The Systemic Risk of the U.S. and European Banking Sector: An Empirical Comparison of Market-based Approaches

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Brief Summary

- The categorisation of a bank as global systemically important may have profound implications for the institution in terms of balance sheet structuring and financial intermediation.
- In this paper we provide further tests for how reliably the systemic risk of banks can be measured, using the three leading market-based measures of systemic risk.
- We test whether the difference within the same category and across different categories of systemic risk of individual banks is significant.
- We find that in general the systemic risk categories defined by the FSB are *different* from those constructed in a full pairwise comparison approach based on the market measures.
- We also measure systemic risk contributions of global systemically important banks as of November 2015 and 2016 and test for a potential increase in their systemic risk contribution during the main high volatility events of 2015 and 2016.
- A more robust ranking method based on nonparametric confidence intervals is introduced.

Motivation

- Macroprudential policy should be targeting *only* firms that can be proved to be systemically risky and only those firms should be asked to increase their capital ratios, (Crockett, 2000).
- Companies may start litigations against the regulator for being given a systemic risk status that will imply operating under more stringent capital requirements than their commercial competitors, as in the case of MetLife suing Financial Stability Oversight Council (FSOC).
- Ideally the regulator should have a mechanism that automatically and transparently rates a company as systemically risky. Then, banks and other firms could self-test their position in the market and the risk of ad-hoc categorizing would be reduced.
- Proving with high confidence that a company is posing systemic risk to a financial system is not straightforward due to estimation uncertainty, (Danielsson et al., 2016).

- Basel Committee on Banking Supervision (BCBS) promotes targeting higher bank capital requirements for Global Systemically Important Banks (G-SIB). The BCBS focuses on banks *"given that their business models have generally placed greater emphasis on trading and capital markets-related activities"*.
- The Financial Stability Board (FSB) decides on the list of the G-SIBs according to this assessment methodology.
- Benoit et al. (2017) find two major shortcomings in the current systemic-risk scoring methodology designed by the BCBS:
  - the first is linked to the categories that, as defined by the official methodology, are quite volatile in the cross section;
  - the second is related to the reference currency used to aggregate bank data across currency zones. They empirically demonstrate that these two shortcomings affect the final ranking.

Literature Review

- Our approach is adjacent to Danielsson et al. (2016) in that we investigate the differences of the systemic risk estimates generated by the three main SRMs and evaluate their ranking power by testing with the bootstrap Kolmogorov-Smirnov (KS) test the capability of these measures to identify the same G-SIBs as the FSB.
- There is still no widely accepted definition of systemic risk (Lo, 2008; Billio et al., 2012; Rodríguez-Moreno and Peña, 2013) and, without an agreed definition, it may be legally controversial to implement public policy that explicitly aims to reduce this risk (Hurd, 2016).
- The analysis in our paper extends the studies of Benoit et al. (2013), Kleinow et al. (2017) and Rodríguez-Moreno and Peña (2013), who compare other market-based SRMs; enriches the research in Nucera et al. (2016), Bernal et al. (2014), Huang et al. (2012) and van de Leur et al. (2017), who employ some of the SRMs to provide a formal ranking based on the contribution to systemic risk; and extends Bernal et al. (2014) and Ahnert and Georg (2017), with respect to hypothesis testing on systemic risk.

Testing the systemic risk contribution

- We measure the systemic risk according to
  - the $\Delta CoVaR$,
  - the MES
  - the SRISK
- Bernal et al. (2014) applied the bootstrap KS test developed by Abadie (2002) for testing the systemic contribution of different financial sectors during the period from 2004 to 2012.
- Ahnert and Georg (2017) use the Wilcoxon signed rank sum test for paired data to test whether or not information contagion due to counterparty risk increases systemic risk.
- We test the systemic contribution of the G-SIBs, as identified by the FSB in November 2015 and 2016, to the overall systemic risk of the US and European banking sector, respectively.
- We also run a dominance test to measure the significance of the rankings listed by the FSB
- Reject the hypothesis:

$$H_0 : SRM^i_{5\%} \geq SRM^{Banking-Sector}_{5\%} \tag{1}$$

means that the FSB identified incorrectly bank i as one of the s-riskier banks.

Table: List of G-SIBs as of November 2016.

Category	G-SIBs in alphabetical order within each category
5 (3.5%)	Empty
4 (2.5%)	Citigroup JP Morgan Chase
3 (2.0%)	Bank of America BNP Paribas Deutsche Bank HSBC
2 (1.5%)	Barclays Credit Suisse, Goldman Sachs Industrial and Commercial Bank of China Limited Mitsubishi UFJ FG, Wells Fargo
1 (1.0%)	Agricultural Bank of China Bank of China Bank of New York Mellon China Construction Bank Groupe BPCE, Groupe Credit Agricole ING Bank, Mizuho FG, Morgan Stanley Nordea, Royal Bank of Scotland, Santander Societe Generale, Standard Chartered, State Street Sumitomo Mitsui FG, UBS, Unicredit Group

- FSB allocates 5 systemic categories corresponding to different requirement levels of additional capital buffers.
- These categories were built in such a way as to leave the highest (5^{th}) empty as a deterrent for banks not to increase their global systemic importance.
- Are higher ranked categories s-riskier than the lower categories?

All the G-SIBs classified in each category are compared using the KS test based on the CDFs of the systemic risk contribution of each category.

$$D_{mn} = \sqrt{\left(\frac{mn}{m+n}\right)} sup_x |S_m(x) - T_n(x)| \tag{2}$$

where $S_m(x)$ and $T_n(x)$ are the CDFs of the SRM within the same category, and, m and n represent the size of the two samples, respectively.
The null hypothesis is defined as follow:

$$H_0 : SRM^{n^{th}} > SRM^{(n-j)^{th}} \quad \text{with} \quad j = 1, 2, ..., n-1 \tag{3}$$

where $SRM^{n^{th}}$ and $SRM^{(n-j)^{th}}$ are the SRM for two the n^{th} and the $(n-j)^{th}$ category.

- We investigate the contribution of the G-SIBs during the main high volatile events of 2015 and 2016.
- Whether or not the contribution of the G-SIBs h-days after the volatile events is greater than h-days before.
- The horizon h is one month (22 days), similar to Brownlees and Engle (2016).
- As main volatile events of 2015 and 2016, we examine the Chinese market crash on August 24^{th}, the Brexit vote on June 23^{th} and the presidential election in U.S. of 2016 (November 8^{th}).

The Wilcoxon signed rank sum test is applied to the following hypothesis:

$$H_0 : SRM^i_{t:t+h} = SRM^i_{t-h:t-1} \tag{4}$$

where SRM is the risk measure considered and i indicates the particular bank under study.

Testing systemic risk ranking

- We use the bootstrap KS test to investigate the dominance relationship among the G-SIBs.
- This dominance test is on the null hypothesis:

$$H_0 : SRM^i_{5\%} > SRM^j_{5\%} \quad \text{with} \quad i = 1, 2, ..., n \quad \text{and} \quad j = 1, 2, ..., n-1 \quad (5)$$

where SRM is the risk measure considered stressed at 5%, i and j indicate the G-SIB entities that are tested.

- Based on the results form the KS dominance test, we rank the G-SIBs at 99% confidence level.
- We use this test to rank the G-SIBs and then to investigate the rankings produced by different SRMs, for 2015 and 2106.

Systemic risk ranking with confidence intervals

- We construct in this paper nonparametric confidence intervals based on bootstrapping.
- We build confidence intervals based on the mean with a re-sampling of (n=) 1000 considering a 1-year moving window.
- If $\overline{x}$ is the sample average, we estimate the bootstrapped mean $\overline{x}^*$ with a (n=) 1000 resampling.
- The bootstrap differences are given by $\delta^* = \overline{x}^* - \overline{x}$.
- Repeating this exercise for 1000 times, we can estimate the critical values at 0.975 and 0.250 ($\delta^*_{0.975}$ and $\delta^*_{0.250}$) leading to the bootstrap confidence interval at 95% confidence level as:

$$[\overline{x} - \delta^*_{0.250}, \overline{x} - \delta^*_{0.975}] \tag{6}$$

- In this paper, we built confidence intervals associated with the $\Delta CoVaR_{99^{th}}$. However, the same methodology can be used for the other SRMs.

- The EU-Wide Stress Test includes a sample of 51 banks covering about 70% of the European banks total assets;
- The Dodd-Frank Act Stress Test covers a sample of 33 BHCs that hold USD50 billion or more in total consolidated assets.
- we did not consider banks:
  - which are not listed or have become de-listed;
  - for which market data are not available;
  - with not enough available observations; in particular, we considered institutions with at least 253 daily observation (1YR);
  - were involved in a M&A process, e.g. Banca Popolare that on the 1st of January 2017 merged with Banca Popolare di Milano creating Banco BPM.

  Our data consists of 32 US BHCs covered by the Dodd-Frank Act Stress Test 2016 and 35 European banks covered by the EU-Wide Stress Test 2016.

Ticker Symbol	Bank Name	Starting Date
ALLY:US	Ally Financial Inc	28/01/2014
AXP:US	American Express Co	03/01/2000
BAC:US	Bank of America Corp	03/01/2000
BBT:US	BB&T Corp	03/01/2000
BBVA:US	Banco Bilbao Vizcaya Argentaria SA	03/01/2000
BK:US	Bank of New York Mellon Corp/The	03/01/2000
BMO:US	Bank of Montreal	03/01/2000
C:US	Citigroup Inc	03/01/2000
CFG:US	Citizens Financial Group Inc	23/09/2014
CMA:US	Comerica Inc	03/01/2000
COF:US	Capital One Financial Corp	03/01/2000
DB:US	Deutsche Bank AG	11/01/2000
DFS:US	Discover Financial Services	14/06/2007
FITB:US	Fifth Third Bancorp	03/01/2000
GS:US	Goldman Sachs Group Inc/The	03/01/2000
HBAN:US	Huntington Bancshares Inc/OH	03/01/2000
HSBC:US	HSBC Holdings PLC	03/01/2000
JPM:US	JPMorgan Chase & Co.	03/01/2000
KEY:US	KeyCorp	03/01/2000
MS:US	Morgan Stanley	03/01/2000
MTB:US	M&T Bank Corp	03/01/2000
MTU:US	Mitsubishi UFJ Financial Group Inc	02/04/2001
NTRS:US	Northern Trust Corp	03/01/2000
PNC:US	PNC Financial Services Group Inc/The	03/01/2000
RF:US	Regions Financial Corp	03/01/2000
SAN:US	Banco Santander SA	03/01/2000
STI:US	SunTrust Banks Inc	03/01/2000
STT:US	State Street Corp	03/01/2000
TD:US	Toronto-Dominion Bank/The	03/01/2000
USB:US	US Bancorp	03/01/2000
WFC:US	Wells Fargo & Co	03/01/2000
ZION:US	Zions Bancorporation	03/01/2000

Code	Country	Ticker Symbol	Bank Name	Starting Date
AT	Austria	EBS:AV	Erste Group Bank AG	03/01/2000
		RBI:AV	Raiffeisen Bank International AG	22/04/2005
BE	Belgium	DEXB:BB	Dexia SA	03/01/2000
		KBC:BB	KBC Group NV	03/01/2000
DE	Germany	CBK:GR	Commerzbank AG	03/01/2000
		DBK:GR	Deutsche Bank AG	03/01/2000
DK	Denmark	DANSKE:DC	Danske Bank A/S	03/01/2000
		JYSK:DC	Jyske Bank A/S	03/01/2000
ES	Spain	BBVA:SM	Banco Bilbao Vizcaya Argentaria SA	03/01/2000
		SAB:SM	Banco de Sabadell SA	18/04/2001
		POP:SM	Banco Popular Español SA	03/01/2000
		SAN:SM	Banco Santander SA	03/01/2000
		BKIA:SM	Bankia SA	19/07/2011
		CABK:SM	CaixaBank SA	10/10/2007
FR	France	BNP:FP	BNP Paribas SA	03/01/2000
		ACA:FP	Crédit Agricole SA	13/12/2001
		GLE:FP	Société Générale SA	03/01/2000
HU	Hungary	OTP:HB	OTP Bank PLC	03/01/2000
IE	Ireland	ALBK:ID	Allied Irish Banks PLC	04/01/2000
		BKIR:ID	Bank of Ireland	04/01/2000
IT	Italy	BMPS:IM	Banca Monte dei Paschi di Siena SpA	03/01/2000
		ISP:IM	Intesa Sanpaolo SpA	03/01/2000
		UCG:IM	Unicredit SpA	03/01/2000
		UBI:IM	Unione Di Banche Italiane SpA	30/06/2003
NL	Netherlands	INGA:NA	ING Groep NV	03/01/2000
NO	Norway	DNB:NO	DNB ASA	03/01/2000
PL	Poland	PKO:PW	Powszechna Kasa Oszczedności Bank Polski SA	09/11/2004
SE	Sweden	NDA:SS	Nordea Bank AB	03/01/2000
		SEBA:SS	Skandinaviska Enskilda Banken AB	03/01/2000
		SHBA:SS	Svenska Handelsbanken AB	03/01/2000
		SWEDA:SS	Swedbank AB	03/01/2000
UK	United Kingdom	BARC:LN	Barclays PLC	04/01/2000
		HSBA:LN	HSBC Holdings PLC	04/01/2000
		LLOY:LN	Lloyds Banking Group PLC	04/01/2000
		RBS:LN	Royal Bank of Scotland Group PLC	04/01/2000

- daily stock price and quarterly balance sheet data from Bloomberg over the period 2000 Q1 - 2016 Q4.
- Our sample period covers the two main crises (2007-2009 and 2009-2012)
- daily log-returns
- we use other measure-specific data from the Federal Reserve Economic Data, the U.S. Department of the Treasury and the European Money Markets Institute in the calculations of the SRMs
- We estimate the CoVaR using the quantile regression methodology

Table: List of the state variables for the US banking sector.

Source Variables	**Ticker Symbol**	**Source**	**Starting Date**
3-M Treasury bill rate	Treasury Bill 3M	treasury.gov	03/01/2000
Composite Long-term bond yield	LT COMPOSITE ($> 10 Yrs$)	treasury.gov	03/01/2000
3-M LIBOR	LIBOR 3M USD	Bloomberg	04/01/2000
3-M Treasury bill	3M TB Secondary Market	fred.stlouisfed.org	03/01/2000
Moody's *Baa*-rated bonds	Moodys Baa	Bloomberg	03/01/2000
Ten year Treasury bill rate	Treasury Bill 10Y	treasury.gov	03/01/2000
S&P500 (return)	SPX:IND	Bloomberg	03/01/2000
Dow Jones U.S. Real Estate Index	DJUSRE:IND	Bloomberg	03/01/2000
Dow Jones U.S. Financial Index	DJUSFN:IND	Bloomberg	03/01/2000
S&P500 (vol)	SPX:IND	Bloomberg	01/12/1999

Table: List of the state variables for the European banking sector.

State Variable	Source Variables	Source	Starting Date
Three-month yield change	Euro Generic Government Bond 3M	Bloomberg	04/01/2000
Slope Change yield curve	Euro Generic Government Bond 3M	Bloomberg	04/01/2000
	Euro Generic Government Bond 10Y	Bloomberg	04/01/2000
Short-term TED spread	Three-month EURIBOR rate	euribor-rates.eu	03/01/2000
	Euro Generic Government Bond 3M	Bloomberg	04/01/2000
Change in the credit spread	BofAML Euro High Yield Index	fred	03/01/2000
	Euro Generic Government Bond 10Y	Bloomberg	04/01/2000
Market return	Euro STOXX 50	Bloomberg	03/01/2000
Return Real-estate over financial	STOXX Europe 600 Real Estate	Bloomberg	29/12/2000
	STOXX Europe 600 Financial Services	Bloomberg	03/01/2000
Equity volatility	STOXX600	Bloomberg	03/01/2000

ΔCoVaR methodology

The $\Delta CoVaR$ of j conditional on institution i being under distress is defined as:

$$\Delta CoVaR_q^{j|i} = CoVaR_q^{j|X^i=VaR_q^i} - CoVaR_q^{j|X^i=VaR_{50^{th}}^i} \tag{7}$$

while its $\Delta CoVaR$ expressed in dollar terms, ie weighted for the size of the institution considered, is defined as follows:

$$\Delta^{\$} CoVaR_{q,t}^{j|i} = Size_t^i \times \Delta CoVaR_{q,t}^{j|i} \tag{8}$$

where the *Size* of the institution is defined as the market value of equity.
We estimate the following quantile regressions using daily-market data:

$$X_t^i = \alpha_q^i + \gamma_q^i M_{t-1} + \varepsilon_{q,t}^i \tag{9}$$

$$X_t^{system|i} = \alpha_q^{system|i} + \gamma_q^{system|i} M_{t-1} + \beta_q^{system|i} X_t^i + \varepsilon_{q,t}^{system|i} \tag{10}$$

$$VaR_{q,t}^i = \hat{\alpha}_q^i + \hat{\gamma}_q^i M_{t-1} \tag{11}$$

$$CoVaR_{q,t}^i = \hat{\alpha}_q^{system|i} + \hat{\gamma}_q^{system|i} M_{t-1} + \hat{\beta}_q^{system|i} VaR_{q,t}^i \tag{12}$$

Multiplying the $\Delta CoVaR_{q,t}^i$ by the respective market value of equity, we obtain a panel weighted measures of systemic risk.

Marginal Expected Shortfall methodology

MES = the average return during the 5% worst days for the market. As a measure of firm-level risk $ES_q = E[R|R \leq VaR_q]$.
If $R = \sum_i y_i R^i$ where R^i is the return of member i and y_i its weight, ES becomes:

$$ES_q = \sum_i y_i E[R^i|R \leq VaR_q] \tag{13}$$

The MES_a^i is then obtained as:

$$\frac{\partial ES_q}{\partial y_i} = E[R^i|R \leq VaR_q] \equiv MES_q^i \tag{14}$$

The MES is estimated at $q\%$=5%, using the daily equity returns, as the equal-weighted average return of firm (R^i) for the $q\%$ worst days of the market returns (R^m):

$$MES_{q\%}^i = \frac{1}{\#days} \sum R_t^i \tag{15}$$

A dollar measure $MES_{i,t}^{\$} = Size_{i,t} \times MES_{i,t}$.

SRISK I

The *Capital Shortfall* is formally defined as:

$$CS_{i,t} = k(D_{i,t} + W_{i,t}) - W_{i,t} \tag{16}$$

where $W_{i,t}$ is the market value of equity, $D_{i,t}$ is the book value of debt.
SRISK is the expected capital shortfall conditional on the market return between period $t+1$ and $t+h$ (h is 22 here) to be below a threshold C, equal to -10%.

$$SRISK_{i,t} = E_t(CS_{i,t+h} | R_{m,t+1:t+h} < C) \tag{17}$$

$$SRISK_{i,t} = E_t(D_{i,t+h} | R_{m,t+1:t+h} < C) - (1-k)E_t(W_{i,t+h} | R_{m,t+1:t+h} < C) \tag{18}$$

Assuming that debt cannot be renegotiated, $\boxed{E_t(D_{i,t+h} | R_{m,t+1:t+h} < C) = D_{i,t}}$

$$SRISK_{i,t} = kD_{i,t} - (1-k)W_{i,t}(1 - LRMES_{i,t}) \tag{19}$$

If $LVG^c_{i,t} = \frac{D_{i,t}+W_{i,t}}{W_{i,t}}$ is the quasi leverage ratio

$$SRISK_{i,t} = W_{i,t}[kLVG_{i,t} + (1-k)LRMES_{i,t} - 1] \tag{20}$$

SRISK II

$LRMES_{i,t}$ is defined as the Long Run Marginal Expected Shortfall, the expectation of the firm equity multi-period arithmetic return conditional on the systemic event:

$$LRMES_{i,t} = -E_t(R_{i,t+1:t+h}|R_{m,t+1:t+h} < C) \tag{21}$$

Acharya et al. (2012) used an approximation of this term:

$$\boxed{LRMES_{i,t} = 1 - exp(-18 \times MES_{i,t})} \tag{22}$$

where the MES is the one day loss expected if market returns are less than 2%. A system-wide measure of financial distress is:

$$SRISK_t = \sum_{i=1}^{N} max(SRISK_{i,t}, 0) \tag{23}$$

The percentage version of SRISK, which indicate the systemic risk share, is denoted by $SRISK\%_{i,t} = \frac{SRISK_{i,t}}{SRISK_t}$.

Main events related to systemic risk

1. the freezing of BNP Paribas funds on August 8^{th}, 2007;
2. the Lehman Brothers bankruptcy on September 15^{th}, 2008;
3. the agreement between the Greek government and the IMF for the First bailout package of EUR 110 billion on May 2^{nd}, 2010;
4. the peak of 44.21% reached by the Greek 10-year bond yields on March 9^{th}, 2012;
5. the Chinese market crash on August 24^{th}, 2015; and,
6. the Brexit referendum result on June 24^{th}, 2016.

The magnitude of systemic risk

Figure: Aggregate systemic risk of the US banking sector.

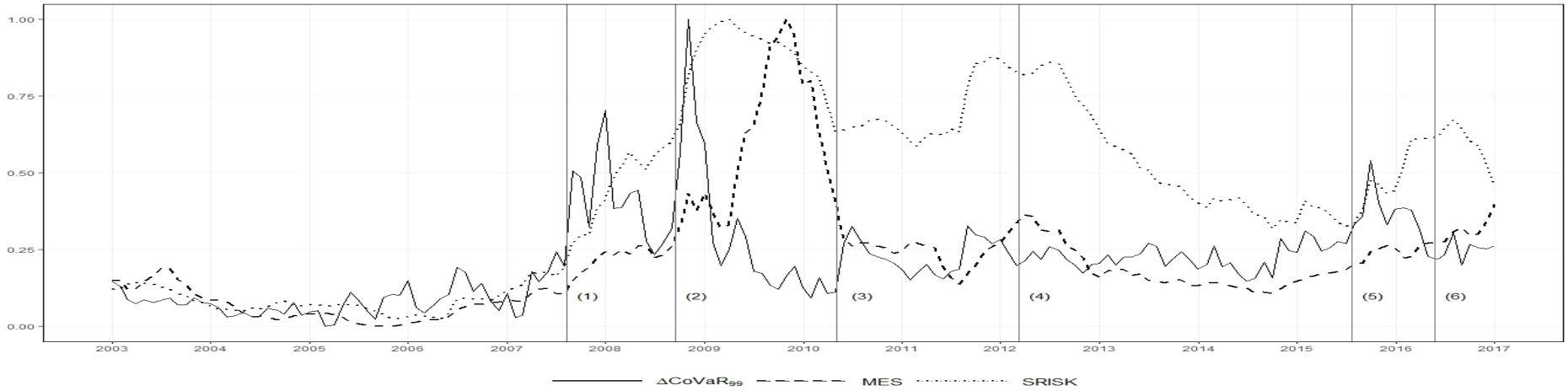
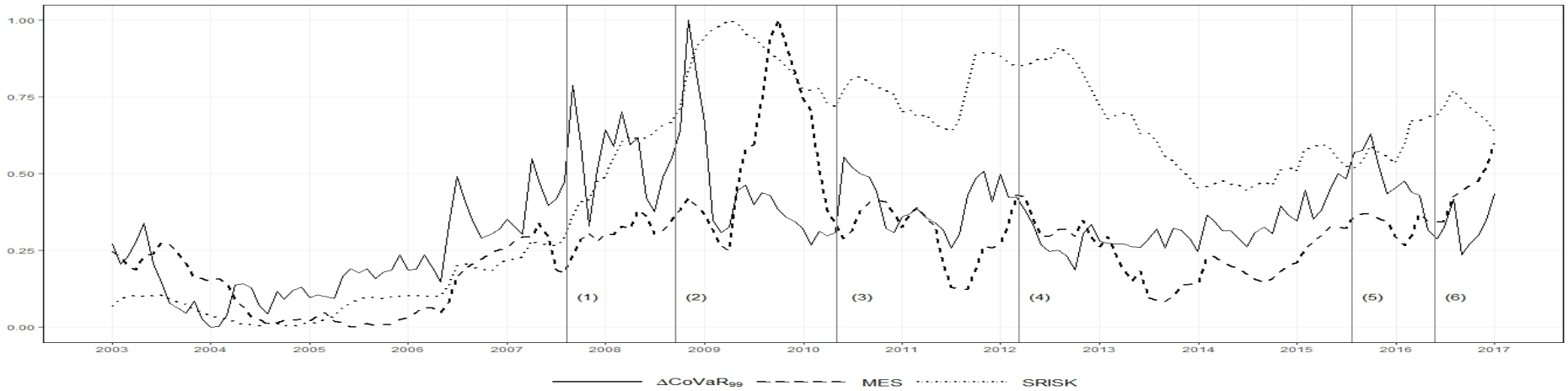


Figure: Aggregate systemic risk of the European banking sector.



	Mean	Median	Std. dev.	Min	Max	No. obs.
US-BHCs						
$CoVaR^{\$}_{50^{th}}$	953.68	600.64	1,142.31	11.49	14,536.47	2973
$CoVaR^{\$}_{75^{th}}$	17,376.37	15,899.44	7,024.35	6,330.12	71,576.01	2973
$CoVaR^{\$}_{95^{th}}$	45,237.63	42,515.21	18,676.96	19,242.36	198,357.58	2973
$CoVaR^{\$}_{99^{th}}$	70,453.73	68,146.40	27,612.41	22,441.11	263,344.06	2973
$MES^{\$}$	52,237.28	45,040.73	28,966.83	18,021.67	189,817.51	2973
$SRISK$	650,451.19	650,029.36	446,642.36	59,776.43	1,553,885.22	2973
EU-Banks						
$CoVaR^{\$}_{50^{th}}$	811.12	456.97	1,039.00	0.00	23,926.69	2955
$CoVaR^{\$}_{75^{th}}$	10,240.54	9,749.44	3,659.79	2,724.62	37,522.77	2955
$CoVaR^{\$}_{95^{th}}$	25,665.28	24,618.34	8,309.69	7,211.98	85,983.43	2955
$CoVaR^{\$}_{99^{th}}$	38,512.82	37,873.78	10,329.61	11,756.22	97,896.28	2955
$MES^{\$}$	29,685.48	29,562.88	11,173.37	9,451.25	78,304.56	2955
$SRISK$	1,023,772.58	1,128,641.56	448,511.97	257,083.06	1,785,800.21	2955

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Table: Dominance test results for the G-SIBs in the U.S and Europe in 2015

$SRM^i_{5\%} \leq SRM^{BankSector}_{5\%}$	$\Delta CoVaR_{99th}$	MES	SRISK	$SRM^i_{5\%} \leq SRM^{BankSector}_{5\%}$	$\Delta CoVaR_{99th}$	MES	SRISK
Bank of America Corp	0.93***	0.93***	0.97***	Banco Santander SA	0.97***	0.99***	0.89***
Bank of New York Mellon	0.47**	0.53***	0.90***	Barclays PLC	0.79***	0.85***	0.97***
Banco Santander SA	0.69***	0.86***	0.97***	BNP Paribas SA	0.94***	0.94***	1.00***
Citigroup Inc	0.86***	0.89***	0.95***	Crédit Agricole SA	0.60***	0.64***	0.95***
Deutsche Bank AG	0.45**	0.56***	0.99***	Deutsche Bank AG	0.71***	0.64***	0.98***
Goldman Sachs	0.75***	0.76***	0.93***	HSBC Holdings PLC	1.00***	0.97***	0.92***
HSBC Holdings PLC	0.86***	0.83***	0.98***	ING Groep NV	0.84***	0.87***	0.88***
JPMorgan Chase	0.96***	0.96***	0.96***	Nordea Bank AB	0.75***	0.61***	0.79***
Morgan Stanley	0.62***	0.71***	0.94***	RBS Group PLC	0.52***	0.58***	0.92***
Mitsubishi UFJ	0.70***	0.79***	1.00***	Société Générale SA	0.68***	0.68***	0.91***
State Street Corp	0.35	0.43**	0.89***	Unicredit SpA	0.58***	0.74***	0.86***
Wells Fargo & Co	1.00***	1.00***	0.91***				

Table: Dominance test results for the G-SIBs in the U.S and Europe in 2016

$SRM^{i}_{5\%} \leq SRM^{BankSector}_{5\%}$	$\Delta CoVaR_{99th}$	MES	SRISK	$SRM^{i}_{5\%} \leq SRM^{BankSector}_{5\%}$	$\Delta CoVaR_{99th}$	MES	SRISK
Bank of America Corp	0.93***	0.92***	0.97***	Banco Santander SA	0.94***	0.97***	0.91***
Bank of New York Mellon	0.54***	0.61***	0.86***	Barclays PLC	0.79***	0.88***	0.95***
Banco Santander SA	0.69***	0.82***	0.96***	BNP Paribas SA	0.96***	0.94***	1.00***
Citigroup Inc	0.87***	0.90***	0.95***	Crédit Agricole SA	0.60***	0.70***	0.94***
Deutsche Bank AG	0.44**	0.48***	0.98***	Deutsche Bank AG	0.63***	0.61***	0.98***
Goldman Sachs	0.74***	0.74***	0.91***	HSBC Holdings PLC	1.00***	1.00***	0.97***
HSBC Holdings PLC	0.89***	0.87***	0.98***	ING Groep NV	0.84***	0.85***	0.85***
JPMorgan Chase	0.96***	0.98***	0.94***	Nordea Bank AB	0.76***	0.64***	0.79***
Morgan Stanley	0.64***	0.75***	0.92***	RBS PLC	0.73***	0.74***	0.89***
Mitsubishi UFJ	0.74***	0.79***	1.00***	Société Générale SA	0.70***	0.73***	0.92***
State Street Corp	0.37*	0.45**	0.86***	Unicredit SpA	0.55***	0.66***	0.88***
Wells Fargo & Co	1.00***	0.94***	0.88***				

Table: Success ratios of the SRMs.

Significance level	$\Delta CoVaR$	MES	SRISK
US G-SIBs - 2015			
0.01	75%	92%	100%
0.05	92%	100%	100%
US G-SIBs - 2016			
0.01	83%	92%	100%
0.05	92%	100%	100%
EU G-SIBs - 2015			
0.01	100%	100%	100%
0.05	100%	100%	100%
EU G-SIBs - 2016			
0.01	100%	100%	100%
0.05	100%	100%	100%

Table: Dominance test results for the categories as defined by the FSB.

	$\Delta CoVaR_{99\%}$		MES		SRISK	
	Stat	p-value	Stat	p-value	Stat	p-value
US G-SIBs - 2015						
$H_a : SRM^{4^{th}-Category} \leq SRM^{3^{th}-Category}$	0.500	0.004	0.667	<0.001	0.734	<0.001
$H_a : SRM^{4^{th}-Category} \leq SRM^{2^{th}-Category}$	0.667	<0.001	0.667	<0.001	0.954	<0.001
$H_a : SRM^{4^{th}-Category} \leq SRM^{1^{th}-Category}$	1.000	<0.001	1.000	<0.001	0.750	<0.001
$H_a : SRM^{3^{th}-Category} \leq SRM^{2^{th}-Category}$	0.333	0.049	0.333	0.049	0.954	<0.001
$H_a : SRM^{3^{th}-Category} \leq SRM^{1^{th}-Category}$	0.667	<0.001	0.472	0.001	0.750	<0.001
$H_a : SRM^{2^{th}-Category} \leq SRM^{1^{th}-Category}$	0.806	<0.001	0.750	<0.001	0.045	0.879
US G-SIBs - 2016						
$H_a : SRM^{4^{th}-Category} \leq SRM^{3^{th}-Category}$	0.500	0.004	0.667	<0.001	0.681	<0.001
$H_a : SRM^{4^{th}-Category} \leq SRM^{2^{th}-Category}$	0.667	<0.001	0.667	<0.001	0.667	<0.001
$H_a : SRM^{4^{th}-Category} \leq SRM^{1^{th}-Category}$	1.000	<0.001	1.000	<0.001	0.750	<0.001
$H_a : SRM^{3^{th}-Category} \leq SRM^{2^{th}-Category}$	0.333	<0.001	0.333	<0.001	0.667	<0.001
$H_a : SRM^{3^{th}-Category} \leq SRM^{1^{th}-Category}$	0.667	<0.001	0.667	<0.001	0.750	<0.001
$H_a : SRM^{2^{th}-Category} \leq SRM^{1^{th}-Category}$	1.000	<0.001	0.500	<0.001	0.500	<0.001
EU G-SIBs - 2015						
$H_a : SRM^{3^{th}-Category} \leq SRM^{2^{th}-Category}$	0.667	<0.001	0.667	<0.001	0.667	<0.001
$H_a : SRM^{3^{th}-Category} \leq SRM^{1^{th}-Category}$	0.524	<0.001	0.524	<0.001	0.740	<0.001
$H_a : SRM^{2^{th}-Category} \leq SRM^{1^{th}-Category}$	0.714	<0.001	0.714	<0.001	1.000	<0.001
EU G-SIBs - 2016						
$H_a : SRM^{3^{th}-Category} \leq SRM^{2^{th}-Category}$	0.667	<0.001	0.667	<0.001	1.000	<0.001
$H_a : SRM^{3^{th}-Category} \leq SRM^{1^{th}-Category}$	0.654	<0.001	0.524	<0.001	1.000	<0.001
$H_a : SRM^{2^{th}-Category} \leq SRM^{1^{th}-Category}$	0.714	<0.001	0.857	<0.001	1.000	<0.001

Table: Wilcoxon signed rank sum test for the G-SIBs in the U.S. during the main volatile events of 2015 and 2016.

	$\Delta CoVaR_{99^{th}}$		MES		SRISK	
	Z	p-value	Z	p-value	Z	p-value
Chinese Market Crash 2015:						
$H_a : SRM^{BAC:US}_{t:t+h} \leq SRM^{BAC:US}_{t-h:t-1}$	-4.009	<0.001	-4.475	<0.001	-4.009	<0.001
$H_a : SRM^{BK:US}_{t:t+h} \leq SRM^{BK:US}_{t-h:t-1}$	-4.009	<0.001	-4.475	<0.001	-4.009	<0.001
$H_a : SRM^{C:US}_{t:t+h} \leq SRM^{C:US}_{t-h:t-1}$	-4.009	<0.001	-4.235	<0.001	-4.009	<0.001
$H_a : SRM^{DB:US}_{t:t+h} \leq SRM^{DB:US}_{t-h:t-1}$	-4.009	<0.001	-1.837	0.066	-4.009	<0.001
$H_a : SRM^{GS:US}_{t:t+h} \leq SRM^{GS:US}_{t-h:t-1}$	-4.009	<0.001	-4.475	<0.001	-4.009	<0.001
$H_a : SRM^{HSBC:US}_{t:t+h} \leq SRM^{HSBC:US}_{t-h:t-1}$	-4.009	<0.001	-4.475	<0.001	-4.009	<0.001
$H_a : SRM^{JPM:US}_{t:t+h} \leq SRM^{JPM:US}_{t-h:t-1}$	-4.009	<0.001	-4.475	<0.001	-4.009	<0.001
$H_a : SRM^{MS:US}_{t:t+h} \leq SRM^{MS:US}_{t-h:t-1}$	-4.009	<0.001	-4.235	<0.001	-4.009	<0.001
$H_a : SRM^{MTU:US}_{t:t+h} \leq SRM^{MTU:US}_{t-h:t-1}$	-4.009	<0.001	-4.475	<0.001	-4.009	<0.001
$H_a : SRM^{SAN:US}_{t:t+h} \leq SRM^{SAN:US}_{t-h:t-1}$	-4.009	<0.001	0.000	1.000	-4.009	<0.001
$H_a : SRM^{STT:US}_{t:t+h} \leq SRM^{STT:US}_{t-h:t-1}$	-4.009	<0.001	-4.475	<0.001	-4.009	<0.001
$H_a : SRM^{WFC:US}_{t:t+h} \leq SRM^{WFC:US}_{t-h:t-1}$	-4.009	<0.001	-4.475	<0.001	0.000	1.000

Table: Wilcoxon signed rank sum test for the G-SIBs in the European zone during the main volatile events of 2015 and 2016.

	$\Delta CoVaR_{99^{th}}$		MES		SRISK	
	Z	p-value	Z	p-value	Z	p-value
Chinese Market Crash 2015:						
$H_a: SRM^{ACA:FP}_{t:t+h} \leq SRM^{ACA:FP}_{t-h:t-1}$	-3.741	<0.001	0.000	1.000	-4.009	<0.001
$H_a: SRM^{BARC:LN}_{t:t+h} \leq SRM^{BARC:LN}_{t-h:t-1}$	0.000	1.000	-4.475	<0.001	-4.009	<0.001
$H_a: SRM^{BNP:FP}_{t:t+h} \leq SRM^{BNP:FP}_{t-h:t-1}$	-1.009	0.313	-0.415	0.678	-4.009	<0.001
$H_a: SRM^{DBK:GR}_{t:t+h} \leq SRM^{DBK:GR}_{t-h:t-1}$	-2.062	0.039	-3.731	<0.001	-4.009	<0.001
$H_a: SRM^{GLE:FP}_{t:t+h} \leq SRM^{GLE:FP}_{t-h:t-1}$	-3.842	<0.001	-4.235	<0.001	-4.009	<0.001
$H_a: SRM^{HSBA:LN}_{t:t+h} \leq SRM^{HSBA:LN}_{t-h:t-1}$	-3.741	<0.001	-4.475	<0.001	-4.009	<0.001
$H_a: SRM^{INGA:NA}_{t:t+h} \leq SRM^{INGA:NA}_{t-h:t-1}$	-3.842	<0.001	-3.278	0.001	-4.009	<0.001
$H_a: SRM^{NDA:SS}_{t:t+h} \leq SRM^{NDA:SS}_{t-h:t-1}$	-1.055	0.292	-1.468	0.142	-4.009	<0.001
$H_a: SRM^{RBS:LN}_{t:t+h} \leq SRM^{RBS:LN}_{t-h:t-1}$	-0.085	0.932	0.000	1.000	-4.009	<0.001
$H_a: SRM^{SAN:SM}_{t:t+h} \leq SRM^{SAN:SM}_{t-h:t-1}$	-3.741	<0.001	0.000	1.000	-4.009	<0.001
$H_a: SRM^{UCG:IM}_{t:t+h} \leq SRM^{UCG:IM}_{t-h:t-1}$	-0.168	0.866	0.000	1.000	-2.640	0.008

Table: Wilcoxon signed rank sum test for the G-SIBs in the U.S. during the main volatile events of 2015 and 2016.

	$\Delta CoVaR_{99^{th}}$		MES		SRISK	
	Z	p-value	Z	p-value	Z	p-value
BREXIT 2016:						
$H_a : SRM^{BAC:US}_{t:t+h} \leq SRM^{BAC:US}_{t-h:t-1}$	-3.427	<0.001	-2.341	0.019	-4.009	<0.001
$H_a : SRM^{BK:US}_{t:t+h} \leq SRM^{BK:US}_{t-h:t-1}$	-3.170	0.002	-4.475	<0.001	-4.009	<0.001
$H_0 : SRM^{C:US}_{t:t+h} \leq SRM^{C:US}_{t-h:t-1}$	-3.523	<0.001	-2.428	0.015	-4.009	<0.001
$H_a : SRM^{DB:US}_{t:t+h} \leq SRM^{DB:US}_{t-h:t-1}$	-2.784	0.005	-2.298	0.022	-4.009	<0.001
$H_a : SRM^{GS:US}_{t:t+h} \leq SRM^{GS:US}_{t-h:t-1}$	-3.611	<0.001	-1.505	0.132	-2.184	0.029
$H_a : SRM^{HSBC:US}_{t:t+h} \leq SRM^{HSBC:US}_{t-h:t-1}$	-3.741	<0.001	-4.621	<0.001	-4.009	<0.001
$H_a : SRM^{JPM:US}_{t:t+h} \leq SRM^{JPM:US}_{t-h:t-1}$	-3.741	<0.001	-3.194	0.001	-4.009	<0.001
$H_a : SRM^{MS:US}_{t:t+h} \leq SRM^{MS:US}_{t-h:t-1}$	-3.741	<0.001	-3.707	<0.001	-4.009	<0.001
$H_a : SRM^{MTU:US}_{t:t+h} \leq SRM^{MTU:US}_{t-h:t-1}$	-3.611	<0.001	-2.320	0.020	-4.009	<0.001
$H_a : SRM^{SAN:US}_{t:t+h} \leq SRM^{SAN:US}_{t-h:t-1}$	-2.309	0.021	-4.475	<0.001	-4.009	<0.001
$H_a : SRM^{STT:US}_{t:t+h} \leq SRM^{STT:US}_{t-h:t-1}$	-1.499	0.134	-3.902	<0.001	-4.009	<0.001
$H_a : SRM^{WFC:US}_{t:t+h} \leq SRM^{WFC:US}_{t-h:t-1}$	-3.335	0.001	-0.219	0.827	-2.184	0.029

Table: Wilcoxon signed rank sum test for the G-SIBs in the Eurozone during the main volatile events of 2015 and 2016.

	$\Delta CoVaR_{99^{th}}$		MES		SRISK	
	Z	p-value	Z	p-value	Z	p-value
BREXIT 2016:						
$H_a: SRM^{ACA:FP}_{t:t+h} \leq SRM^{ACA:FP}_{t-h:t-1}$	-4.009	<0.001	-3.731	<0.001	-4.009	<0.001
$H_a: SRM^{BARC:LN}_{t:t+h} \leq SRM^{BARC:LN}_{t-h:t-1}$	-0.002	0.998	-4.475	<0.001	-4.009	<0.001
$H_a: SRM^{BNP:FP}_{t:t+h} \leq SRM^{BNP:FP}_{t-h:t-1}$	-4.009	<0.001	-4.118	<0.001	-4.009	<0.001
$H_a: SRM^{DBK:GR}_{t:t+h} \leq SRM^{DBK:GR}_{t-h:t-1}$	-4.009	<0.001	-0.001	0.999	-4.009	<0.001
$H_a: SRM^{GLE:FP}_{t:t+h} \leq SRM^{GLE:FP}_{t-h:t-1}$	-3.088	0.002	-3.463	0.001	-4.009	<0.001
$H_a: SRM^{HSBA:LN}_{t:t+h} \leq SRM^{HSBA:LN}_{t-h:t-1}$	-4.009	<0.001	-4.475	<0.001	-4.009	<0.001
$H_a: SRM^{ING A:NA}_{t:t+h} \leq SRM^{ING A:NA}_{t-h:t-1}$	-4.009	<0.001	-4.040	<0.001	-4.009	<0.001
$H_a: SRM^{NDA:SS}_{t:t+h} \leq SRM^{NDA:SS}_{t-h:t-1}$	-2.438	0.015	-3.956	<0.001	-4.009	<0.001
$H_a: SRM^{RBS:LN}_{t:t+h} \leq SRM^{RBS:LN}_{t-h:t-1}$	-3.335	0.001	-3.218	0.001	-0.002	0.998
$H_a: SRM^{SAN:SM}_{t:t+h} \leq SRM^{SAN:SM}_{t-h:t-1}$	-3.842	<0.001	-2.882	0.004	-4.009	<0.001
$H_a: SRM^{UCG:IM}_{t:t+h} \leq SRM^{UCG:IM}_{t-h:t-1}$	-0.346	0.729	-1.024	0.306	-4.009	<0.001

Table: Wilcoxon signed rank sum test for the G-SIBs in the U.S. during US Presidential Election of 2016.

	$\Delta CoVaR_{99^{th}}$		MES		SRISK	
	Z	p-value	Z	p-value	Z	p-value
U.S. Presidential Election 2016:						
$H_a: SRM^{BAC:US}_{t:t+h} \leq SRM^{BAC:US}_{t-h:t-1}$	-4.009	<0.001	-4.621	<0.001	0.000	1.000
$H_a: SRM^{BK:US}_{t:t+h} \leq SRM^{BK:US}_{t-h:t-1}$	-2.640	0.008	-4.621	<0.001	0.000	1.000
$H_a: SRM^{C:US}_{t:t+h} \leq SRM^{C:US}_{t-h:t-1}$	-3.523	<0.001	-3.874	<0.001	0.000	1.000
$H_a: SRM^{DB:US}_{t:t+h} \leq SRM^{DB:US}_{t-h:t-1}$	-4.009	<0.001	-4.621	<0.001	0.000	1.000
$H_a: SRM^{GS:US}_{t:t+h} \leq SRM^{GS:US}_{t-h:t-1}$	-4.009	<0.001	-3.874	<0.001	0.000	1.000
$H_a: SRM^{HSBC:US}_{t:t+h} \leq SRM^{HSBC:US}_{t-h:t-1}$	-2.857	0.004	-4.621	<0.001	0.000	1.000
$H_a: SRM^{JPM:US}_{t:t+h} \leq SRM^{JPM:US}_{t-h:t-1}$	-2.857	0.004	-4.621	<0.001	0.000	1.000
$H_a: SRM^{MS:US}_{t:t+h} \leq SRM^{MS:US}_{t-h:t-1}$	-3.427	0.001	-4.621	<0.001	0.000	1.000
$H_a: SRM^{MTU:US}_{t:t+h} \leq SRM^{MTU:US}_{t-h:t-1}$	-4.009	<0.001	-4.621	<0.001	0.000	1.000
$H_a: SRM^{SAN:US}_{t:t+h} \leq SRM^{SAN:US}_{t-h:t-1}$	-0.346	0.729	-0.140	0.889	-0.168	0.866
$H_a: SRM^{STT:US}_{t:t+h} \leq SRM^{STT:US}_{t-h:t-1}$	-1.101	0.271	-4.621	<0.001	0.000	1.000
$H_a: SRM^{WFC:US}_{t:t+h} \leq SRM^{WFC:US}_{t-h:t-1}$	-3.335	0.001	-4.621	<0.001	0.000	1.000

Table: Wilcoxon signed rank sum test for the G-SIBs in the Eurozone during US Presidential Election of 2016.

	$\Delta CoVaR_{99^{th}}$		MES		SRISK	
	Z	p-value	Z	p-value	Z	p-value
U.S. Presidential Election 2016:						
$H_a: SRM^{ACA:FP}_{t:t+h} \leq SRM^{ACA:FP}_{t-h:t-1}$	-4.009	<0.001	-4.475	<0.001	0.000	1.000
$H_a: SRM^{BARC:LN}_{t:t+h} \leq SRM^{BARC:LN}_{t-h:t-1}$	-4.009	<0.001	-4.475	<0.001	0.000	1.000
$H_a: SRM^{BNP:FP}_{t:t+h} \leq SRM^{BNP:FP}_{t-h:t-1}$	-1.827	0.068	-4.475	<0.001	0.000	1.000
$H_a: SRM^{DBK:GR}_{t:t+h} \leq SRM^{DBK:GR}_{t-h:t-1}$	-2.504	0.012	-4.475	<0.001	0.000	1.000
$H_a: SRM^{GLE:FP}_{t:t+h} \leq SRM^{GLE:FP}_{t-h:t-1}$	-2.002	0.045	-4.475	<0.001	0.000	1.000
$H_a: SRM^{HSBA:LN}_{t:t+h} \leq SRM^{HSBA:LN}_{t-h:t-1}$	-2.373	0.018	-4.475	<0.001	0.000	1.000
$H_a: SRM^{INGA:NA}_{t:t+h} \leq SRM^{INGA:NA}_{t-h:t-1}$	-3.335	0.001	-4.475	<0.001	0.000	1.000
$H_a: SRM^{NDA:SS}_{t:t+h} \leq SRM^{NDA:SS}_{t-h:t-1}$	-2.857	0.004	-4.475	<0.001	0.000	1.000
$H_a: SRM^{RBS:LN}_{t:t+h} \leq SRM^{RBS:LN}_{t-h:t-1}$	0.000	1.000	0.000	1.000	-4.009	<0.001
$H_a: SRM^{SAN:SM}_{t:t+h} \leq SRM^{SAN:SM}_{t-h:t-1}$	-0.793	0.428	-0.291	0.771	-1.009	0.313
$H_a: SRM^{UCG:IM}_{t:t+h} \leq SRM^{UCG:IM}_{t-h:t-1}$	-0.004	0.997	-0.001	0.999	-1.827	0.068

Table: Ranking of the G-SIBs in the U.S. as of November 2015 and 2016.

$\Delta CoVaR_{99th}$				MES				SRISK			
Nov. 2015		Nov. 2016		Nov. 2015		Nov. 2016		Nov. 2015		Nov. 2016	
Institution		Institution		Institution		Institution		Institution		Institution	Rank
WFC:US	1.	WFC:US	1.	WFC:US	1.	JPM:US	1.	MTU:US	1.	MTU:US	1.
JPM:US	2.	JPM:US	2.	JPM:US	2.	BAC:US		DB:US	2.	DB:US	2.
BAC:US	3.	BAC:US	3.	BAC:US	3.	C:US	2.	HSBC:US	3.	HSBC:US	3.
C:US	4.	HSBC:US	4.	C:US	4.	WFC:US	3.	SAN:US	4.	BAC:US	4.
HSBC:US		C:US	5.	SAN:US	5.	HSBC:US	4.	BAC:US	5.	C:US	5.
GS:US	5.	GS:US	6.	HSBC:US	6.	SAN:US	5.	JPM:US	6.	SAN:US	6.
MTU:US		MTU:US		GS:US	7.	MS:US	6.	C:US	7.	JPM:US	7.
SAN:US		SAN:US	7.	MTU:US	8.	MTU:US	7.	MS:US	8.	MS:US	8.
MS:US	6.	MS:US	8.	MS:US	9.	GS:US	8.	GS:US	9.	GS:US	9.
BK:US	7.	BK:US	9.	DB:US	10.	BK:US	9.	WFC:US	10.	WFC:US	10.
DB:US	8.	DB:US	10.	BK:US	11.	DB:US	10.	BK:US	11.	STT:US	11.
STT:US	9.	STT:US	11.	STT:US	12.	STT:US	11.	STT:US	12.	BK:US	12.

Table: Ranking of the G-SIBs in the Eurozone as of November 2015 and 2016.

$\Delta CoVaR_{99th}$				MES				SRISK			
Nov. 2015		Nov. 2016		Nov. 2015		Nov. 2016		Nov. 2015		Nov. 2016	
Institution		Institution		Institution		Institution		Institution		Institution	Rank
HSBA:LN	1.	HSBA:LN	1.	SAN:SM	1.	HSBA:LN	1.	BNP:FE	1.	BNP:FE	1.
SAN:SM	2.	BNP:FE	2.	HSBA:LN	2.	SAN:SM	2.	DBK:GR	2.	DBK:GR	2.
BNP:FE	3.	BARC:LN	3.	BNP:FE	3.	BNP:FE	3.	BARC:LN	3.	HSBA:LN	3.
INGA:NA	4.	SAN:SM	4.	INGA:NA	4.	BARC:LN	4.	ACA:FE	4.	BARC:LN	4.
BARC:LN	5.	INGA:NA	5.	BARC:LN	5.	INGA:NA	5.	HSBA:LN	5.	ACA:FE	5.
NDA:SS	6.	NDA:SS	6.	UCG:IM	6.	GLE:FE	6.	RBS:LN		GLE:FE	6.
DBK:GR	7.	RBS:LN	7.	GLE:FE	7.	RBS:LN	7.	GLE:FE	6.	SAN:SM	7.
GLE:FE		GLE:FE	8.	DBK:GR		ACA:FE	8.	SAN:SM	7.	RBS:LN	8.
ACA:FE	8.	DBK:GR	9.	ACA:FE	8.	NDA:SS	9.	INGA:NA	8.	UCG:IM	9.
UCG:IM		ACA:FE	10.	NDA:SS	9.	UCG:IM	10.	NDA:SS	9.	INGA:NA	10.
RBS:LN	9.	UCG:IM	11.	RBS:LN	10.	DBK:GR	11.	UCG:IM	10.	NDA:SS	11.

Figure: Bootstrap distribution of the $\Delta CoVaR_{99th}$ for the US BHCs.

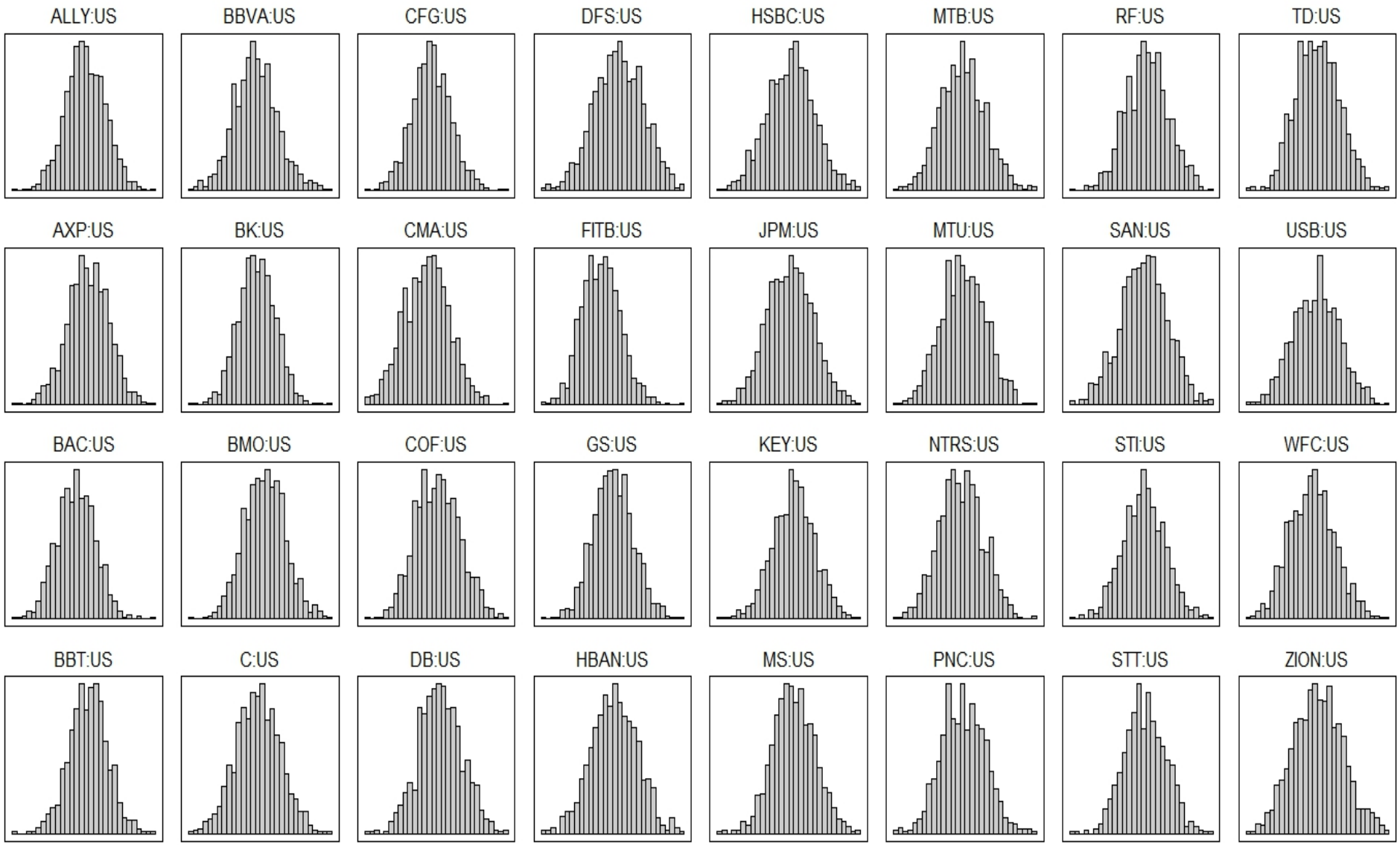

Figure: Bootstrap distribution of the $\Delta CoVaR_{99th}$ for the European banks.

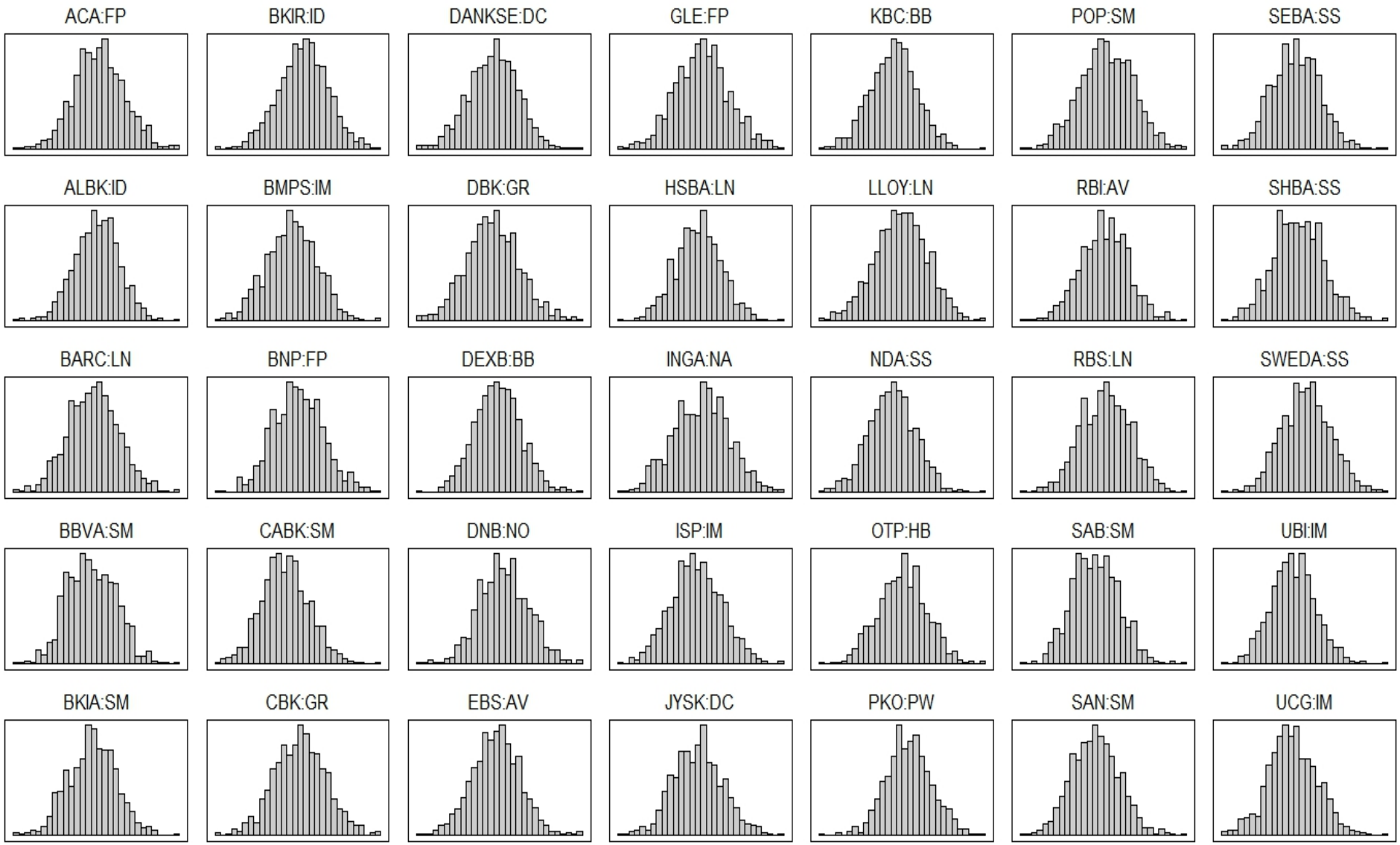

Figure: Confidence intervals 95% of the $\Delta CoVaR_{99th}$ for the US BHCs.

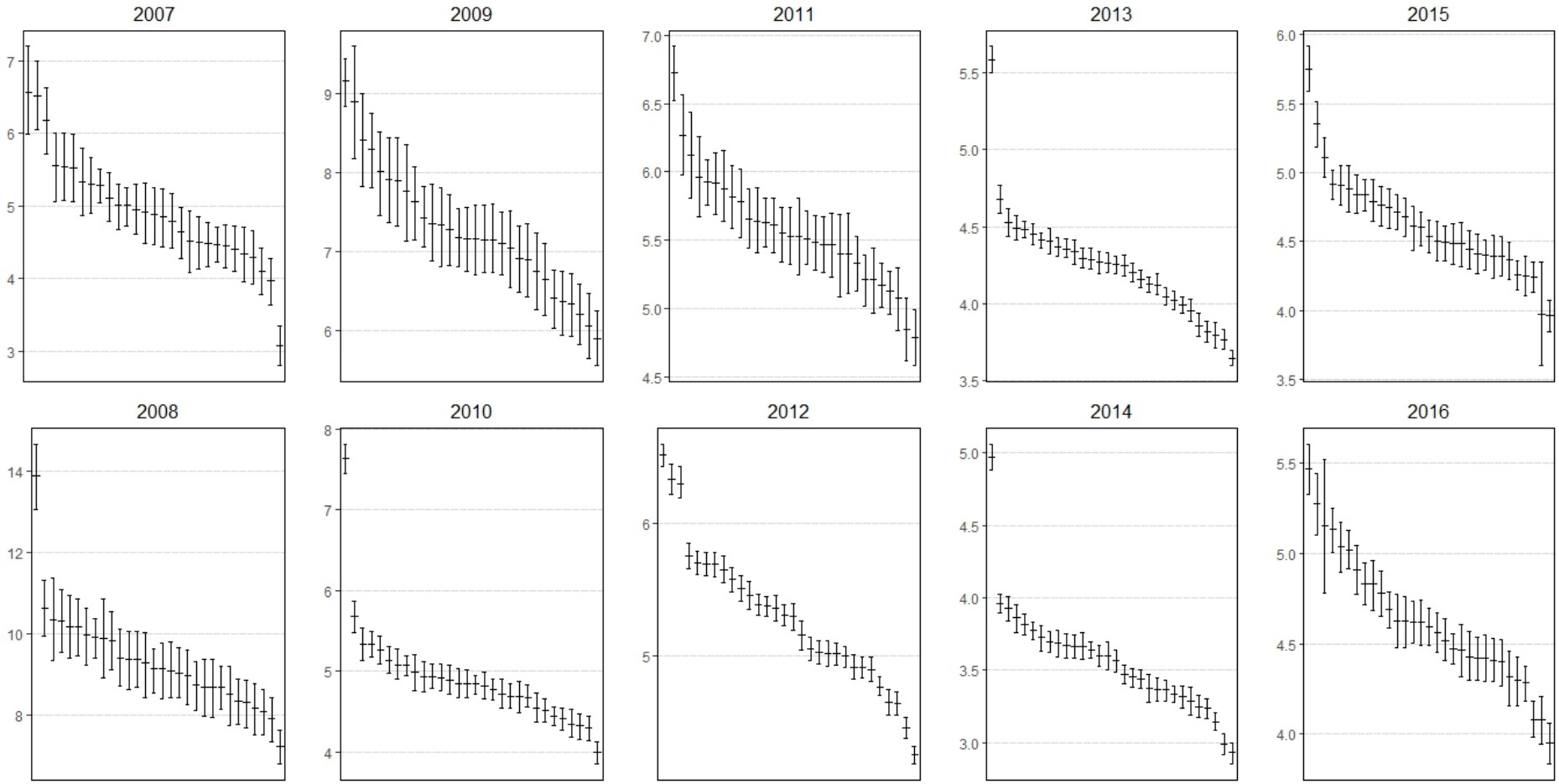

Figure: Confidence intervals 95% of the $\Delta CoVaR_{99th}$ for the European large banks.

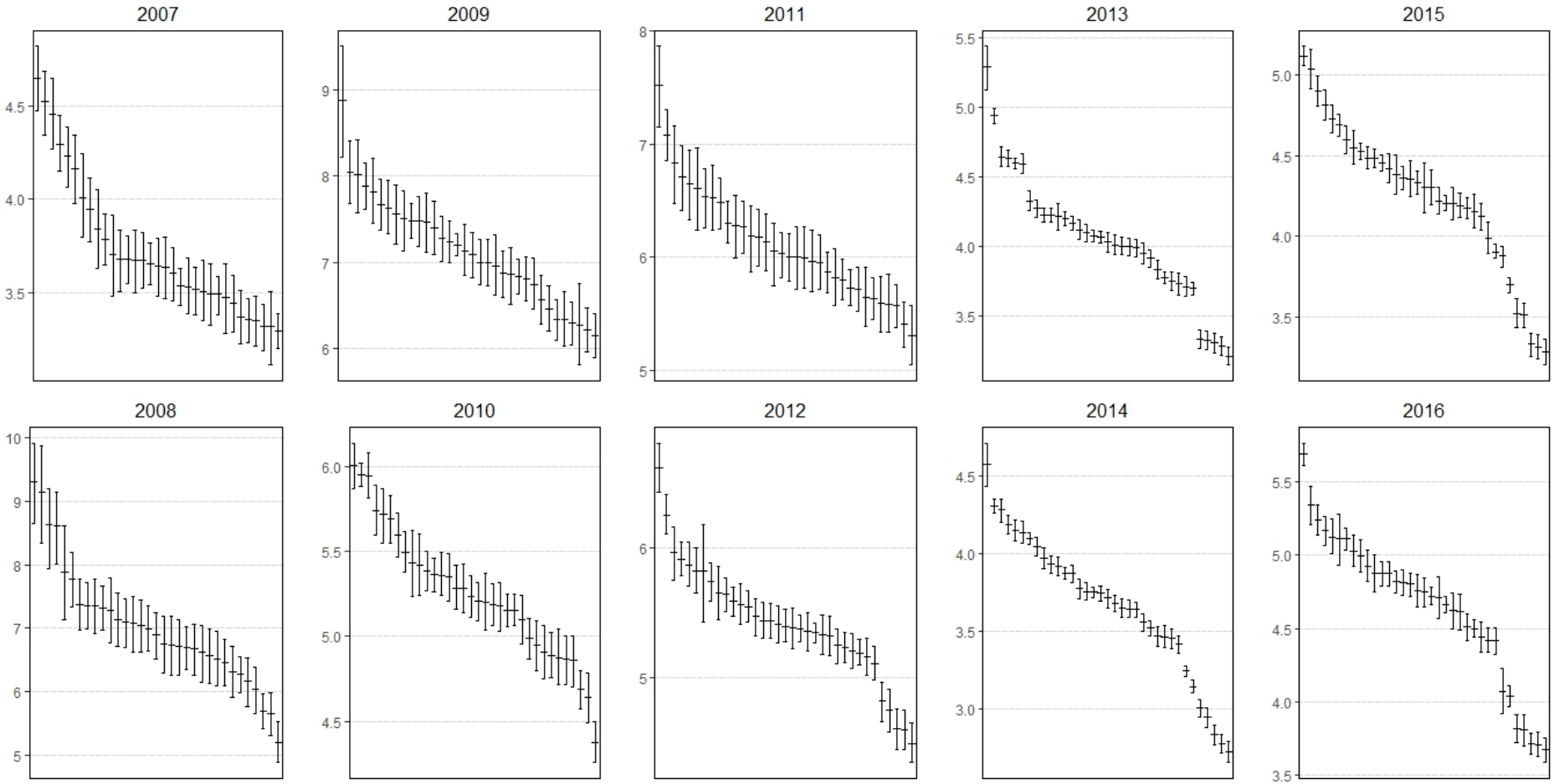

Table: Number of overlapping confidence intervals over the period from 2007 to 2016.

	Panel A: US-BHCs						Panel B: EU-Banks					
	All BHCs			G-SIBs			All Banks			G-SIBs		
Year	N	n	%	N	n	%	N	n	%	N	n	%
2007	29	26	89.66%	12	7	58.33%	33	31	93.94%	11	8	72.73%
2008	30	27	90.00%	12	8	66.67%	33	29	87.88%	11	8	72.73%
2009	30	29	96.67%	12	9	75.00%	34	32	94.12%	11	6	54.55%
2010	30	26	86.67%	12	6	50.00%	34	30	88.24%	11	7	63.64%
2011	30	28	93.33%	12	8	66.67%	34	32	94.12%	11	7	63.64%
2012	30	21	70.00%	12	7	58.33%	35	31	88.57%	11	7	63.64%
2013	30	24	80.00%	12	9	75.00%	35	26	74.29%	11	6	54.55%
2014	30	25	83.33%	12	8	66.67%	35	22	62.86%	11	6	54.55%
2015	31	26	83.87%	12	8	66.67%	35	26	74.29%	11	5	45.45%
2016	31	27	87.10%	12	8	66.67%	35	28	80.00%	11	5	45.45%

Conclusion

- Our results on systemic risk measurement reveal that the information provided by $\Delta CoVaR$, MES and SRISK is heterogeneous.
- The SRMs do not reach their peak during the same period, suggesting that systemic risk assessments based on a single measure may lead to contradictory assessments.
- The G-SIBs as identified by the FSB contribute more than the other banks in the banking sector to the overall systemic risk.
- The Wilcoxon signed rank sum test shows a significant increase of the systemic risk for most of the G-SIBs during high volatile periods.
- The ranking obtained using the bootstrap KS test does not indicate the same systemic categories as those on the FSB list.
- The risk of the G-SIBs can be different within same risk category at 1% critical level. Moreover, different SRMs may rank the G-SIBs differently.
- Our new approach emphasizes the possibility of the employing market-based SRMs in order to identify and rank SIFIs.
- Regulators could use SRMs estimates and their confidence intervals to monitor and regulate the SIFIs.

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Table: Results of the panel regression analyses of individual systemic risk measures on bank specific characteristics for the US bank holding companies. The systemic risk measures are computed over the period from 2007 Q3 to 2009 Q3. The predictors are measured during the period form 2005 Q2 to 2007 Q2.

	$\Delta^{\$} CoVaR_{99th}$			$MES^{\$}$			SRISK		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Total assets	274.48**	271.48**	288.43**	154.11*	198.58**	169.71**	2,521.31	4,748.70*	
	2.03	2.01	1.98	1.69	2.15	1.87	0.97	1.79	
Book lev. Ratio			2,499.01		6,470.34			358,686.80**	
			0.25		1.28			2.10	
P/B ratio	-734.27***	-871.04***	-696.56**	-415.15**	-268.45*	-391.70**			-11,306.35**
	-2.89	-2.98	-2.34	-2.42	-1.64	-2.01			-2.03
Market lev. Ratio		45.72				21.07	2,867.85***		2,053.30**
		0.96				0.68	3.43		2.27
Bank stock returns			554.30			-355.99			-24,374.97
			0.19			-0.18			-0.42
ROA	768.93**	665.53**	698.59	346.51			-3,339.00	-21,583.21	
	2.32	1.91	1.60	1.55			-0.48	-3.01	
RWA/TA	3,087.30***	2,585.83**	3,024.74**	2,215.17***	2,282.02***	2,439.12***	137,109.05***	99,177.60***	110,935.86***
	2.59	1.99	2.47	2.76	2.81	2.86	5.75	4.04	5.20
TIER 1 Ratio	409.80***	385.55***	411.10***	266.78***	277.83***	271.53***	10,445.99***	8,953.39***	9,797.97***
	3.71	3.40	3.72	3.59	3.77	3.56	4.61	4.03	4.80
Loans/TA	1,634.81	1,576.02	1,665.80	1,325.95*	1,373.26**	1,280.92*	41,936.73***	41,397.80***	40,040.63***
	1.57	1.51	1.59	1.89	1.95	1.82	2.01	1.97	1.92
Constant	-6,901.81**	-5,476.40*	-7,247.71**	-4,471.48**	-5,568.15***	-4,285.26*	-222,512.40***	-191,571.88***	-138,980.84***
	-2.38	-1.68	-2.28	-2.28	-2.83	-1.94	-3.93	-3.43	-3.94
Adj. R^2 (%)	10.67	10.65	10.34	11.11	10.98	10.61	17.26	16.10	0.1777
No. obs.	530	530	530	530	530	530	530	530	530

Table: Results of the panel regression analyses of individual systemic risk measures on bank specific characteristics for the European banks. The systemic risk measures are computed over the period from 2007 Q3 to 2009 Q3. The predictors are measured during the period form 2005 Q2 to 2007 Q2.

	$\Delta^{\$} CoVaR_{99th}$			$MES^{\$}$			SRISK		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Total assets	234.86***	231.49***	226.82***	235.62***	237.56***	221.13***	-191.26	-2,422.43	
	3.26	3.14	3.15	4.00	3.93	3.65	-0.08	-0.90	
Book lev. Ratio	22,320.87***		21,577.75***	24,598.78***				-74,171.04	
	5.39		5.29	5.44				-0.41	
P/B ratio	101.50	-95.00		278.42***	37.24	99.66			10,207.11***
	0.99	-0.81		2.65	0.39	1.07			2.65
Market lev. Ratio		13.51			18.29**	8.47	3,881.66***		3,951.09***
		1.15			1.90	0.95	9.97		10.68
Bank stock returns			-52.39			-172.54			29,343.90
			-0.05			-0.21			0.87
ROA		713.64***		-484.40**	485.60**		14,375.57	-22,272.11***	
		3.08		-2.11	2.55		1.86	-2.65	
RWA/TA	-3,292.27***	-2,747.83***	-3,241.70***	-2,475.63***	-1,953.04***	-1,760.67***	1,291.20	-29,143.53*	10,782.86
	-6.92	-5.59	-6.85	-6.32	-4.84	-4.42	0.08	-1.62	0.65
TIER 1 Ratio	-124.07**	-38.27	-101.82**	-108.14**	-28.71	10.53	3,464.28**	4,572.21**	3,523.19**
	-2.29	-0.74	-2.06	-2.44	-0.68	0.27	1.99	2.37	2.30
Loans/TA	1,625.79**	2,284.92***	1,773.05***	1,045.19**	1,750.98***	1,785.79***	-22,099.20	-71,512.98***	-24,404.54
	2.43	3.35	2.71	1.91	3.13	3.16	-0.94	-2.90	-1.26
Constant	-1,257.69	-1,925.38	-1,192.88	-1,630.38	-2,423.07**	-2,210.49*	-40,920.16	111,033.87**	-57,650.31***
	-0.96	-1.35	-0.90	-1.52	-2.08	-1.87	-0.85	2.26	-3.04
Adj. R^2(%)	10.12	7.35	9.99	11.85	8.40	7.50	30.48	20.03	30.93
No. obs.	667	667	667	667	667	667	667	667	667

Table: Results of the panel regression analyses of individual systemic risk measures on bank specific characteristics for the US bank holding companies. The systemic risk measures are computed over the period from 2010 Q3 to 2012 Q3. The predictors are measured during the period form 2008 Q2 to 2010 Q2.

	$\Delta^{\$} CoVaR_{99th}$			$MES^{\$}$			SRISK		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Total assets	227.63***	220.27***	134.18**	443.70***	284.04**	360.90***			-2,465.04
	3.99	3.85	2.11	4.27	2.55	3.57			-0.94
Book lev. Ratio			-8,361.07***		-10,428.19**			-301,269.16***	-345,209.51***
			-3.31		-2.35			-3.26	-3.33
P/B ratio	-110.57	-44.72	-172.92	-827.34***	-1,124.56***	-638.48***	-19,614.80***	-25,014.44***	-26,711.08***
	-0.99	-0.37	-1.53	-4.07	-6.37	-3.16	-4.15	-5.86	-5.76
Market lev. Ratio		4.24				25.01***	314.15***		
		1.45				4.65	2.62		
Bank stock returns			-198.12			703.12			
			-0.82			1.54			
ROA	-180.58***	-166.10***	-135.05***	-240.24***			8,436.70***	8,550.82***	9,106.49***
	-3.77	-3.39	-2.73	-2.75			4.29	4.38	4.46
RWA/TA	2,820.80***	2,855.75***	3,127.04***	4,297.77***	4,607.64***	4,438.87***	74,088.52***	86,377.73***	85,293.92***
	9.45	9.54	10.08	7.90	8.08	8.22	6.23	6.79	6.68
TIER 1 Ratio	26.54	35.92	31.47	171.05***	182.09***	224.77***	3,060.24***	3,293.64***	2,734.54**
	0.82	1.09	0.98	2.90	3.09	3.79	2.59	2.79	2.07
Loans/TA	-1,497.69***	-1,372.01***	-1,639.49***	-1,655.56**	-1,802.75**	-933.03	-32,558.83**	-37,378.84**	-45,247.10**
	-3.38	-3.04	-3.71	-2.05	-2.22	-1.15	-1.95	-2.31	-2.49
Constant	-2,634.56**	-2,891.79**	-945.44	-6,185.24***	-3,319.23	-6,913.01***	-13,106.45	13,372.81	60,754.49
	-2.22	-2.41	-0.73	-2.86	-1.44	-3.22	-0.63	0.77	1.14
Adj. R^2 (%)	14.37	14.51	15.69	16.69	16.43	18.33	10.81	11.31	11.30
No. obs.	656	656	656	656	656	656	656	656	656

Table: The results of the panel regression analyses of individual systemic risk measures on bank specific characteristics for the European banks. The systemic risk measures are computed over the period from 2010 Q3 to 2012 Q3. The predictors are measured during the period form 2008 Q2 to 2010 Q2.

	$\Delta^{\$} CoVaR_{99th}$			$MES^{\$}$			SRISK		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Total assets	139.60***	138.88***	135.08***	151.48***	136.97***	123.67***	8,164.46***	8,152.51***	
	3.13	3.12	3.01	3.55	3.22	2.91	4.18	4.14	
Book lev. Ratio	6,649.37***		7,480.88***	10,102.80***				12,990.55	
	3.05		3.45	4.48				0.13	
P/B ratio	209.63***	42.35		270.62***	112.54	237.10***			10,476.11***
	2.71	0.43		2.98	1.19	2.88			2.74
Market lev. Ratio		-1.15*			-2.62***	-2.98***	-70.28**		-59.59**
		-1.73			-4.13	-4.43	-2.52		-1.92
Bank stock returns			79.67			-87.01			10,040.15
			0.52			-0.56			1.40
ROA		164.77**		85.98	169.02***		10,363.74***	12,394.31***	
		2.50		1.27	2.69		4.20	4.89	
RWA/TA	-2,025.15***	-1,527.20***	-1,908.82***	-2,185.34***	-1,356.58***	-1,268.87***	-62,213.41***	-61,989.33***	-79,605.60***
	-5.57	-4.90	-5.26	-6.25	-4.55	-4.25	-4.58	-3.89	-6.25
TIER 1 Ratio	-14.53	2.89	-1.70	-31.40	-10.15	-15.18	130.80	136.46	-2,024.58**
	-0.68	0.13	-0.08	-1.52	-0.49	-0.73	0.15	0.15	-2.26
Loans/TA	305.71	273.86	229.64	-333.16	-375.22	-344.20	-38,225.76***	-36,914.32**	-60,414.46***
	0.91	0.82	0.68	-1.04	-1.17	-1.07	-2.60	-2.50	-4.54
Constant	-578.44	-488.32	-507.48	-250.08	93.96	224.90	-13,162.85	-18,737.24	127,161.25***
	-0.70	-0.59	-0.61	-0.32	0.12	0.28	-0.36	-0.51	11.74
Adj. R^2 (%)	12.88	12.91	12.06	18.39	18.07	17.31	25.39	24.76	23.15
No. obs.	759	759	759	759	759	759	759	759	759

Capital ratio calculations

- The adjusted market value (Adj. MV) is the market value of equity after the capital shortfall, estimated as $MV \times (1 - SRM(\%))$.
- We consider different benchmark capital ratio of market equity to total assets (MV/TA)
- The average MV/TA ratio was: 8.37 and 7.62 for the G-SIBs in the US; 3.98 and 3.29 for the G-SIBs in Europe, as of Nov. 2015 and 2016, respectively.
- Our scenarios include a ratio of 4%, 6%, 8%, 10% and 12%. If the banks have a ratio above these benchmarks, they experience a capital surplus. It means that they are not required to raise capital after the capital shortfall.
- In case of capital shortfall, the G-SIBs in Europe are more undercapitalized than the ones in the US. This may explain the difference between the stress test exercises run by the FED and the EBA.
- The US BHCs have to satisfy the capital requirements under most severe scenarios, compared to the European one. Moreover, even considering capital constrain results, the EU-Wide Stress Test does not contain a pass or fail threshold, and, its consequences are not rigorous.

Table: Total shortfall risk of the US BHCs classified as G-SIBs, as of November 2015.

		Benchmark MV/TA Ratios				
US G-SIBs	Adj. MV	4%	6%	8%	10%	12%
$\Delta CoVaR_{99}$						
BAC	169,710	0	0	2,177	45,149	88,121
BK	44,712	0	0	0	0	1,573
C	155,563	0	0	0	21,355	56,739
DB	37,333	36,476	73,380	110,285	147,189	184,093
GS	78,781	0	0	0	8,301	25,718
HSBC	135,132	0	13,549	63,109	112,669	162,229
JPM	230,374	0	0	0	8,016	55,694
MS	62,521	0	0	2,313	18,522	34,730
MTU	89,264	8,291	57,068	105,846	154,623	203,401
SAN	76,932	0	11,001	40,312	69,623	98,934
STT	27,402	0	0	0	0	2,144
WFC	270,587	0	0	0	0	0
Total	1,378,310	44,767	154,998	324,042	585,448	913,376
MES						
BAC	169,587	0	0	2,301	45,273	88,244
BK	44,653	0	0	0	0	1,631
C	154,640	0	0	0	22,278	57,661
DB	37,136	36,673	73,577	110,482	147,386	184,290
GS	78,737	0	0	0	8,346	25,763
HSBC	135,369	0	13,311	62,871	112,432	161,992
JPM	230,568	0	0	0	7,822	55,500
MS	62,258	0	0	2,575	18,784	34,992
MTU	88,207	9,348	58,125	106,903	155,680	204,458
SAN	76,443	0	11,490	40,801	70,112	99,423
STT	27,309	0	0	0	0	2,237
WFC	270,416	0	0	0	0	0
Total	1,375,324	46,021	156,504	325,933	588,112	916,192

Note: The required capital amount that the US BHCs classified as G-SIBs have to raise in order to cover the expected capital shortfall as predicted by the $\Delta CoVaR_{99th}$, MES and SES (fitted), respectively, and to maintain a specific MV/TA ratio as benchmark, as of November 2015. The adjusted MV is calculated as $MV * (1 - SRM(\%))$. The banks are sorted by alphabetical order.

Table: Total shortfall risk of the US BHCs classified as G-SIBs, as of November 2016.

		Benchmark MV/TA Ratios				
US G-SIBs	Adj. MV	4%	6%	8%	10%	12%
$\Delta CoVaR_{99}$						
BAC	164,117	0	0	11,203	55,034	98,864
BK	44,915	0	0	0	0	0
C	137,948	0	0	6,460	42,562	78,664
DB	18,596	57,796	95,992	134,188	172,384	210,580
GS	69,955	0	0	894	18,606	36,319
HSBC	130,837	0	23,683	75,190	126,697	178,204
JPM	241,733	0	0	0	8,867	58,987
MS	61,740	0	0	3,581	19,911	36,241
MTU	71,018	38,683	93,533	148,383	203,233	258,083
SAN	67,447	0	18,415	47,035	75,656	104,277
STT	26,740	0	0	0	0	3,191
WFC	224,529	0	0	0	0	7,806
Total	1,259,574	96,479	231,623	426,934	722,949	1,071,213
MES						
BAC	160,317	0	0	15,003	58,833	102,664
BK	44,564	0	0	0	0	0
C	134,229	0	0	10,179	46,281	82,383
DB	17,914	58,478	96,673	134,869	173,065	211,261
GS	68,947	0	0	1,902	19,615	37,327
HSBC	130,234	0	24,287	75,793	127,300	178,807
JPM	239,687	0	0	0	10,913	61,033
MS	60,045	0	0	5,276	21,606	37,936
MTU	70,430	39,270	94,120	148,970	203,820	258,671
SAN	65,707	0	20,154	48,775	77,396	106,016
STT	26,307	0	0	0	0	3,623
WFC	224,982	0	0	0	0	7,352
Total	1,243,365	97,748	235,235	440,768	738,829	1,087,072

Note: The required capital amount that the US BHCs classified as G-SIBs have to raise in order to cover the expected capital shortfall as predicted by the $\Delta CoVaR_{99th}$ and MES, respectively, and to maintain a specific MV/TA ratio as benchmark, as of November 2016. The adjusted MV is calculated as $MV * (1 - SRM(\%))$. The banks are sorted by alphabetical order.

Table: Total shortfall risk of the European banks classified as G-SIBs, as of November 2015.

		Benchmark MV/TA Ratios				
US G-SIBs	Adj. MV	4%	6%	8%	10%	12%
$\Delta CoVaR_{99}$						
ACA	29,498	31,570	62,104	92,637	123,171	153,705
BARC	53,248	10,497	42,369	74,241	106,113	137,985
BNP	67,078	15,668	57,041	98,414	139,787	181,159
DB	34,148	32,766	66,223	99,680	133,136	166,593
GLE	33,237	20,481	47,341	74,200	101,059	127,918
HSBC	135,499	0	0	44,293	89,241	134,190
INGA	49,911	0	1,194	18,229	35,264	52,299
NDA	39,691	0	80	13,337	26,594	39,852
RBS	28,134	17,657	40,552	63,447	86,342	109,237
SAN	71,049	0	8,781	35,391	62,001	88,611
UCG	34,263	408	17,743	35,078	52,414	69,749
Total	575,754	129,046	343,427	648,947	955,123	1,261,298
MES						
ACA	29,383	31,684	62,218	92,752	123,286	153,819
BARC	52,738	11,006	42,878	74,750	106,622	138,494
BNP	66,290	16,456	57,829	99,201	140,574	181,947
DB	33,761	33,153	66,610	100,066	133,523	166,980
GLE	32,828	20,891	47,750	74,609	101,469	128,328
HSBC	135,202	0	0	44,591	89,539	134,487
INGA	49,178	0	1,927	18,961	35,996	53,031
NDA	39,709	0	62	13,319	26,577	39,834
RBS	27,945	17,846	40,741	63,636	86,531	109,426
SAN	69,598	0	10,232	36,842	63,452	90,062
UCG	33,526	1,145	18,480	35,816	53,151	70,486
Total	570,157	132,180	348,726	654,544	960,720	1,266,895

Note: The required capital amount that the European banks classified as G-SIBs have to raise in order to cover the expected capital shortfall as predicted by the $\Delta CoVaR_{99^{th}}$ and MES, respectively, and to maintain a specific MV/TA ratio as benchmark, as of November 2015. The adjusted MV is calculated as $MV * (1 - SRM(\%))$. The banks are sorted by alphabetical order.

Table: Total shortfall risk of the European banks classified as G-SIBs, as of November 2016.

		Benchmark MV/TA Ratios				
US G-SIBs	Adj. MV	4%	6%	8%	10%	12%
$\Delta CoVaR_{99}$						
ACA	26,385	36,523	67,977	99,431	130,885	162,340
BARC	33,860	27,672	58,438	89,204	119,970	150,736
BNP	63,941	21,076	63,584	106,093	148,601	191,109
DB	16,867	51,106	85,092	119,078	153,064	187,050
GLE	27,426	28,317	56,188	84,059	111,931	139,802
HSBC	131,404	0	6,437	52,384	98,332	144,279
INGA	44,541	0	6,927	24,084	41,240	58,396
NDA	37,029	0	1,156	13,885	26,613	39,342
RBS	23,654	15,978	35,795	55,611	75,427	95,243
SAN	61,707	0	18,353	45,040	71,726	98,413
UCG	13,399	21,283	38,623	55,964	73,304	90,645
Total	480,212	201,955	438,572	744,833	1,051,094	1,357,356
MES						
ACA	25,622	37,287	68,741	100,195	131,649	163,103
BARC	31,665	29,867	60,633	91,399	122,165	152,931
BNP	62,159	22,858	65,366	107,874	150,383	192,891
DB	16,199	51,773	85,759	119,745	153,731	187,717
GLE	25,996	29,747	57,618	85,489	113,361	141,232
HSBC	129,069	0	8,772	54,719	100,666	146,614
INGA	43,123	0	8,346	25,502	42,658	59,814
NDA	36,672	0	1,513	14,242	26,970	39,699
RBS	22,261	17,371	37,187	57,004	76,820	96,636
SAN	59,667	0	20,393	47,080	73,767	100,453
UCG	12,766	21,915	39,256	56,596	73,937	91,278
Total	465,199	202,007	453,585	759,846	1,066,108	1,372,369

Note: The required capital amount that the European banks classified as G-SIBs have to raise in order to cover the expected capital shortfall as predicted by the $\Delta CoVaR_{99^{th}}$ and MES, respectively, and to maintain a specific MV/TA ratio as benchmark, as of November 2016. The adjusted MV is calculated as $MV * (1 - SRM(\%))$. The banks are sorted by alphabetical order.