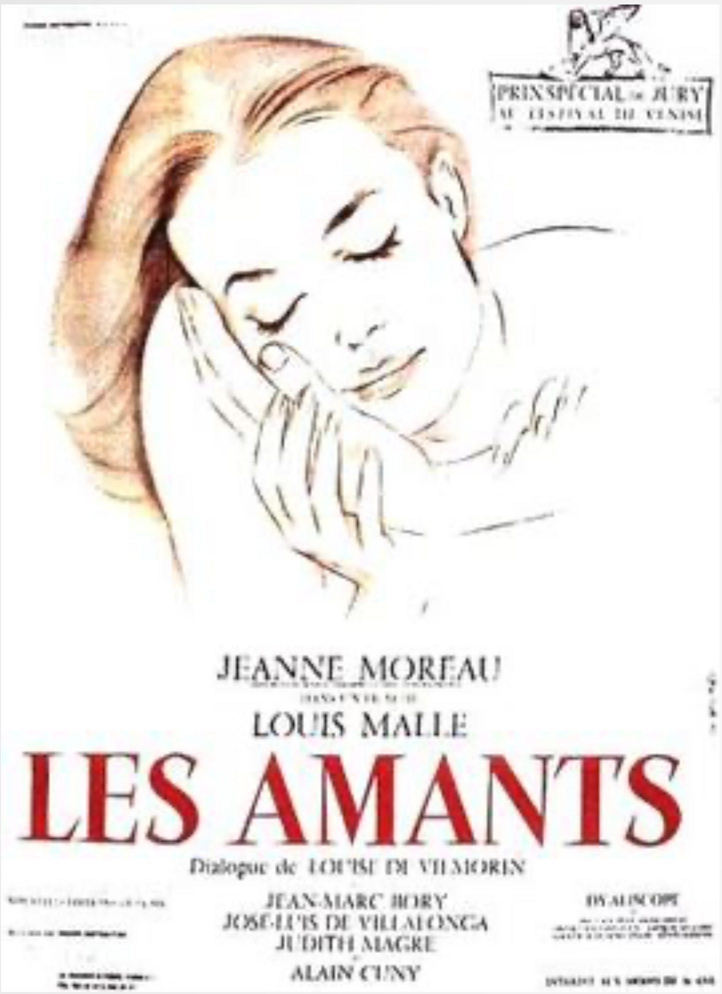
- Tail event (TE) co-movements of Financial Institutions (FI)
- COStress: High risk exposure
- Limitations of risk measurements
- TENET Tail Event NETwork risk, Härdle Wang Yu (2016) J E'trics
- FRM Financial Risk Meter for joint TEs

CITIC SECURITIES CO-A





Risk, Model Risk, Systemic Risk

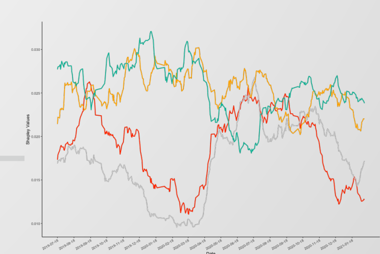


The financial cycle and the business cycle are not synchronised, implying that risks can emerge especially in the periods of „disconnect" between the two cycles.", Vítor Constâncio, VP ECB, 2015

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

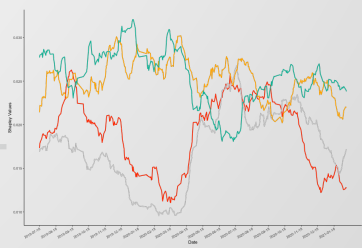
„I know it when I see it", Justice Potter Stewart (1964)

- Tail Behavior
- 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

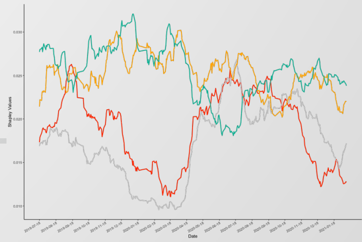


FRM FinancialRiskMeter

- Quantile Lasso CoVaR based
- Capture tail event co-movements.
- Define interdependencies in a network topology
- Estimate systemic risk and identify risk factors
- Predict recession probabilities

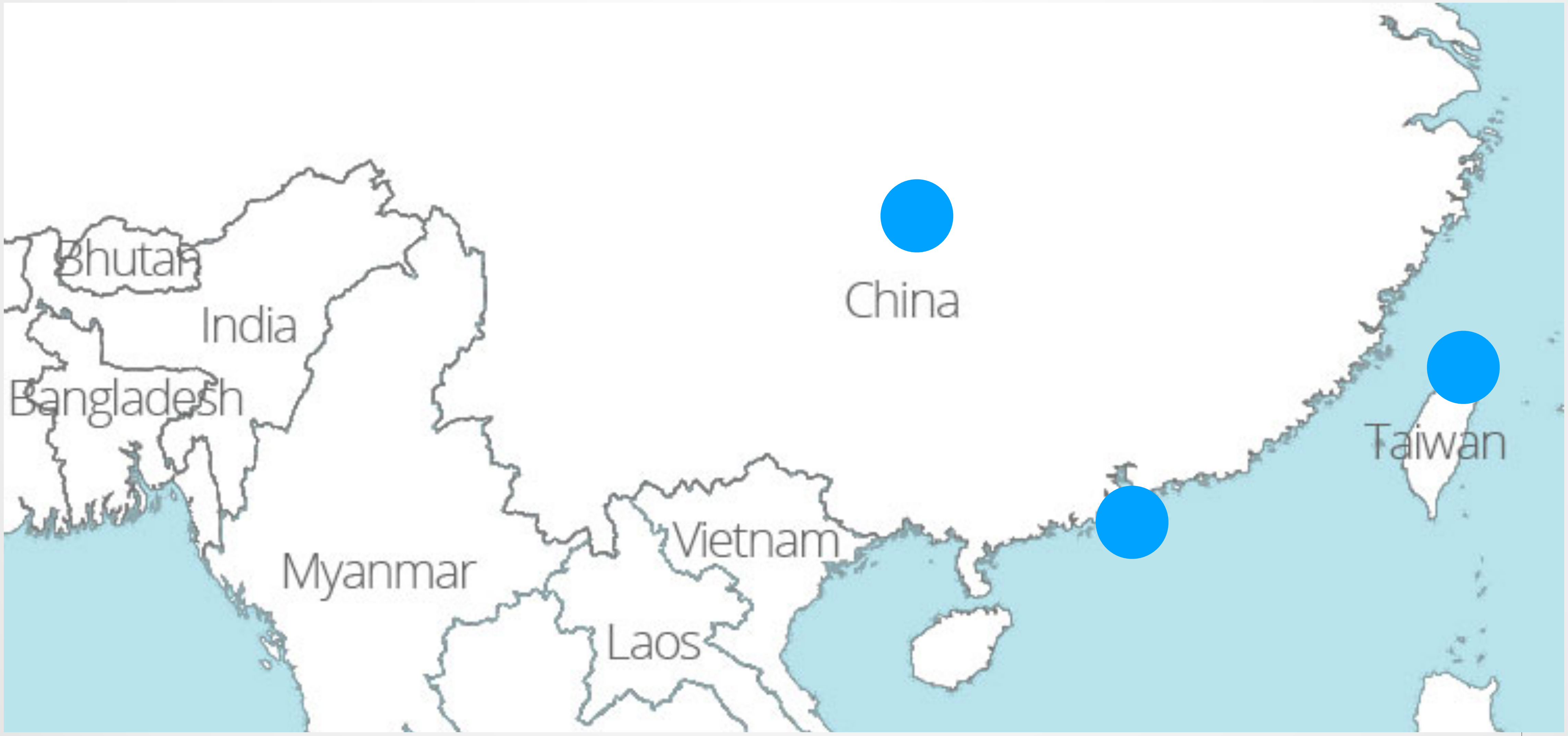
Indicate tail event behaviour in a network of financial risk factors

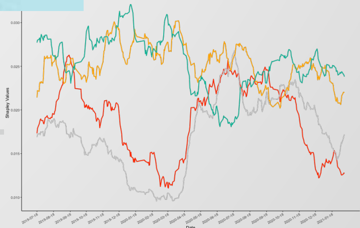
Adrian and Brunnermeier (AB) (2016)



The Chinese Region

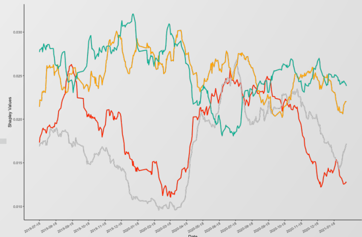
- The second biggest economic region
- Shocks in domestic market and global events
- Co-movements between Chinese regions





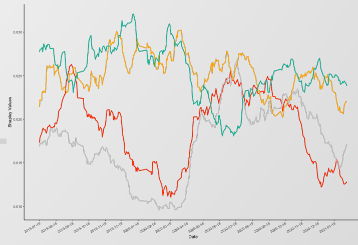
Contribution

- Less noisy and early trigger risk indicator
- FRM extension by exploring feature importance
- Risk drivers of TE (short term MP & forward guidance)
- Mainland, Hong Kong and Taiwan's spillover
- Regional tool set for regulators



Outline

1. Motivation ✓
2. Genesis
3. Methodology
4. Results



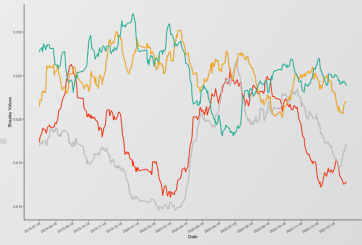
Financial Risk Meter FRM: Overview

Risk Measures

- VaR: tail event probability, single node
- CoVaR (Adrian et al 2016): bivariate tail dependence system
- TENET (Härdle et al 2016): quantile regression on macroeconomic variables, network node

Financial Risk Meter FRM

- Systemic risk measure,
- High-dimensional tail stress into a single real value indicator.
- Capture all interdependencies in one single number.
- J companies and M macroeconomic risk factors

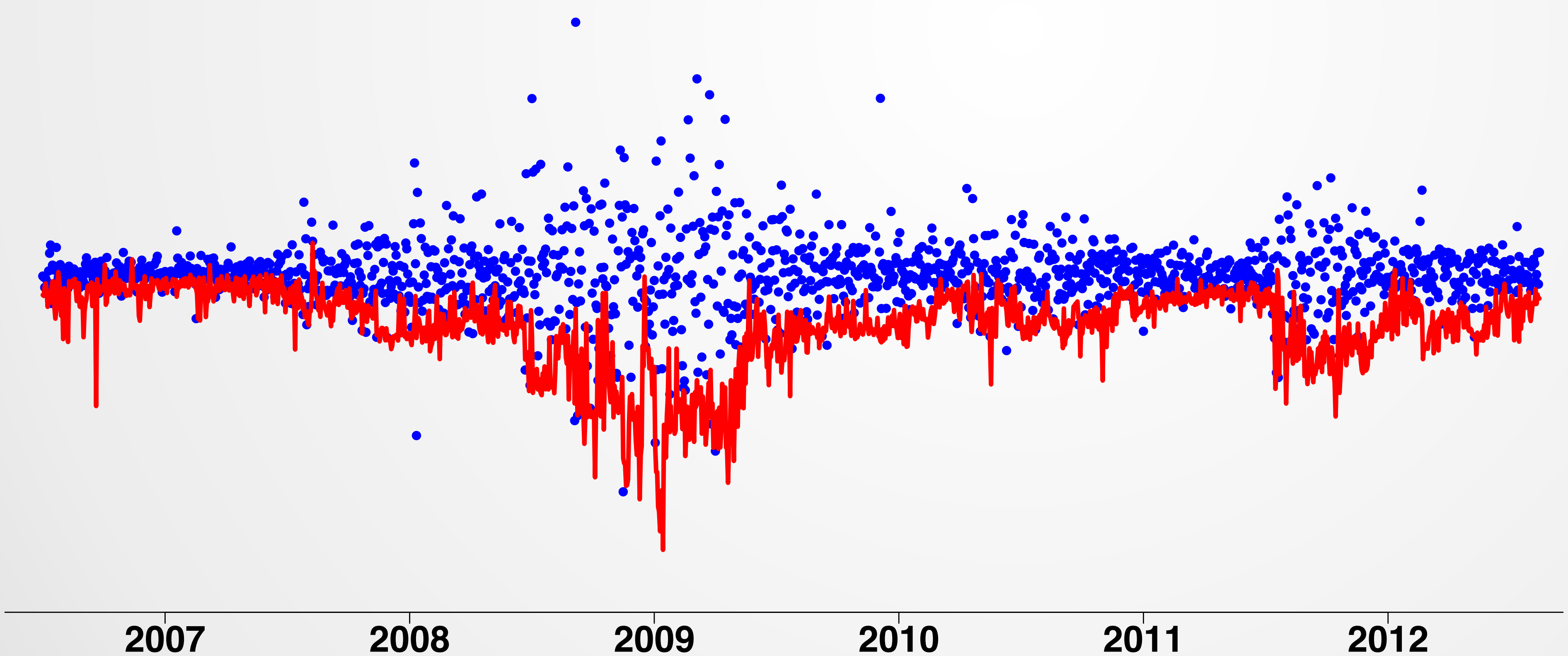


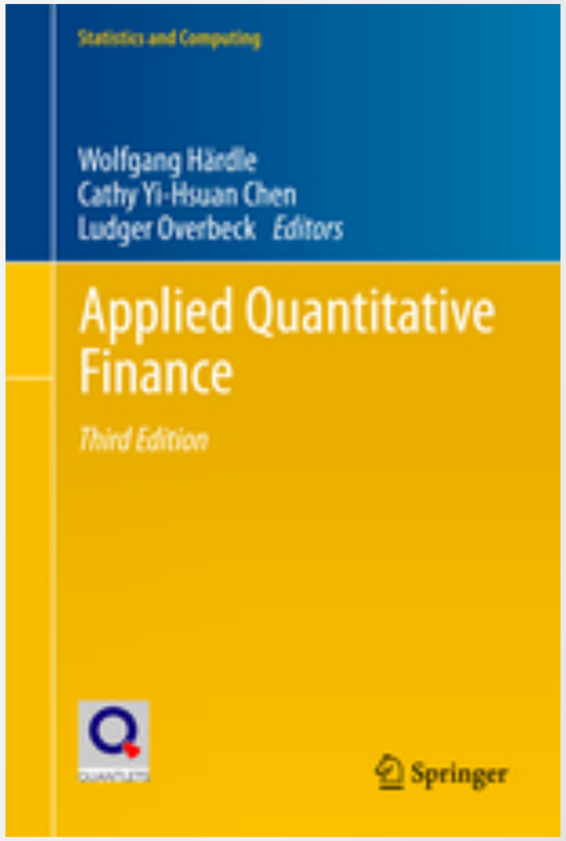
VaR Value at Risk

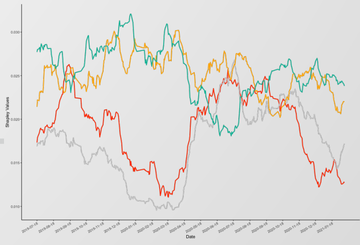
- Probability measure based

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

- $X_{i,t}$ log return of risk factor (institution) 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

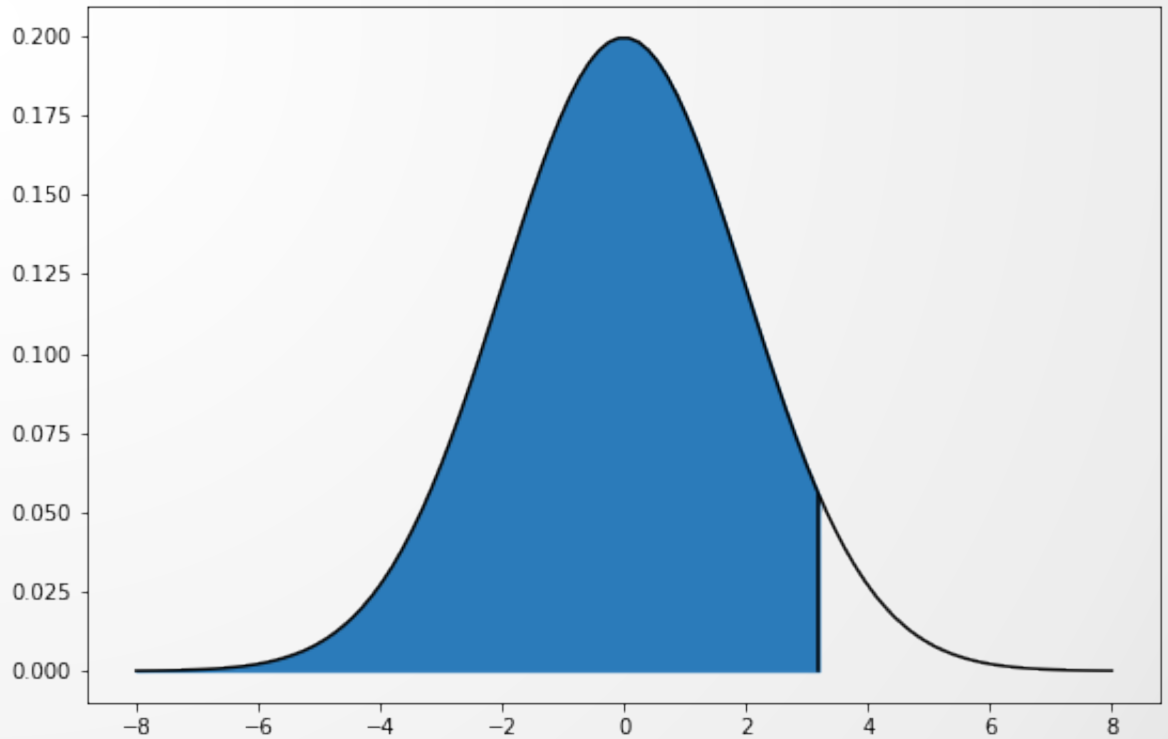
$$q^{\tau} = \arg\min_{\theta} \mathsf{E}\left\{\rho_{\tau}(Y-\theta)\right\}$$

asymmetric loss function

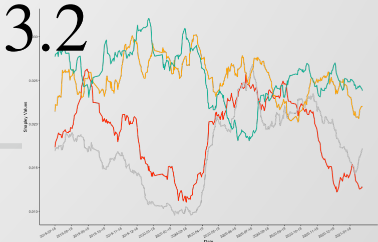
$$\rho_{\tau}(u) = |u|^{c}\,|\tau - \mathrm{I}_{\{u<0\}}|$$

$c = 1$ for quantiles

$c = 2$ for expectiles

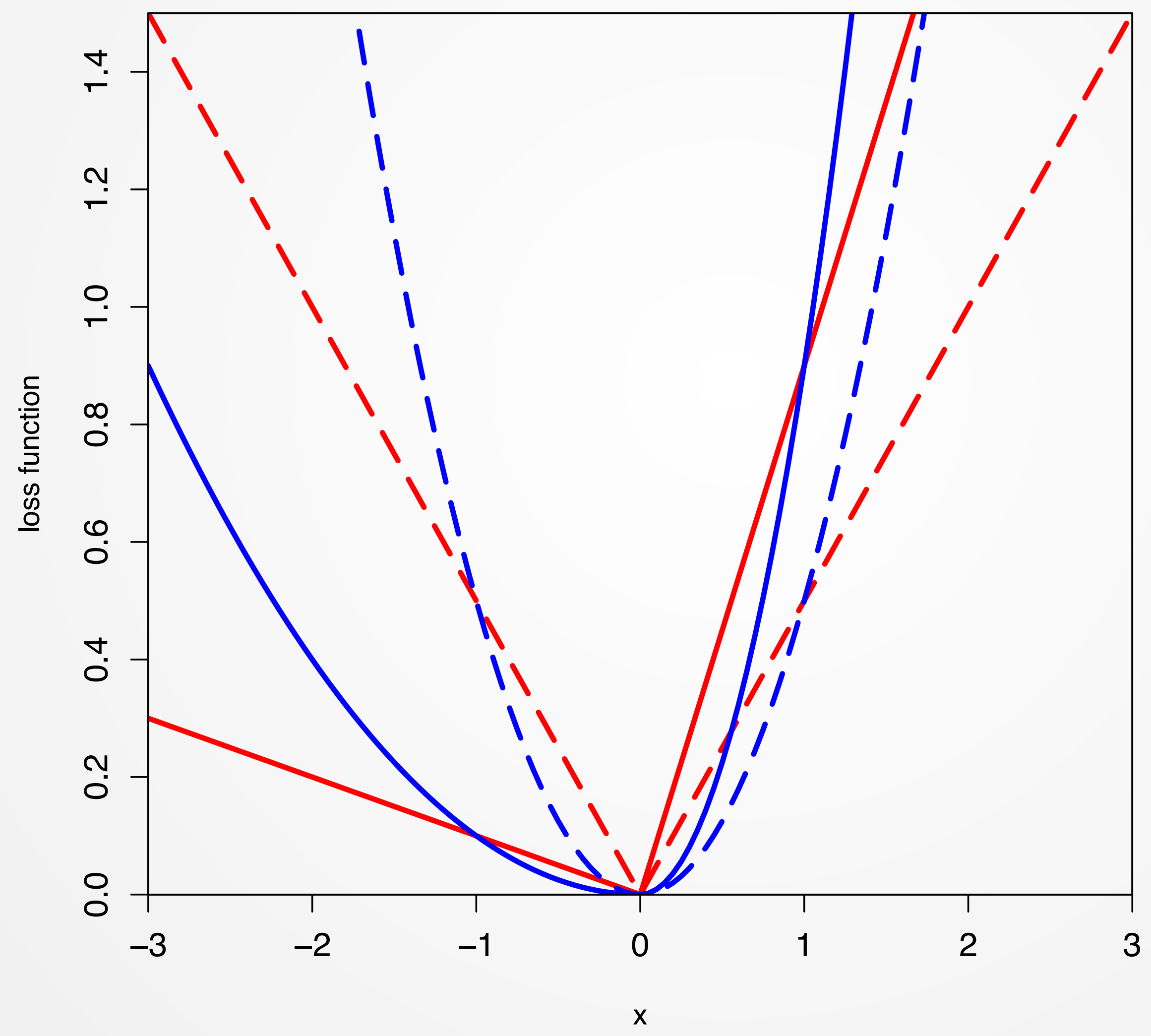


$\tau = 0.7,\ \ N(0,2),\ \ \text{Quantile} = 3.2$



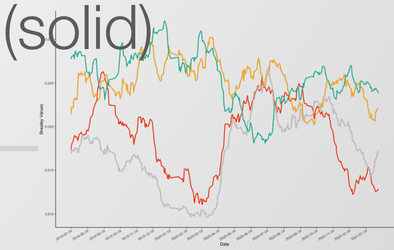
Quantiles and Expectiles

- Check function



LQRcheck

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

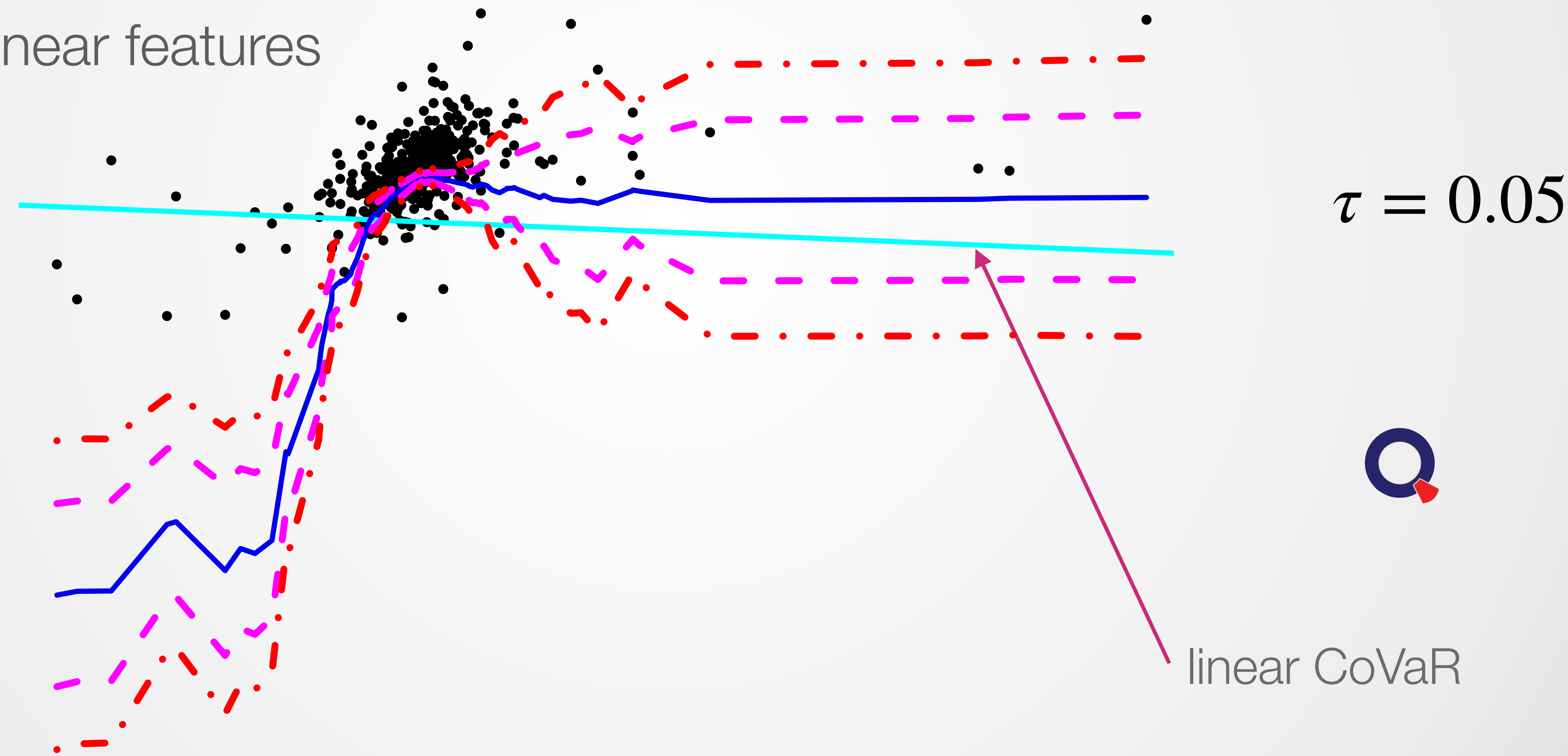


Conditional Value at Risk

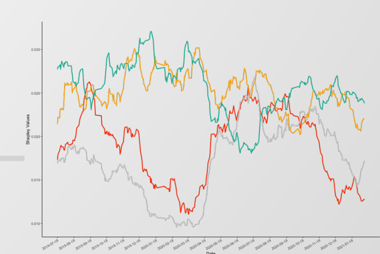
- Adrian and Brunnermeier (2016) introduced CoVaR

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

- 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

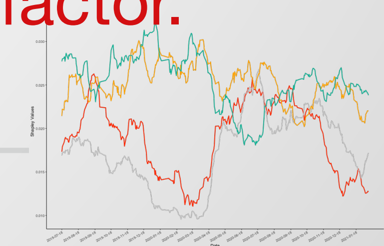
$$X_{i,t} = \alpha_i + \gamma_i^\top M_{t-1} + \varepsilon_{i,t}\,,$$

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

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

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

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



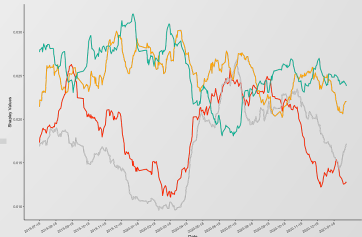
Linear Quantile Lasso Regression

$$X^{s}_{j,t} = \alpha^{s}_{j,t} + A^{s\top}_{j,t}\beta^{s}_{j} + \varepsilon^{s}_{j,t}, \tag{1}$$

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

where:

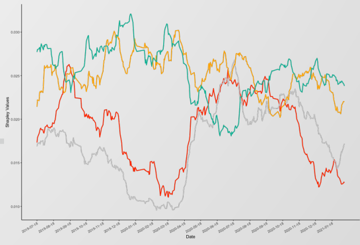
- $X^{s}_{-j,t}$ log returns of all other assets except $j = \{1,\ldots,J\}$ at time $t = \{2,\ldots,T\}$
- s length of moving window
- M^{s}_{t-1} log return of macro prudential variable at time $t-1$
- Application, $J = 50,\ s = 63$



Lasso Quantile Regression

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

- Check function $\rho_\tau(u) = |u|^c \, |\tau - \mathrm{I}_{\{u<0\}}|$ with $c = 1, 2$ corresponding 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



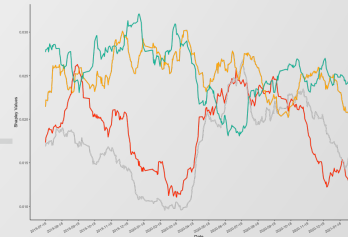
λ Role in Linear Lasso Regression

- Osborne et al. (2000)
- Dependence, time-varying, institution-specific
- Size of model coefficients depends on,

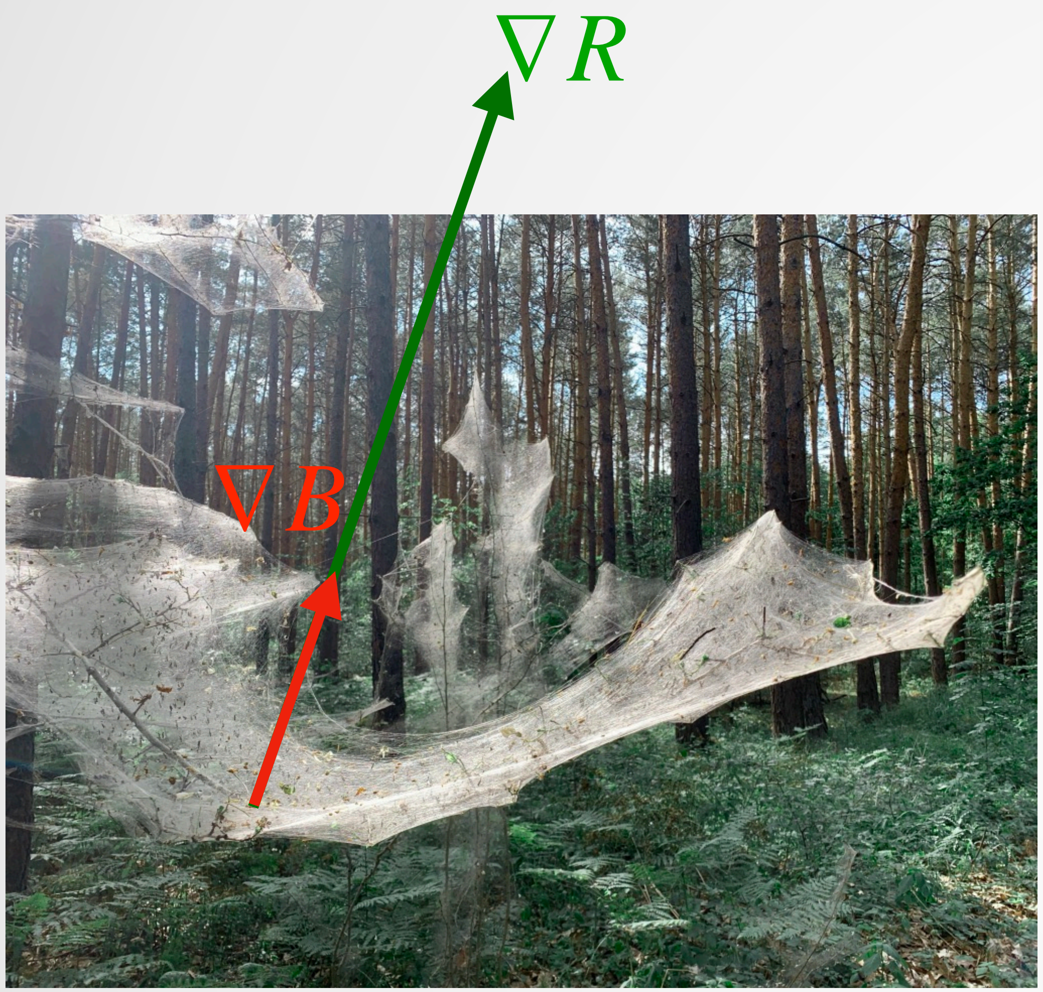
$$\lambda = \frac{\{Y - X\beta(\lambda)\}^{\top} X\beta(\lambda)}{\|\beta\|_1}$$

Coeff's depend on λ

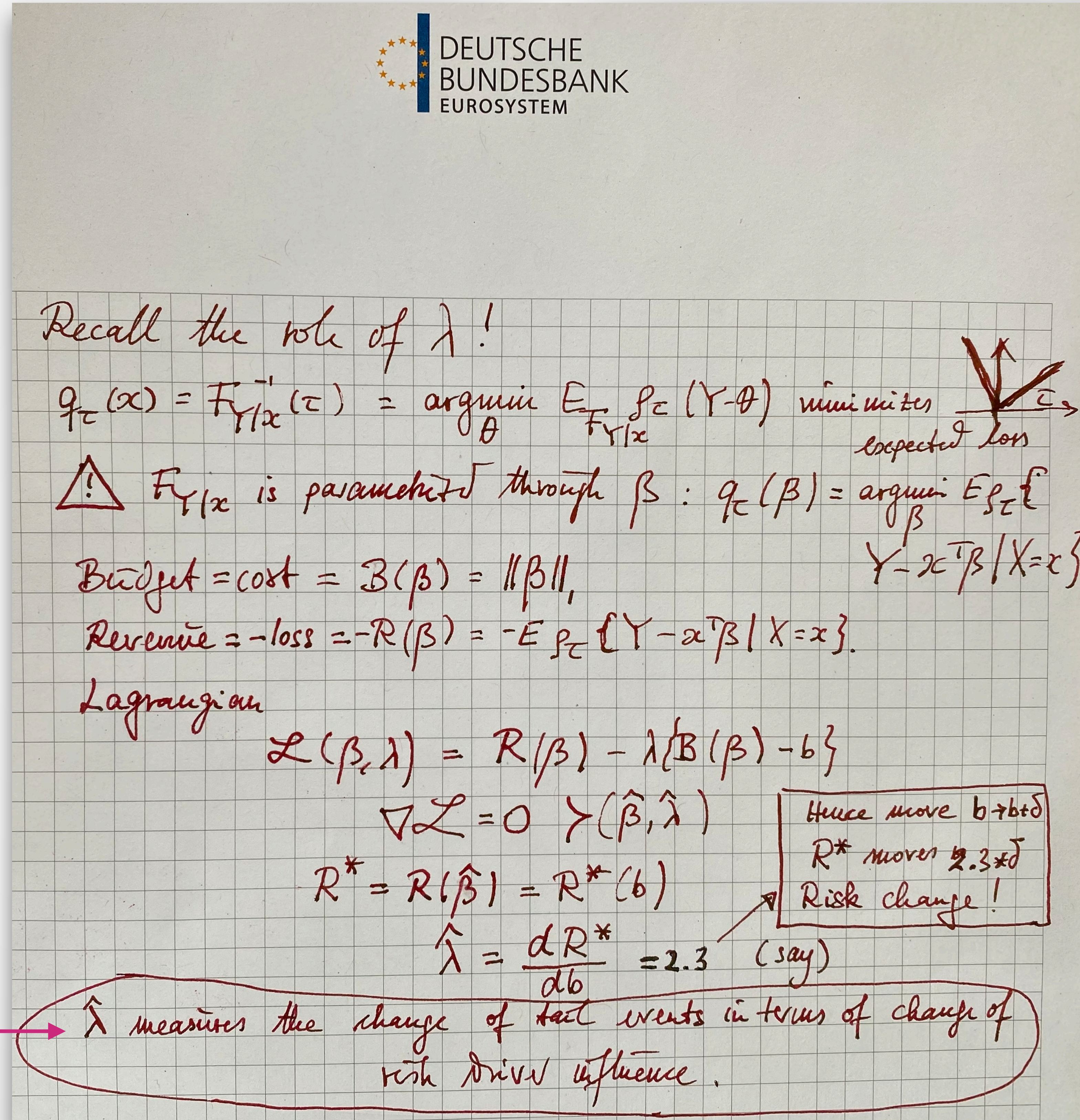
- λ depends on:
  - Residual size
  - Condition of design matrix
  - Active set



λ to the rescue!



change of TEs
in terms of risk
driver influence!


DEUTSCHE BUNDESBANK EUROSYSTEM

Recall the role of λ!

$q_\tau(x) = F^{-1}_{Y|x}(\tau) = \arg\min_\theta E_{F_{Y|x}} \rho_\tau(Y-\theta)$ minimizes expected loss

⚠ $F_{Y|x}$ is parametrized through β: $q_\tau(\beta) = \arg\min_\beta E\rho_\tau\{Y - x^\top\beta \mid X=x\}$

Budget = cost = $B(\beta) = \|\beta\|_1$

Revenue = −loss = $-R(\beta) = -E\rho_\tau\{Y - x^\top\beta \mid X=x\}$.

Lagrangian

$$\mathcal{L}(\beta,\lambda) = R(\beta) - \lambda\{B(\beta)-b\}$$

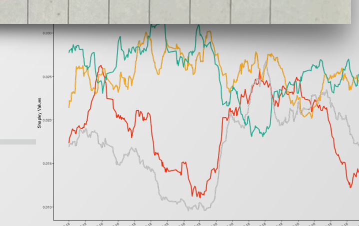
$$\nabla\mathcal{L}=0 \succ (\hat\beta,\hat\lambda)$$

$$R^* = R(\hat\beta) = R^*(b)$$

$$\hat\lambda = \frac{dR^*}{db} = 2.3 \quad \text{(say)}$$

Hence move $b \to b+\delta$
R^* moves $2.3 * \delta$
Risk change!

$\hat\lambda$ measures the change of tail events in terms of change of risk driver influence.



λ Role in Linear Quantile Regression

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

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

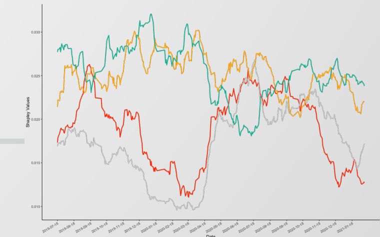
Coeff's (λ)

$$(\alpha - \gamma)^{\top} = \tau \, \mathrm{I}_{\{Y - X\beta(\lambda) > 0\}} + (\tau - 1) \, \mathrm{I}_{\{Y - X\beta(\lambda) < 0\}}$$

- Average penalty: indicator for tail risk,

$$FRM^t \stackrel{def}{=} J^{-1} \sum_{j=1}^{J} \lambda_j^t$$

- The FRM time series is **one** index for joint TEs!



λ Selection

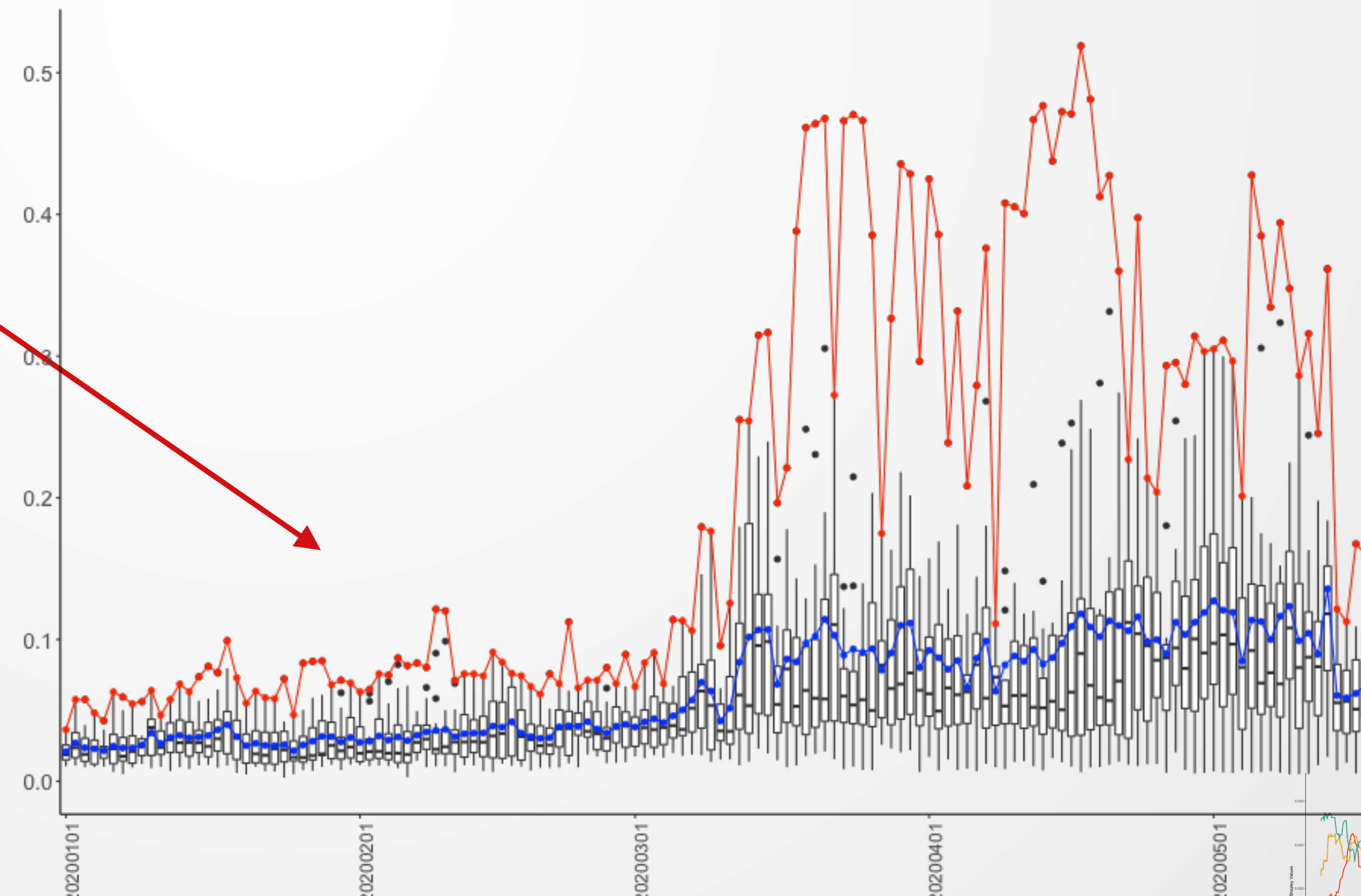
- Generalized approximate cross-validation (GACV)

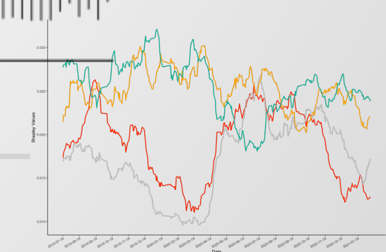
$$\min GACV(\lambda_j^s) = \min \frac{\sum_{t=s}^{s+(n-1)} \rho_\tau(X_{j,t}^s - \alpha_j^s - A_{j,t}^{s,\top}\beta_j^s)}{n - df} \qquad (3)$$

Coeff's depend on λ

where: df dimensionality of fitted model

- λ as function of j, t
- Distribution of λ^s
- ID the TE drivers





TE transfer direction: degree centralization

- Definition

$$D = \sum_{j=1}^{N} \sum_{i=1}^{N} \mathbf{1}(\beta_{j,i}^{k})$$

where

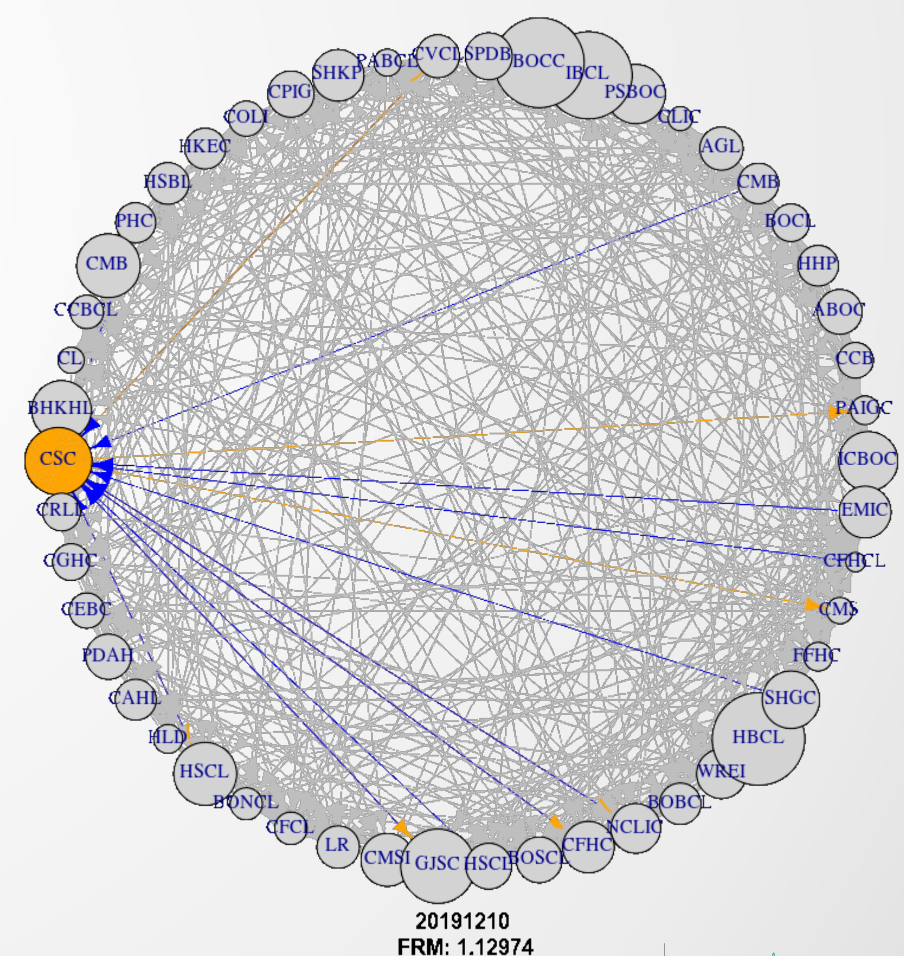
$$\mathbf{1}(\beta_{j,i}^{k}) = \begin{cases} 1 & if \;\; \beta_{j,i}^{k} \neq 0 \\ 0 & if \;\; \beta_{j,i}^{k} = 0 \end{cases}$$

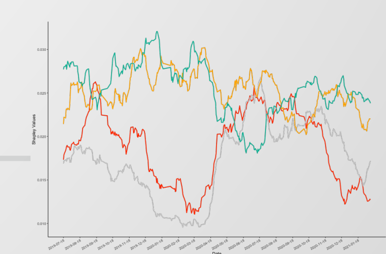
- In-degree of FI j:

$$Ind_j = \sum_{i=1}^{N} \mathbf{1}(\beta_{j,i}^{k})$$

- Out-degree of FI i:

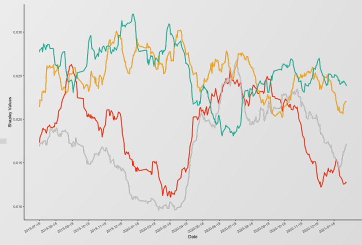
$$Outd_i = \sum_{j=1}^{N} \mathbf{1}(\beta_{j,i}^{k})$$





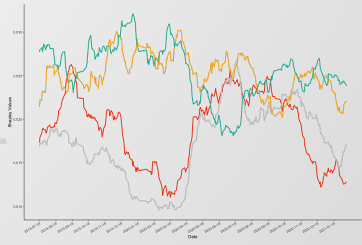
Steps

- 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 J biggest companies)
- Calculate stock and macro variable 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



Macroeconomic variable selection

- Adrian J, Brunnermeier M (2016), but for Chinese Region
- Common exposure
- Macroeconomic risk factors
  - 3M yield $\succ$ 2yr Chinese treasury yield rate
  - Yield curve slope $\succ$ Chinese 10-2yr spread
  - FXI $\succ$ CBOE Top 50 China ETF
  - VXFXI $\succ$ Implied Volatility traded on FXI



The function of Shapley (from RM)

Can we pin down why a certain model made a particular prediction?

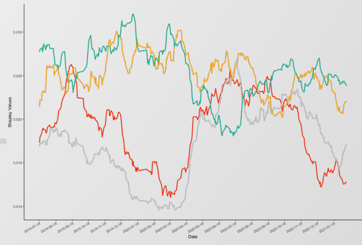
No

Then the model can be defined as a **black box model**.

Possible solution: Post-hoc explanation methods

Yes

Then we know which features were of importance.



Macro ≻ FRM: non-linear

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

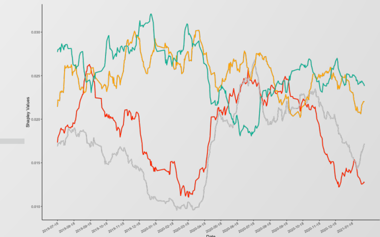
Macro

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

$$(\alpha - \gamma)^{\top} = \tau \, \mathrm{I}_{\{Y - X\beta(\lambda) > 0\}} + (\tau - 1) \, \mathrm{I}_{\{Y - X\beta(\lambda) < 0\}}$$

- Average penalty: indicator for tail risk

$$FRM^t \overset{def}{=} J^{-1} \sum_{j=1}^{J} \lambda_j^t$$

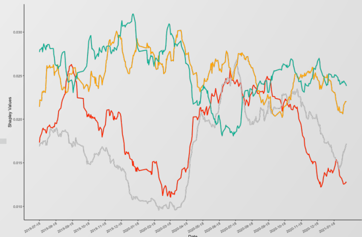


Basic idea (from RM)

Calculation of the Shapley values

$$\phi_j = \sum_{S \subseteq F \backslash j} \frac{|S|!(|F|-|S|-1)!}{|F|!}\{P(S \cup j) - P(S)\}$$

- ϕ_j is Shapley value for player j
- F is a set containing all players of the game
- S is a coalition of players w/o player j
- $P(S)$ is payoff for this coalition



Calculation Process: eg FXI.US

x_a: FXI.US
x_b: VXFXI
x_c: CN2YR
x_d: CN210Slope
$\hat{f}$: FRM
$S' = \{49FIs'stockreturn\}$

- Case1:

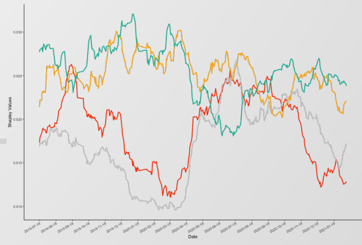
$$\phi_a^1 = \frac{0!(4-0-1)!}{4!}\left\{\hat{f}(S' \cup x_a) - \hat{f}(S')\right\}$$

- Case2:

$$\phi_a^2 = \frac{1!(4-1-1)!}{4!}\left\{\hat{f}(S' \cup x_a \cup x_b) - \hat{f}(S' \cup x_b) + \hat{f}(S' \cup x_a \cup x_c) - \hat{f}(S' \cup x_c) + \hat{f}(S' \cup x_a \cup x_d) - \hat{f}(S' \cup x_d)\right\}$$

- Case3:

$$\phi_a^3 = \frac{2!(4-2-1)!}{4!}\left\{\hat{f}(S' \cup x_a \cup x_b \cup x_c) - \hat{f}(S' \cup x_b \cup x_c) + \hat{f}(S' \cup x_a \cup x_b \cup x_d) - \hat{f}(S' \cup x_b \cup x_d) + \hat{f}(S' \cup x_a \cup x_c \cup x_d) - \hat{f}(S' \cup x_c \cup x_d)\right\}$$



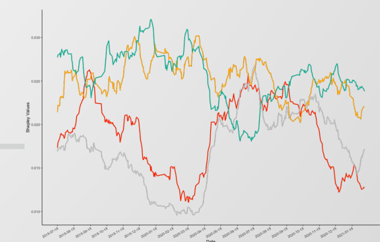
Calculation Process: eg FXI.US

- Case4:

$$\phi_a^4 = \frac{3!(4-3-1)!}{4!}\left\{\hat{f}(S' \cup x_a \cup x_b \cup x_c \cup x_d) - \hat{f}(S' \cup x_b \cup x_c \cup x_d)\right\}$$

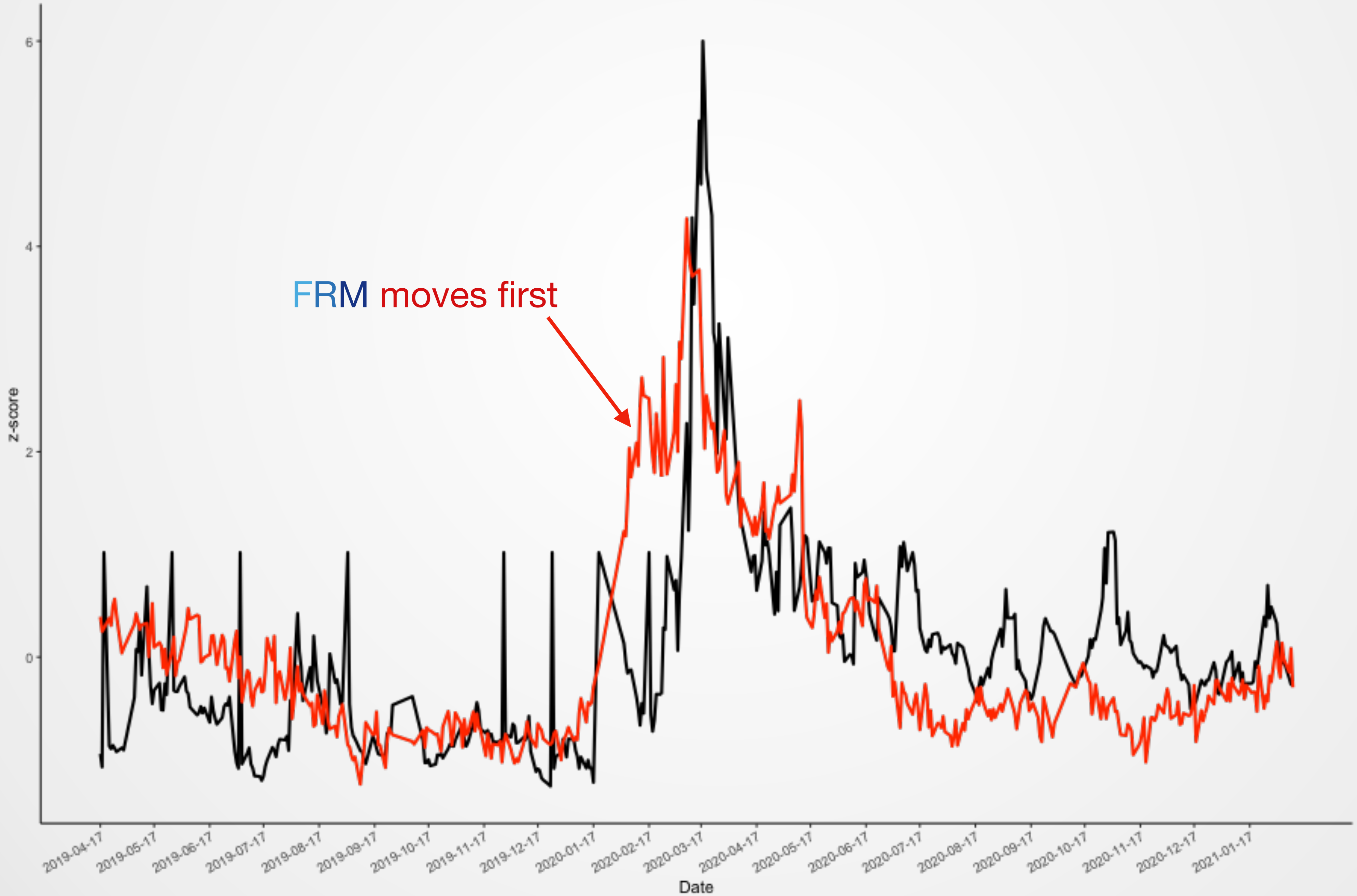
- Shapley value of “a”:

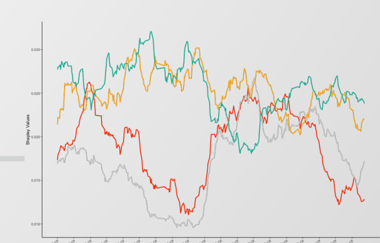
$$\phi_a = \phi_a^1 + \phi_a^2 + \phi_a^3 + \phi_a^4$$



FRM: earlier and less noise FRM_China

- 2019-04-17 to 2021-02-10, CBOE FIX Volatility Index, FRM@China

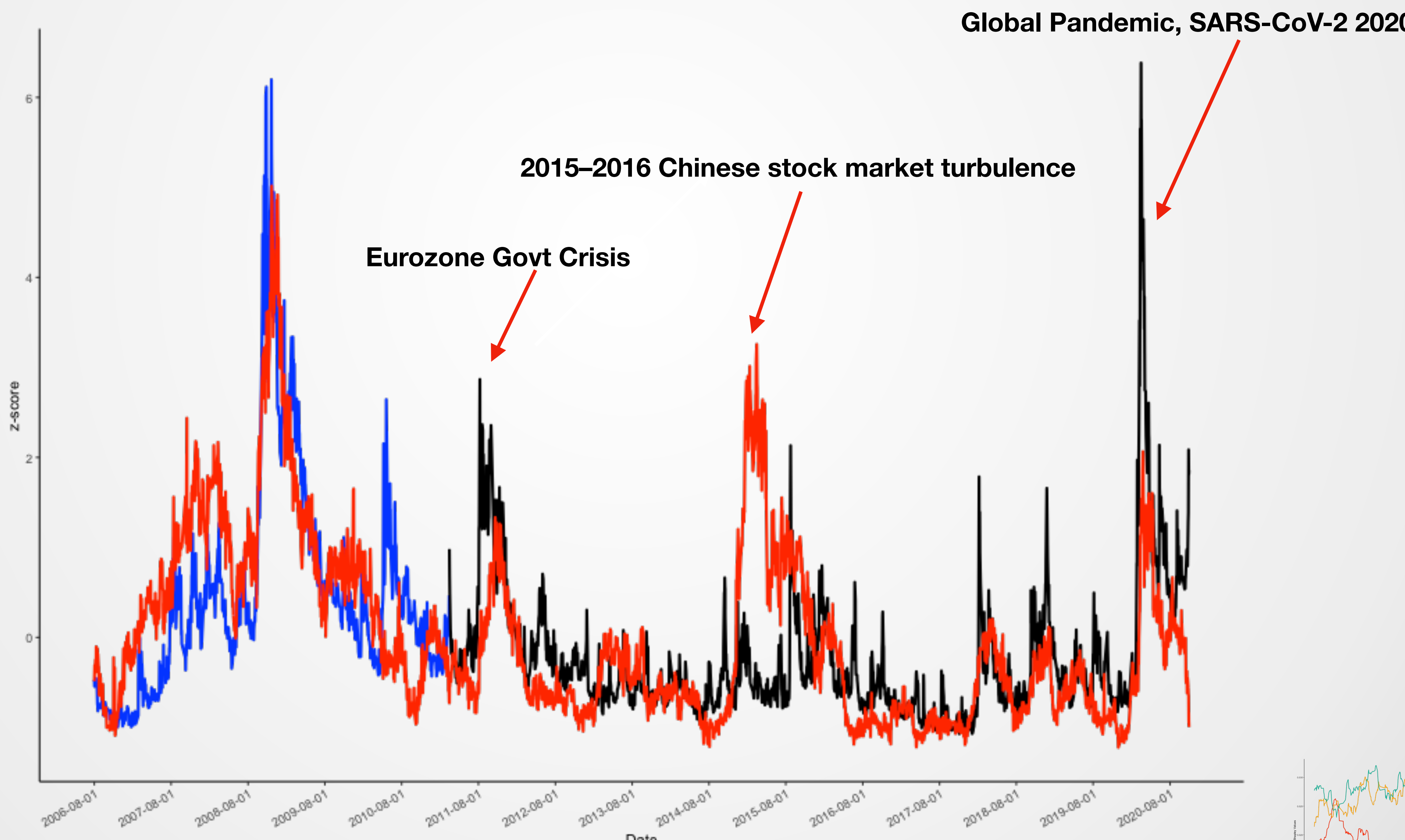


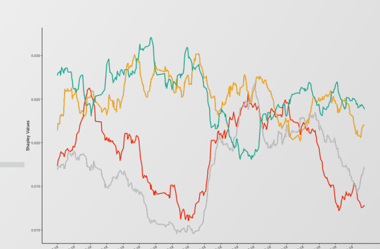


FRM: earlier and less noise

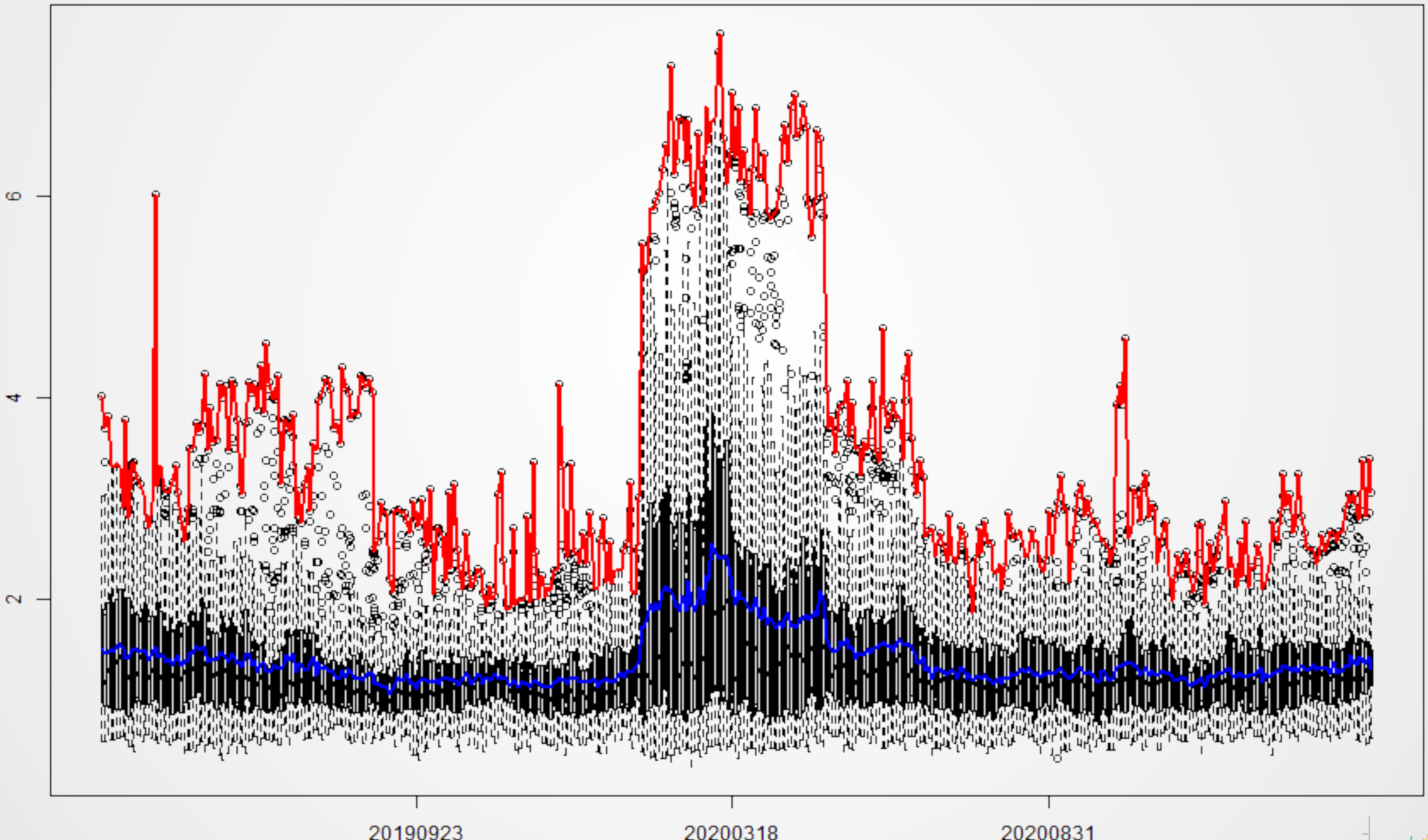
FRM_China

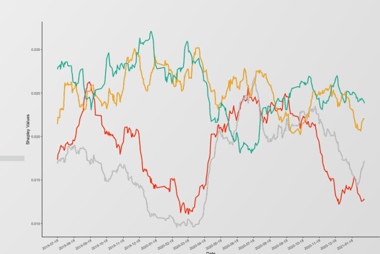
- 2006-08-01 to 2021-02-10, VIX Index, CBOE FIX Volatility Index, FRM@China





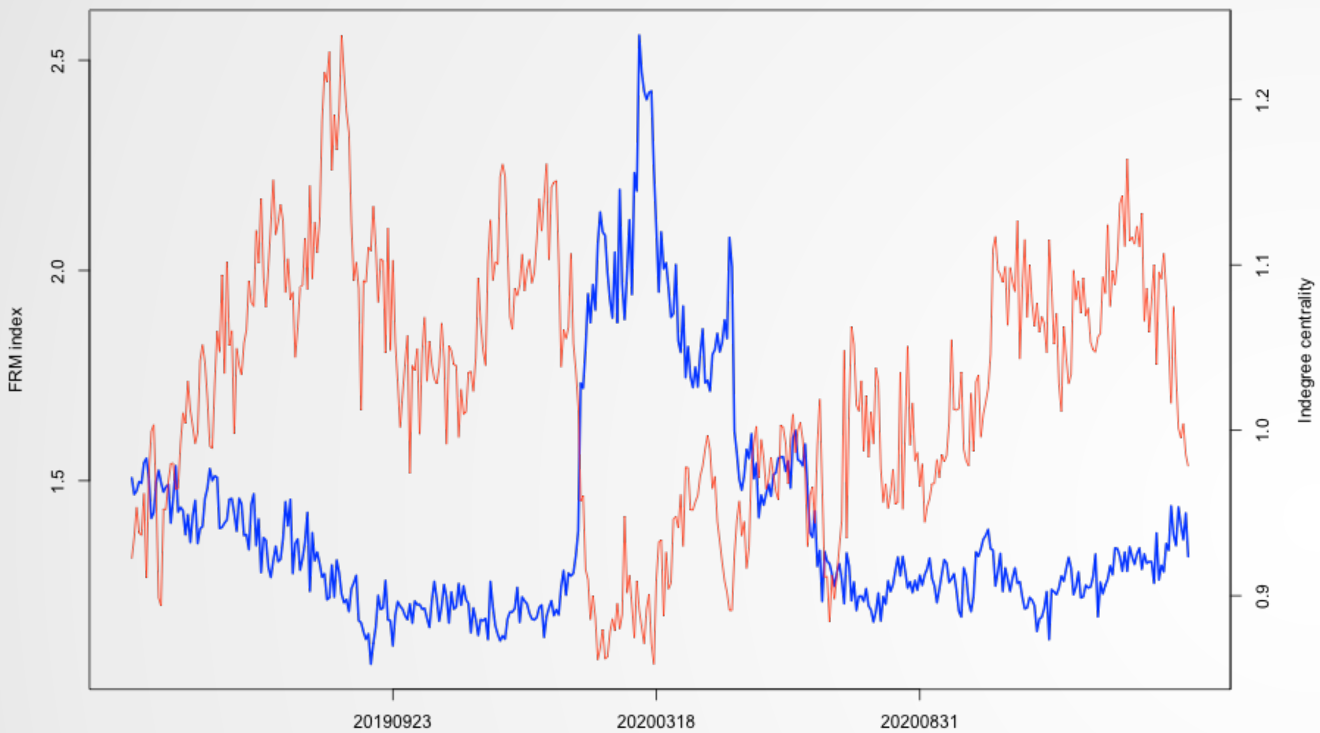
Visualising the Trend: FRM the Boxplot FRM_China



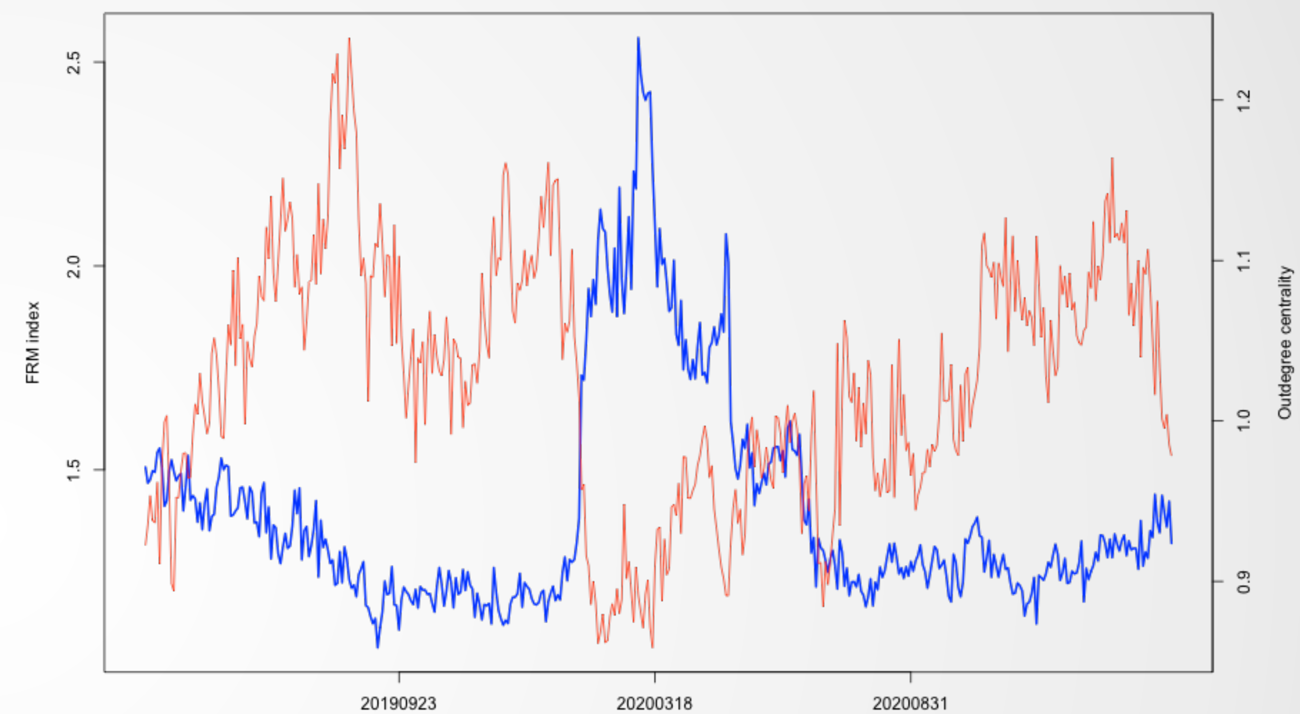


Visualising the Trend: FRM, In-degree, Out-degree

FRM_China

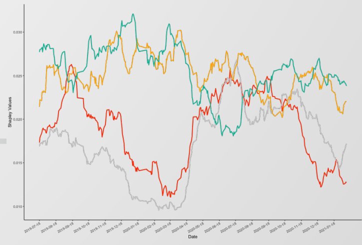


FRM and In-degree



FRM and Out-degree

Degree ↓ ≻ FRM ↑

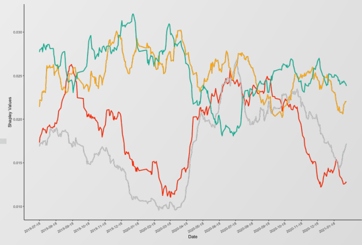


Dynamic risk transmission

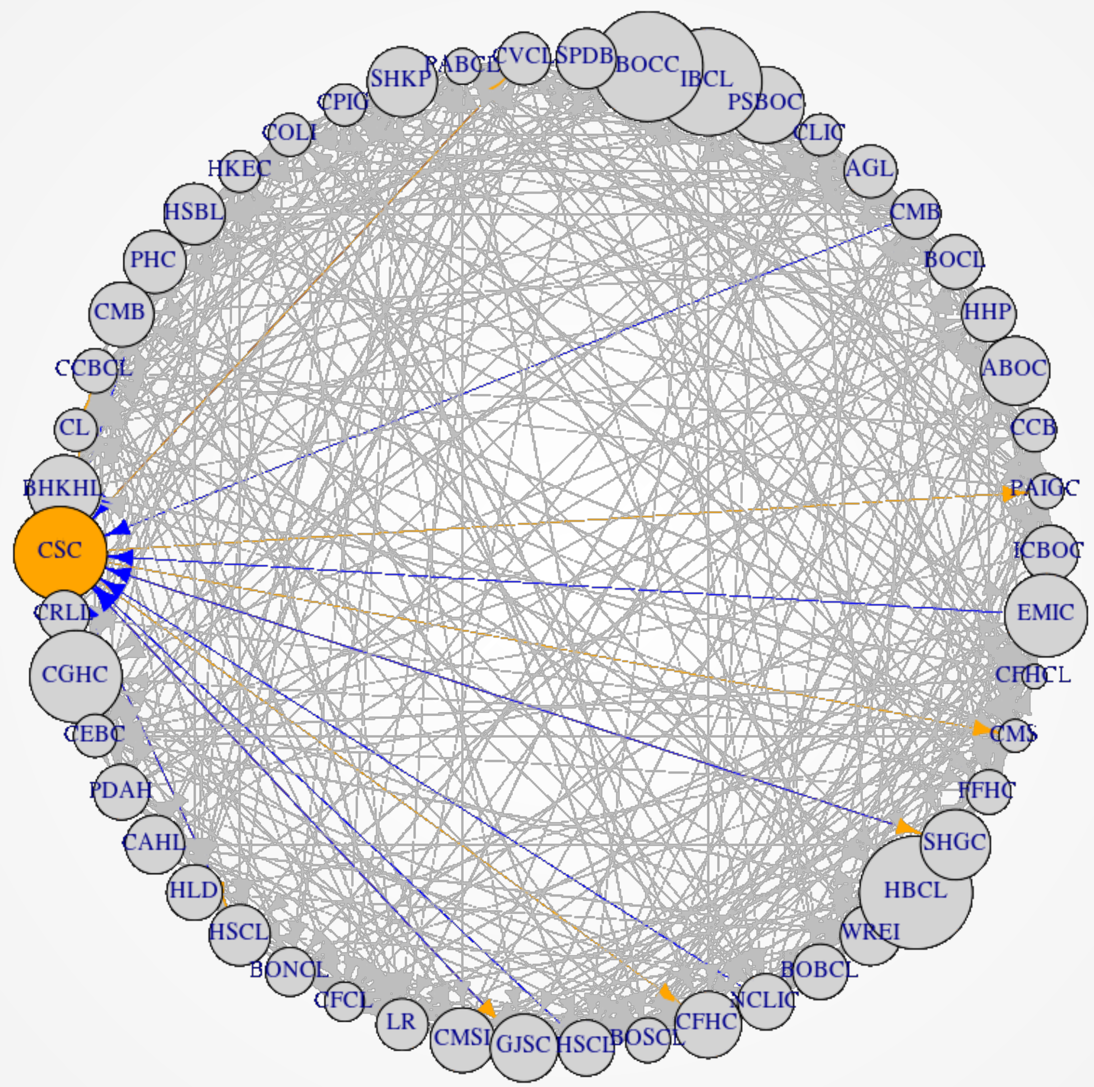
- The most risky sector

  Bank (before covid-19) $\succ$ Security (after covid-19)
- CITIC, the most risky FI after Covid-19

  $$\begin{cases} \text{Spill-in effects} \uparrow \\ \text{Spill-out effects} \downarrow \end{cases}$$
- TE Interaction between mainland, Taiwan and Hong Kong

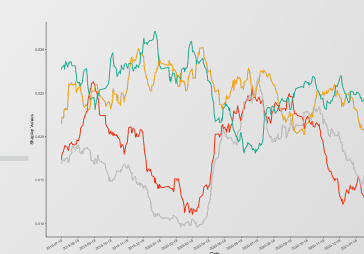


Visualising the Matrix: CITIC 600030 CH

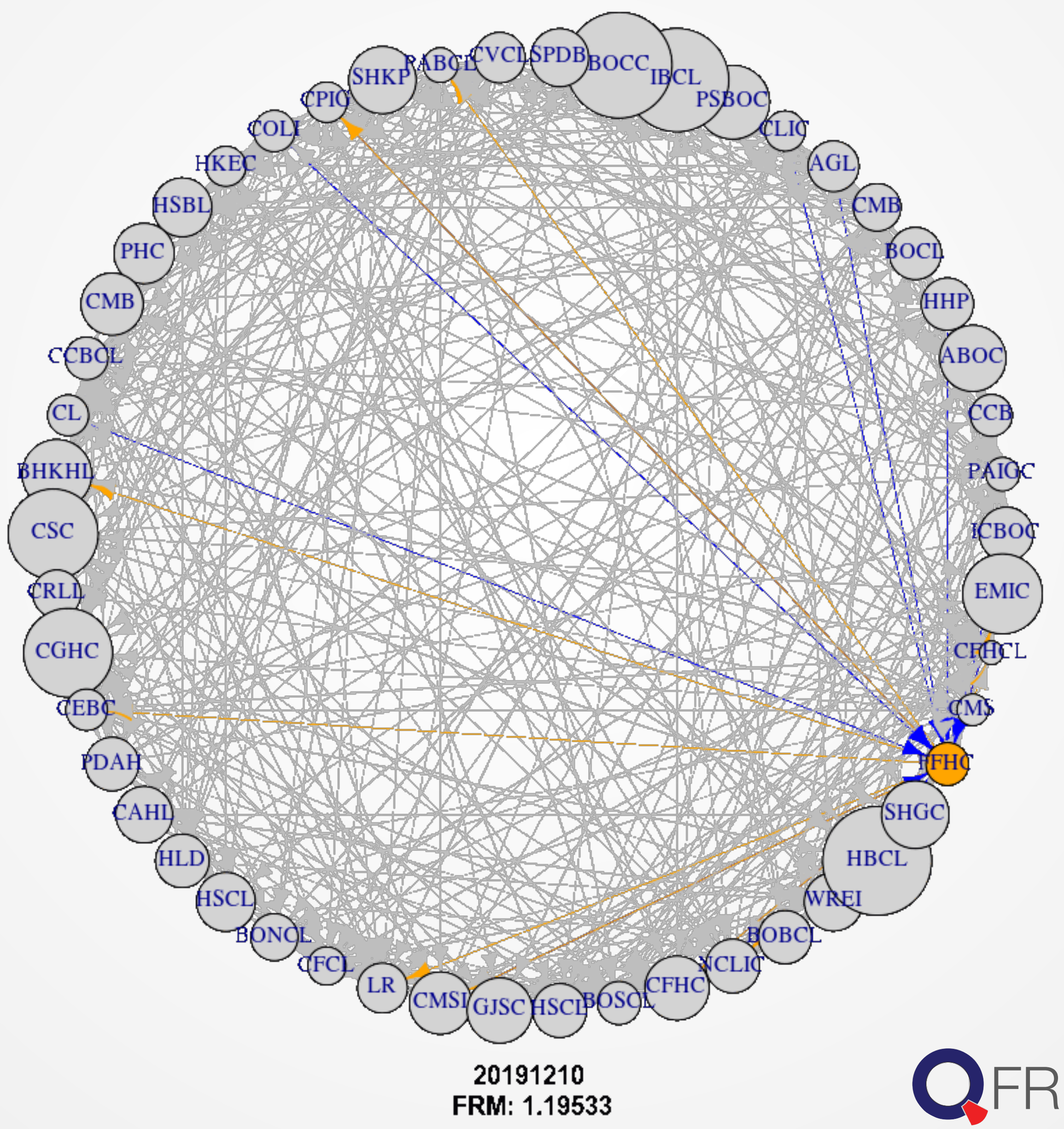


20191210
FRM: 1.19533

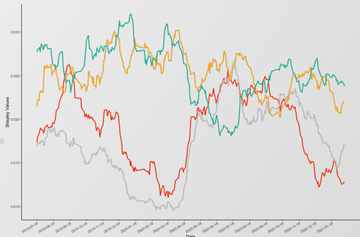
FRM_China



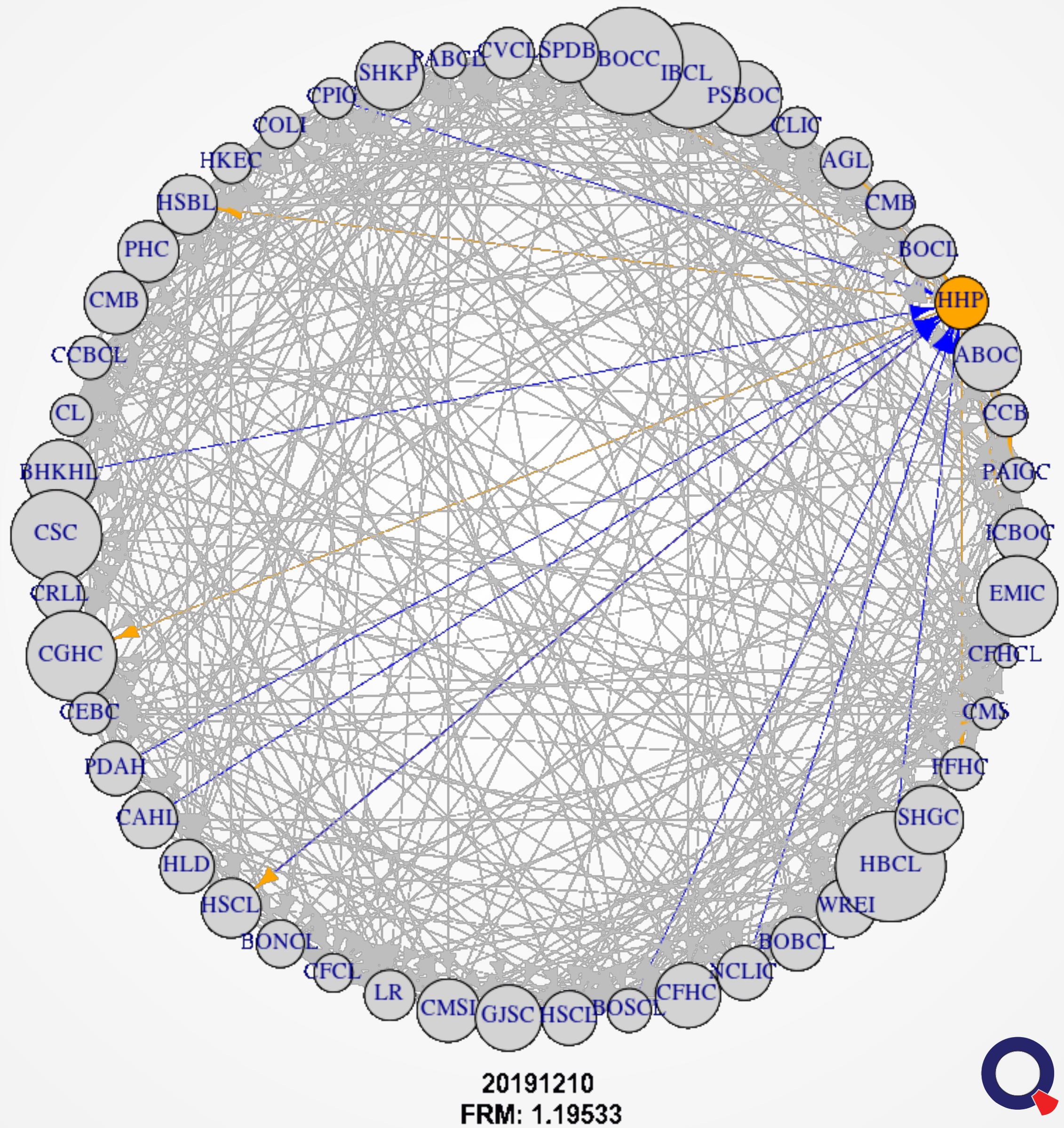
Visualising the Matrix: FUBON FINANCIAL HOLDING CO (2881 TT CH)



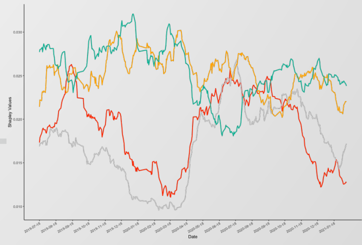
FRM_China



Visualising the Matrix: HSBC HOLDINGS PLC(5 HK CH)

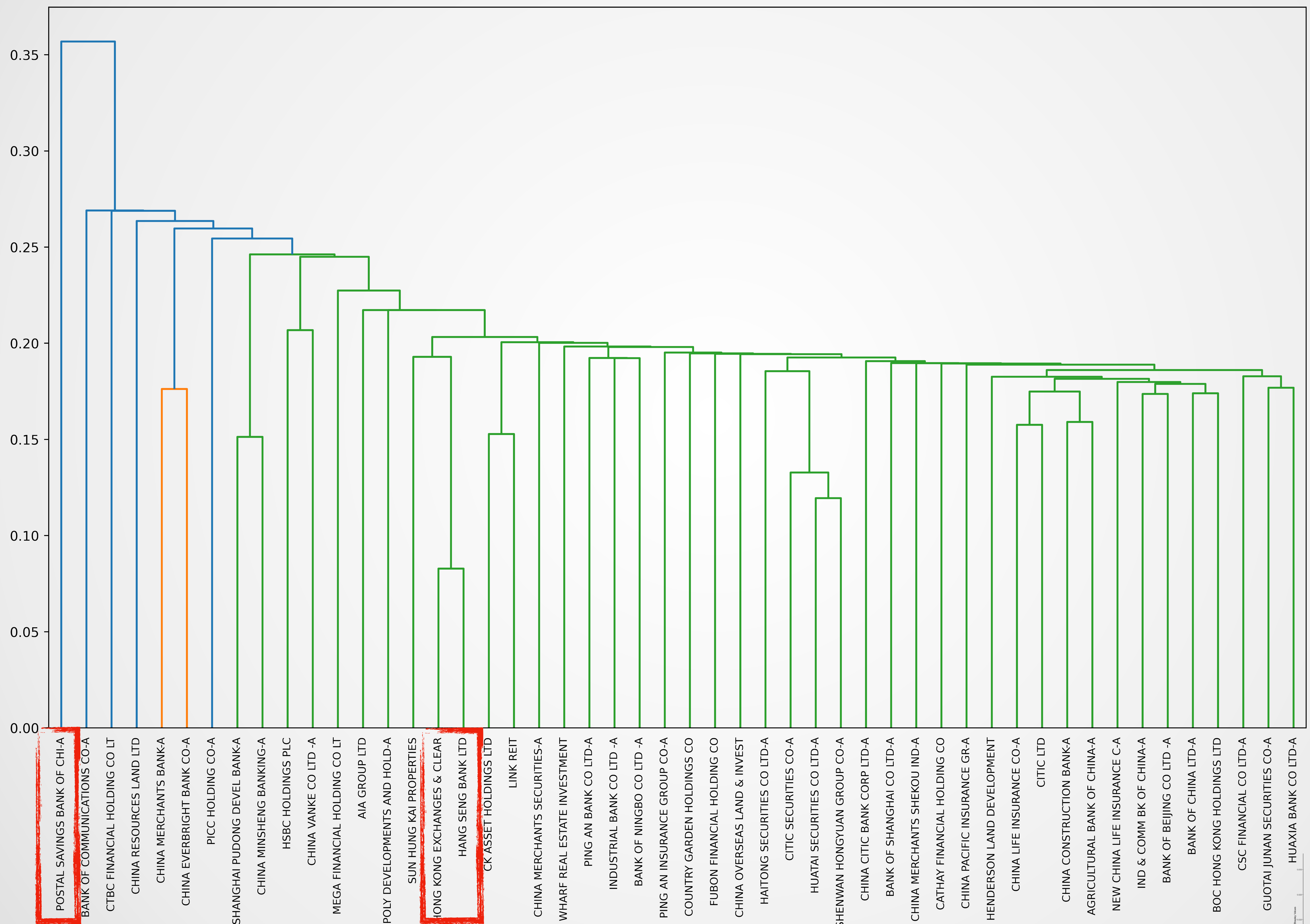


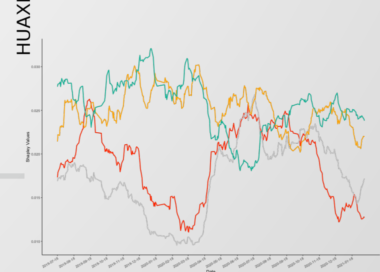
FRM_China



HRP Cluster of FIs on 2020-02-03

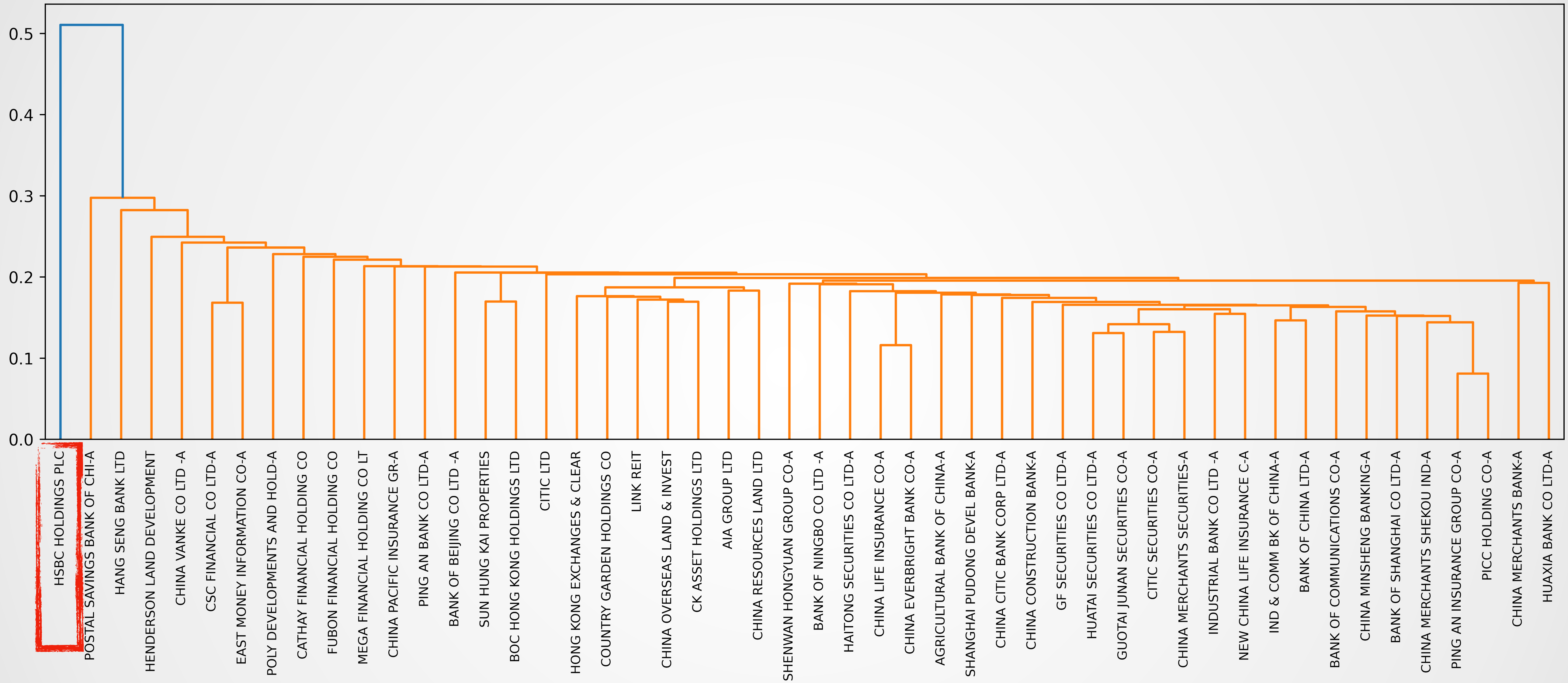
FRM_China

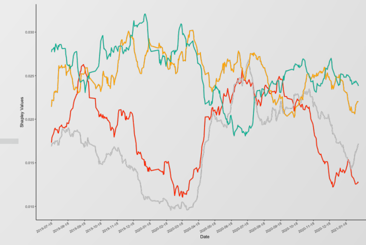




HRP Cluster of FIs on 2020-04-29

FRM_China





Adjacency Matrix of FIs

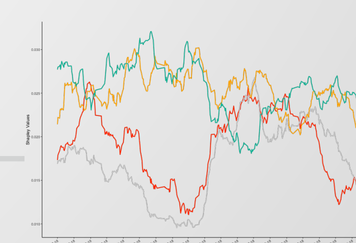
FRM_China

			ICBCAS	CHINAM	BOCOM	SHANPU	CHIOLI	BCHINA	CHIMIN	CSFCO	COGARD	CHEVBK	CKASST	LINREI	HTSC	BKNIBO	GTJA	HAISEC	CATFIN	NCHLII	SYWGSE	GFSECU	FXI US EQUITY	VXFXI INDEX	CN2YR	CN210SLOPE	TED	RealEstateDiff	Spread_InduBond_Less1Y	Spread_InduBond_1T3Y	Spread_InduBond_3T5Y	Spread_InduBond_5T10Y	Spread_InduBond_Over10Y
			CH	CH	CH	CH	HK	HK	CH	CH	CH	CH	HK	HK	CH	CH	CH	CH	TA	CH	CH	CH											
		20200203, tau=0.05	Banks	Banks	Banks	Banks	Real Estate Ma	Banks	Banks	Capital Market	Real Estate Ma	Banks	Real Estate Ma	Equity Real Esta	Capital Market	Banks	Capital Market	Capital Market	Insurance	Insurance	Capital Market	Capital Market											
CITICS	CH	Capital Markets											0.01		0.13	0.03	0.34	0.10		0.05	0.24												
CITLTD	HK	Industrial Conglomerates		0.03		0.06	0.11	0.16	0.02		0.28		0.11	0.22																			
FUBON	TA	Insurance	0.06		0.00					-0.08		0.22		0.10					0.38	0.04		0.16			-0.11			0.05		0.05			

Adjacency Matrix on 2021-02-03

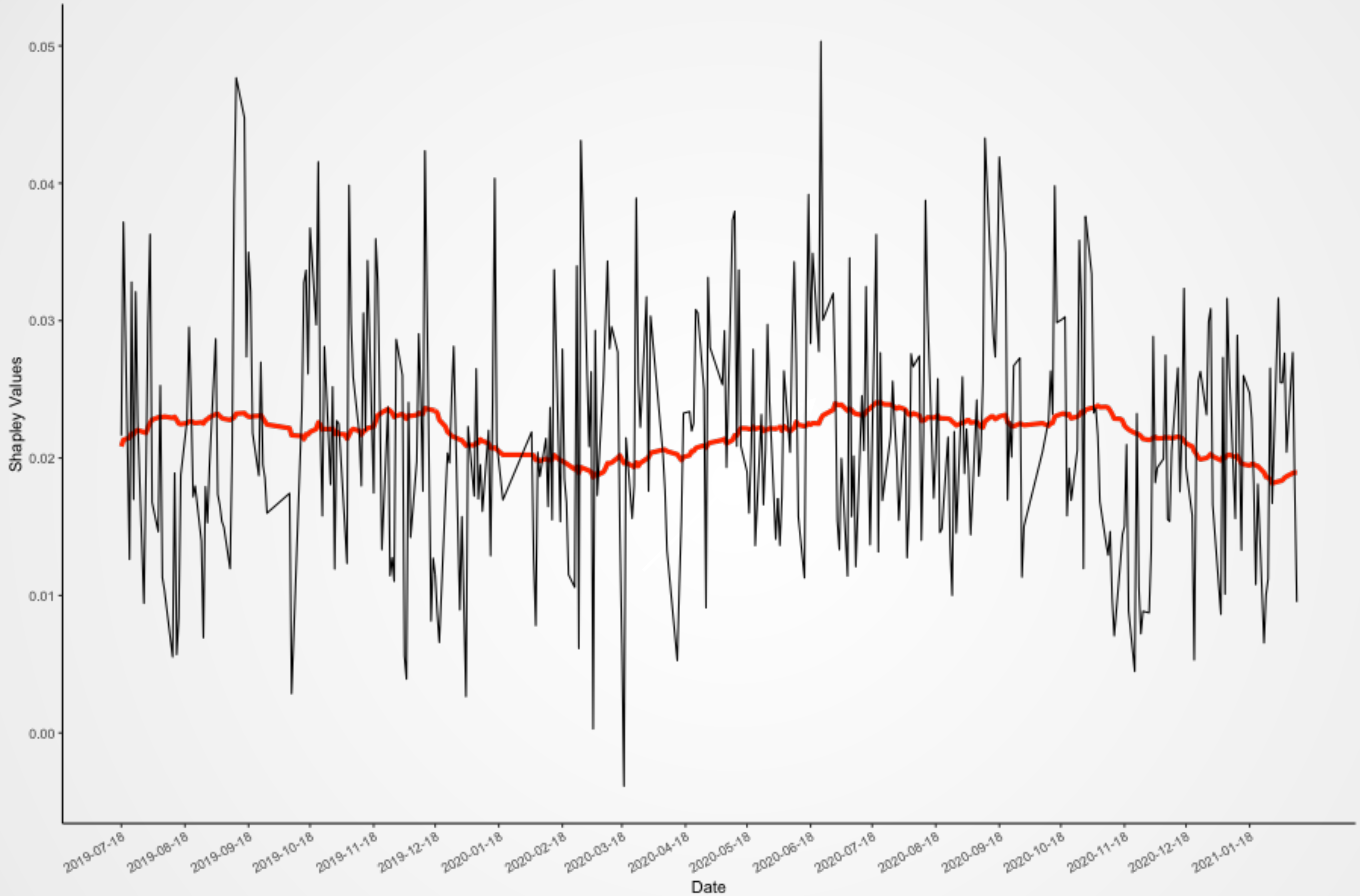
			CHINAM	AIA	HSBC	CHINPACINS	CHIMIN	HANSEN	CSFCO	CRHZCH	CHEVBK	HTSC	HENLND	GTJA	CHMERC	LINREI	HAISEC	CATFIN	SYWGSE	FUBON	MEGA	GFSECU	FXI US EQUITY	VXFXI INDEX	CN2YR	CN210SLOPE	TED	RealEstateDiff	Spread_InduBond_Less1Y	Spread_InduBond_1T3Y	Spread_InduBond_3T5Y	Spread_InduBond_5T10Y	Spread_InduBond_Over10Y
			CH	HK	GB	CH	CH	HK	CH	HK	CH	CH	HK	CH	CH	HK	CH	TA	CH	TA	TA	CH											
		20200429, tau=0.05	Banks	Insurance	Banks	Insurance	Banks	Banks	Capital Market	Real Estate Ma	Banks	Capital Market	Real Estate Ma	Capital Market	Real Estate Ma	Equity Real Esta	Capital Market	Insurance	Capital Market	Insurance	Banks	Capital Market											
CITICS	CH	Capital Markets		0.00					0.08		0.02	0.16		0.37					0.27			0.11								0.03			
CITLTD	HK	Industrial Conglomerates			0.17		0.03	0.22		0.33			0.05	0.00	0.05	0.05	0.00		0.19	-0.11								-0.16					
FUBON	TA	Insurance	0.05	0.16		0.01			-0.05									0.34			0.29		0.10				-0.11	0.06					

Adjacency Matrix on 2021-04-29



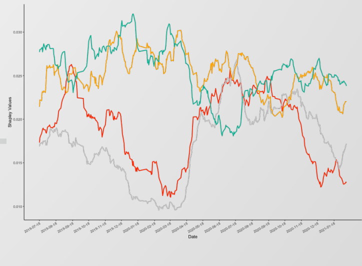
Shapley value of macro features

FRM_China



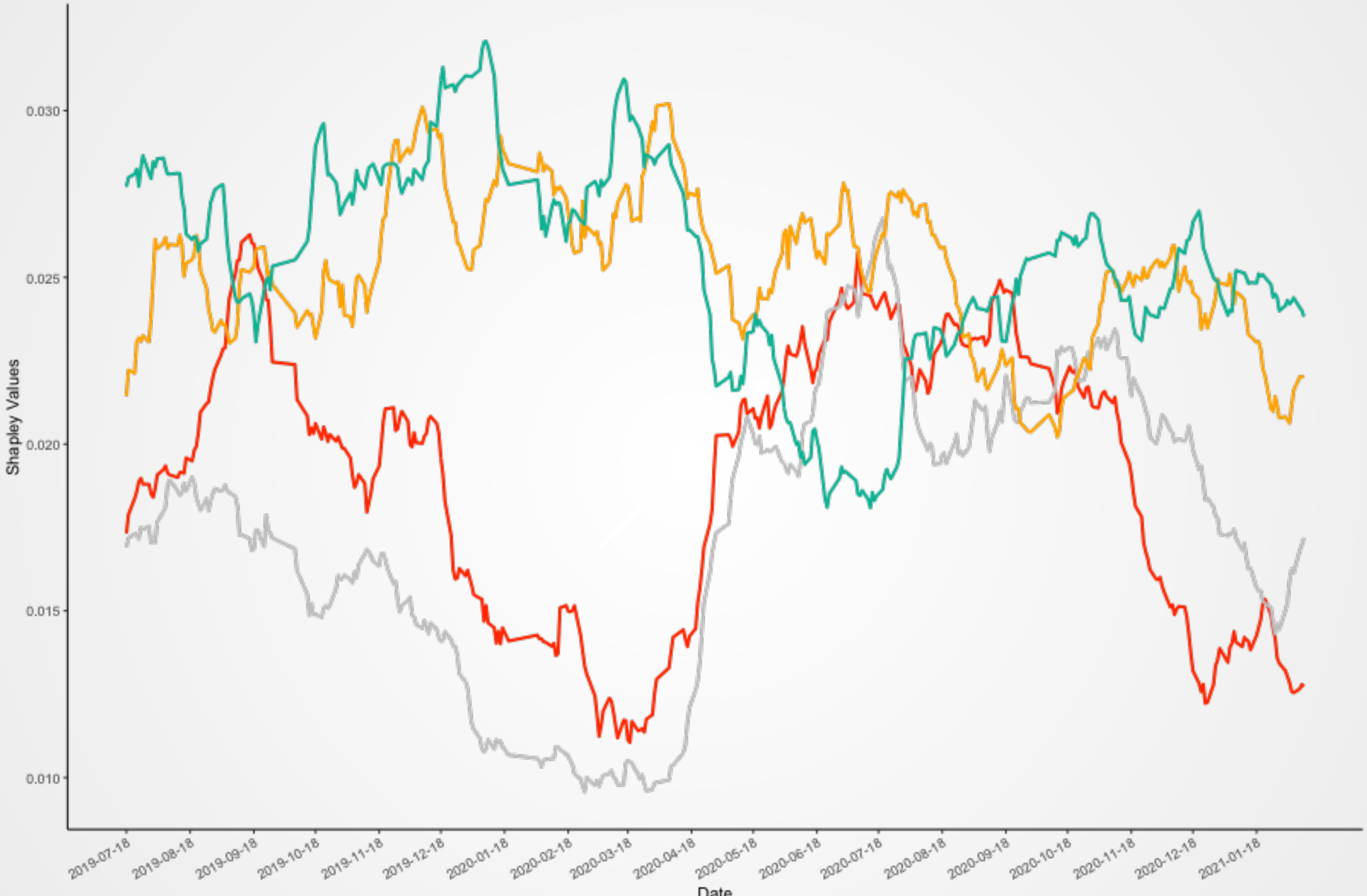
Mean of Shapley Values of 4 macro features at each time point

63 D box car window smooth



Shapley value of macro features

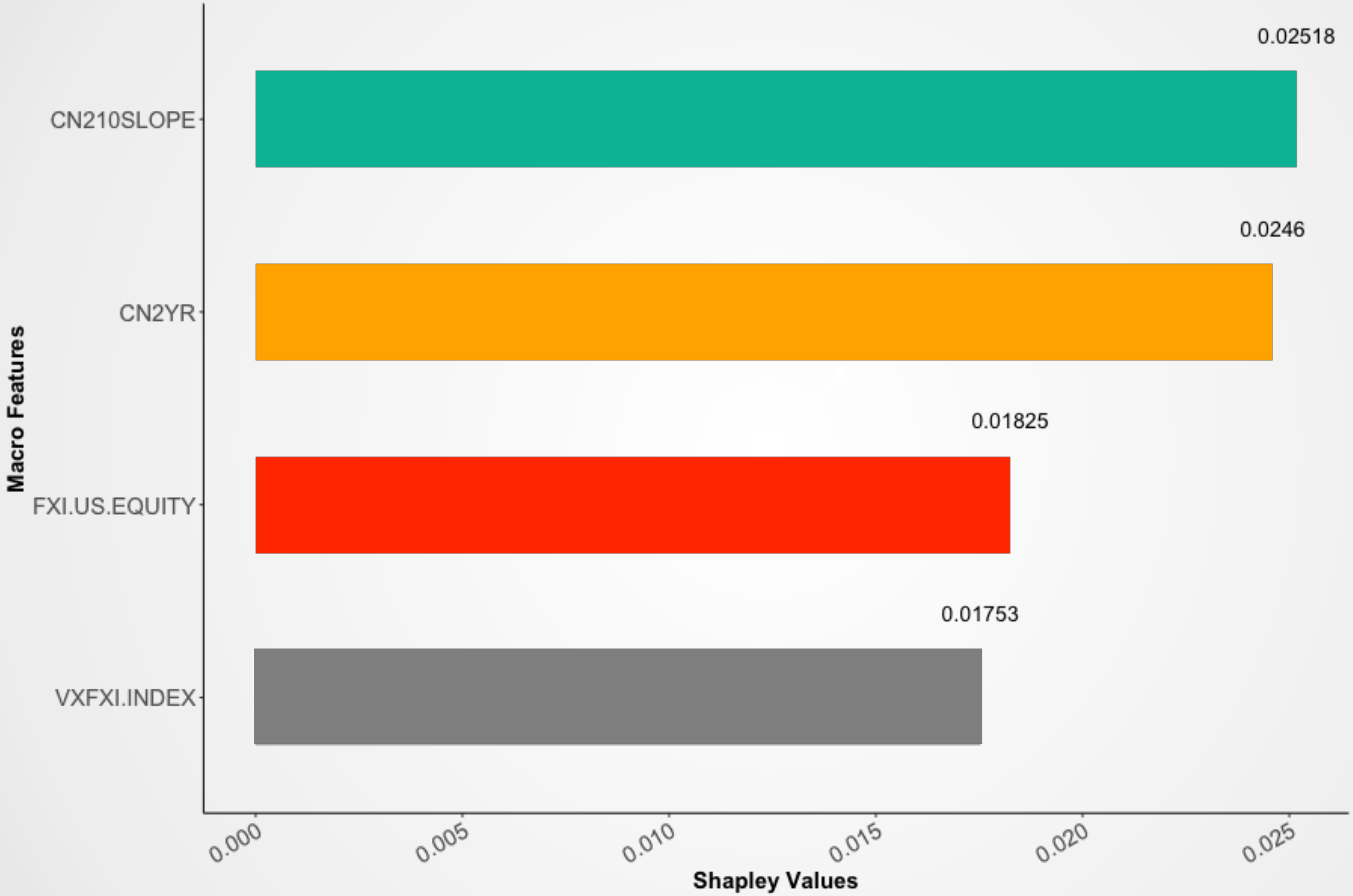
FRM_China



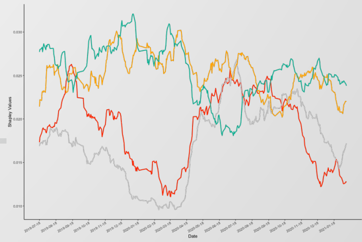
Feature importance based on Shapley Value
(τ= 0.05, rolling window = 63 days),
FXI.US.EQUITY, VXFXI.INDEX, CN2YR, CN210SLOPE

Shapley value of macro features

FRM_China

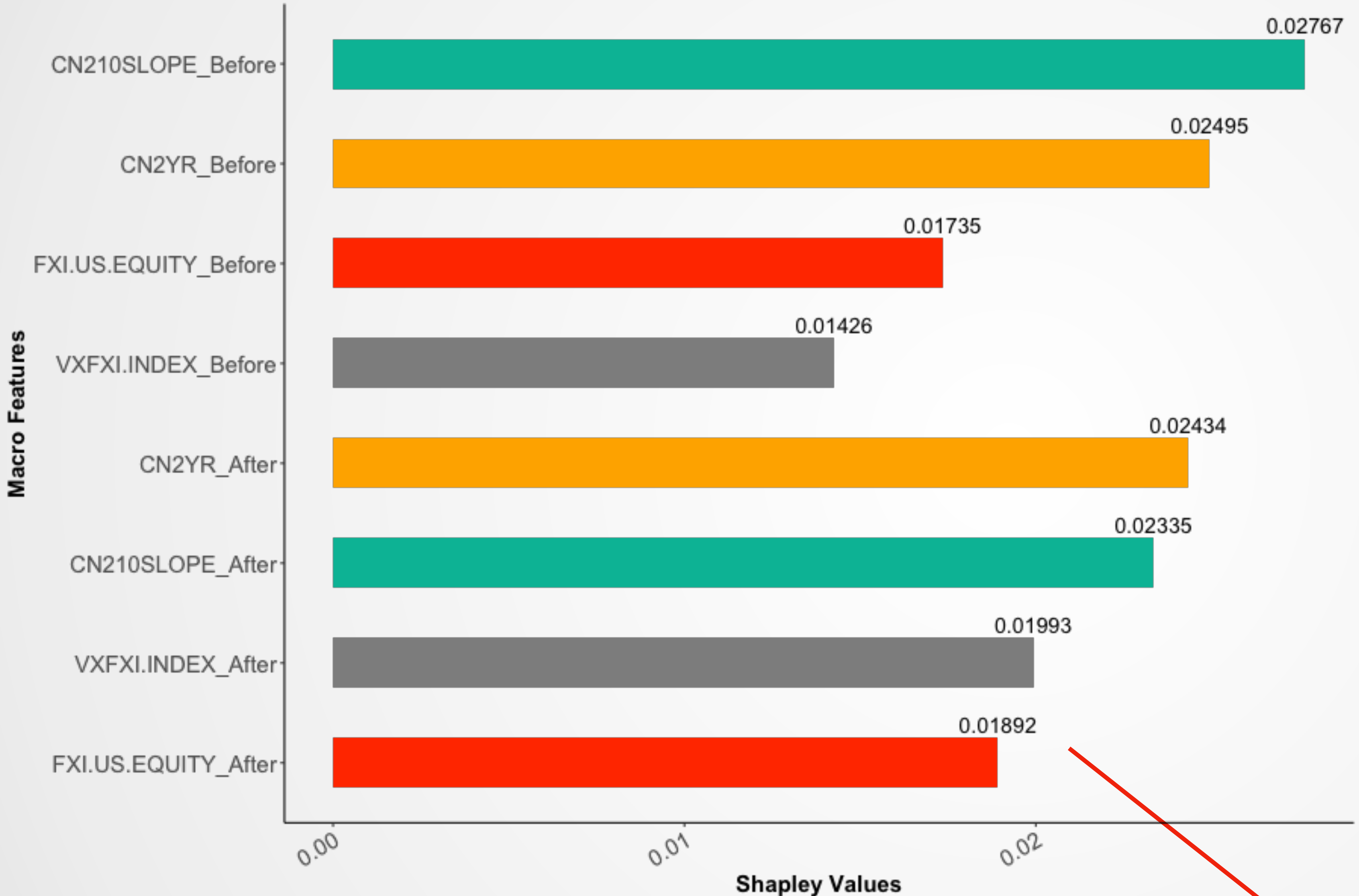


the Mean of Shapley Value Grouped by 4 macro features (FXI.US.EQUITY, VXFXI.INDEX, CN2YR, CN210SLOPE)



Shapley value of macro features

FRM_China



Conflicts with US ↓

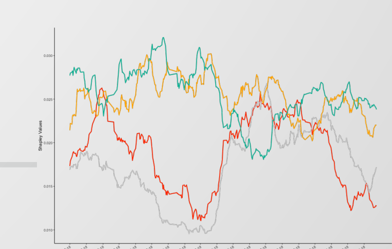
QFII ↑

≻ Stock markets ↑

Open market: RMB 3.33 trillion
Re-lending & re-discounting: RMB 1.8 trillion
Rate ↓

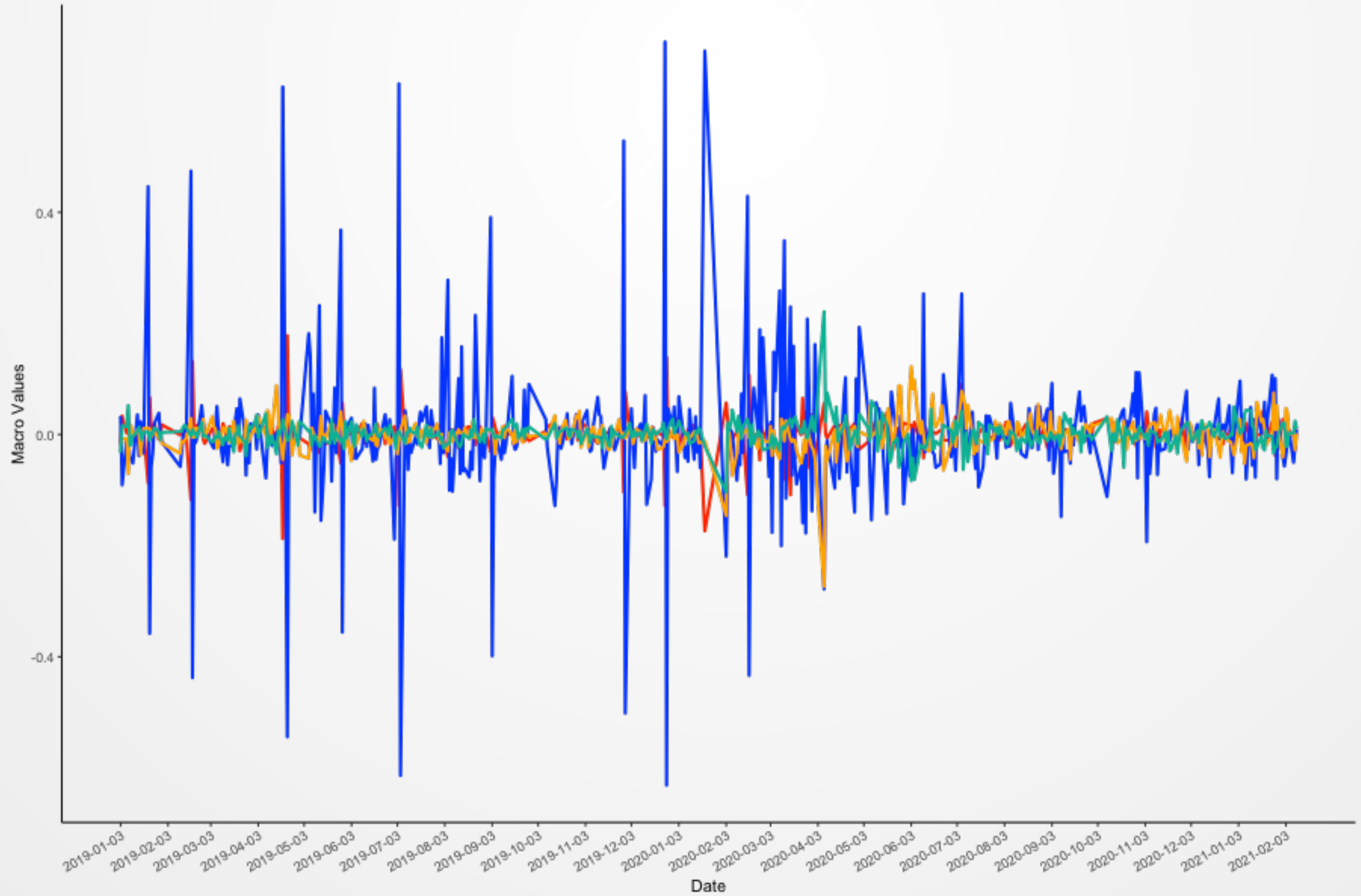
Covid ≻ Stock markets ↓

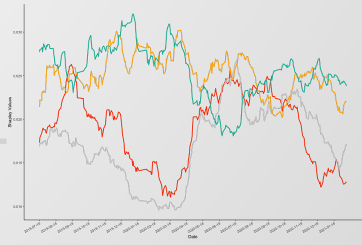
Increase of FXFXI and FXI



Correlation between Macro Variables

	FXI.US.EQUITY	VXFXI.INDEX	CN2YR	CN210SLOPE
FXI.US.EQUITY		-0.85	0.020	0.032
VXFXI.INDEX	-0.85		0.032	-0.024
CN2YR	0.020	0.032		-0.517
CN210SLOPE	0.032	-0.024	-0.517	





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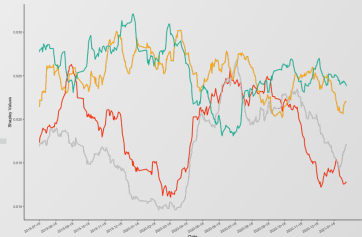

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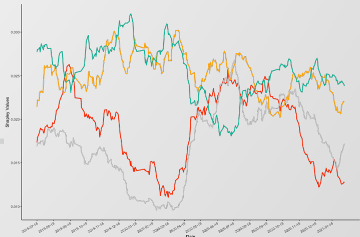

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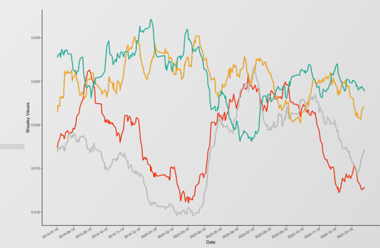

FRM@China
FinancialRiskMeter for China

Ruting Wang
Michael Althof
Wolfgang Karl Härdle

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