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Iseo Summer School

THE ECONOMETRIC ANALYSIS OF SYSTEMIC RISK

DEFINITION

- How much capital would a financial institution need to raise in order to function normally if we have another financial crisis?
- We measure this econometrically based on market data on equities and balance sheet data on liabilities. We update weekly on V-LAB for US and Global financial firms. We call this *SRISK*.
- Principle investigators: Viral Acharya, Matt Richardson and me at the Volatility Institute at NYU's Stern School. Collaboration with HEC Lausanne and the Institute for Global Finance at University of New South Wales. Contributions by Christian Brownlees, Rob Capellini, Diane Perriet, Emil Siriwardane.

RESEARCH ON SYSTEMIC RISK

- Regulators measure this based on supervisory data and stress scenarios.
- Many other related measures are being developed or are in use by regulators in Europe and the US.
- Some measures are firm specific such as CoVaR, and network models that trace linkages. Others are financial industry quality measures such as volatility.
- Recent surveys by Brunnermeier and Oehmke and by Bisias, Flood, Lo and Valvanis cover many measures.

SRISK

- SRISK is computed from:

$$\begin{aligned} SRISK_{i,t} &= E_{t-1}\left(Capital\ \ Shortfall_i \middle| Crisis\right) \\ &= E_{t-1}\left(k\left(Debt + Equity\right) - Equity \middle| Crisis\right) \\ &= kDebt - \left(1-k\right)\left(1 - LRMES_{i,t}\right)Equity_{i,t} \end{aligned}$$

- Where k is a prudential level of equity relative to assets taken to be 8% (and 5.5% for IFRS firms) and LRMES is the decline in equity values to be expected if there is another financial crisis.
- **SRISK depends upon size, leverage and risk.**

FOR EXAMPLE:

- Bank of America has a market cap of $114 billion. Its accounting liabilities are $1.9 trillion for a leverage ratio of 17.9
- If we have another financial crisis which is assumed to be a fall of 40% in broad US equities over six months, then we estimate shares in BAC will fall by 60%.
- This reflects a Dynamic Conditional Beta of 1.7 today that will move in the future due to mean reversion in volatilities and correlations and also will rise with downside returns.
- SRISK = $112 billion.
  - It is undercapitalized somewhat today and this will be more severe under the stress of an equity decline.

FOR EXAMPLE:

- Credit Agricole has a market cap of $19 billion
- It has liabilities of $2.1 trillion for a leverage ratio of 124
- Any fluctuation in asset or liability valuations can easily move the firm into bankruptcy.
- Most of the capital shortfall is needed to bring the leverage down now. The risk is only a small part of the capital shortfall calculation.
- Most likely, Credit Agricole is no longer making loans except possibly the most secure.

WHY IS THIS A MEASURE OF SYSTEMIC RISK?

- If we have a financial crisis, then all firms with positive SRISK will try simultaneously to raise capital and the only source is likely to be taxpayers. The bigger SRISK, the more serious the threat to financial stability.
- SRISK is estimated conditional on an endogenous variable – a stress test does not indicate causality.
- But how does this happen?

A MACRO-FINANCE LINK

- If any firms have high SRISK, they will recognize their vulnerability and will begin to delever and derisk, thereby impacting the real economy.   If only a few firms have high SRISK, the remaining firms can take up the slack.
- As the macro economy slows, stock prices will fall, volatility will rise, and SRISK will go up more.
- Firms may delever and derisk by attempting to sell illiquid assets and hoarding cash leading to further declines in real and financial sectors.

SPIRAL

- Investors recognize financial institution weakness and lower valuations, increasing SRISK
- Forward looking investors could make this happen in one step.
- Bankruptcies and other failures will occur until eventually, the return to capital is high enough to bring new capital to the industry.

IF TAXPAYERS STEP UP

- The spiral can be arrested before the bottom.

- However, this will erode market discipline and may impose huge regulatory costs on the financial sector going forward.

- Thus regulation is needed in advance. Ideally it would be countercyclical.

SO WHY WOULD ANY INSTITUTION HAVE POSITIVE SRISK?

- Externalities – if only one firm has high SRISK, there is no spiral.
- Implicit and Explicit government guarantees such as deposit insurance or "too big to fail"
- Regulatory incentives – the measure: "risk weighted assets" ignores correlation and hence leads to non-diversified asset mix
- Risk weights may be poor measures of risk.

MISCALCULATION

- Miscalculation: use short run risk measures to choose leverage rather than long run risk.
- Miscalculation: valuing exotic securities such as CDOs without recognizing all the risks.
- Miscalculation: housing prices can go down
- Agency problems – wall street big shots.
- ....Too many possibilities

REGULATION


BANK
I'M OKAY.
I LANDED
ON A
TAXPAYER.


Too Big to Fail Bank
BAILOUT
BAILOUT


KEEP BAILING!
TAX PAYERS
FINANCIAL INSTITUTION


PLEASE
CLOSE
GATE

FIRM SPECIFIC CAPITAL REQUIREMENTS

- Regulators might require that firms hold sufficient capital so that their SRISK is zero. Thus they would not have to raise capital in a future crisis.
- Thus firms would be required to reduce SRISK which can be done by
  - Deleveraging
  - Demerging
  - Derisking
  - Declining to follow the herd with identical bets.

COUNTER CYCLICAL CAPITAL REQUIREMENTS

- It is best if capital requirements can be increased in good times since the banks can easily raise capital and increase their buffer.

- In bad times, it is natural to reduce requirements because new capital is very hard and expensive to raise at that time and because draconian cuts will hurt the rest of the economy.

ECONOMETRICS OF SRISK

DYNAMIC CONDITIONAL BETA

ARE BETAS CONSTANT?

- LEAST SQUARES MODELS ARE USED IN COUNTLESS EMPIRICAL STUDIES IN FINANCE AND ECONOMICS
- RARELY IS THE HYPOTHESIS THAT BETAS ARE CONSTANT GIVEN CAREFUL SCRUTINY
- WHAT TOOLS DO WE HAVE?

MODELLING TIME VARYING BETA

- ROLLING REGRESSION
- INTERACTING VARIABLES WITH TRENDS, SPLINES OR OTHER OBSERVABLES
- TIME VARYING PARAMETER MODELS BASED ON KALMAN FILTER
- STRUCTURAL BREAK AND REGIME SWITCHING MODELS
- EACH OF THESE SPECIFIES CLASSES OF PARAMETER EVOLUTION THAT MAY NOT BE CONSISTENT WITH ECONOMIC THINKING OR DATA.

THE BASIC IDEA

- $(y_t, x_t),\ t = 1,\ldots,T$ is a collection of k+1 random variables that are distributed as

$$\begin{pmatrix} y_t \\ x_t \end{pmatrix} \Big| \mathbb{F}_{t-1} \sim N(\mu_t, H_t) \quad = N\left(\begin{pmatrix} \mu_{y,t} \\ \mu_{x,t} \end{pmatrix}, \begin{pmatrix} H_{yy,t} & H_{yx,t} \\ H_{xy,t} & H_{xx,t} \end{pmatrix} \right)$$

- Then

$$y_t \big| x_t, \mathbb{F}_{t-1} \sim N\left(\mu_{y,t} + H_{yx,t} H_{xx,t}^{-1} \left(x_t - \mu_{x,t} \right), H_{yy,t} - H_{yx,t} H_{xx,t}^{-1} H_{xy,t} \right)$$

- Hence: $\beta_t = H_{xx,t}^{-1} H_{xy,t}$

HOW TO ESTIMATE H

- Econometricians have developed a wide range of approaches to estimating large covariance matrices. These include
  - Multivariate GARCH models such as VEC and BEKK
  - Constant Conditional Correlation models
  - Dynamic Conditional Correlation models
  - Dynamic Equicorrelation models
  - Multivariate Stochastic Volatility Models
  - Many many more
- Exponential Smoothing with prespecified smoothing parameter.

Is beta constant?

- For none of these methods will beta appear constant.
- In the one regressor case this requires the ratio of $h_{yx,t} / h_{xx,t}$ to be constant.
- This is a non-nested hypothesis (or more technically a partially nested hypothesis)

NON-NESTED HYPOTHESES

- Model Selection based on information criteria
  - Two possible outcomes
- Artificial Nesting
  - Four possible outcomes
- Testing equal closeness- Quang Vuong
  - Three possible outcomes

ARTIFICIAL NESTING

- Consider the model where $\circ$ means element by element multiplication or Hadamard product:

$$y_t = \phi' x_t + \left(\lambda \circ \beta_t\right)' x_t + v_t$$

- If lambda is zero, the parameters are constant
- If phi is zero, the parameters are time varying.
- If both are non-zero, the nested model may be entertained.

A. CALDER 1973, *LA PORTE DE L'ESPACE*


US FIGU
SKATIN


EXIT

GLOBAL SYSTEMIC RISK

Time zones

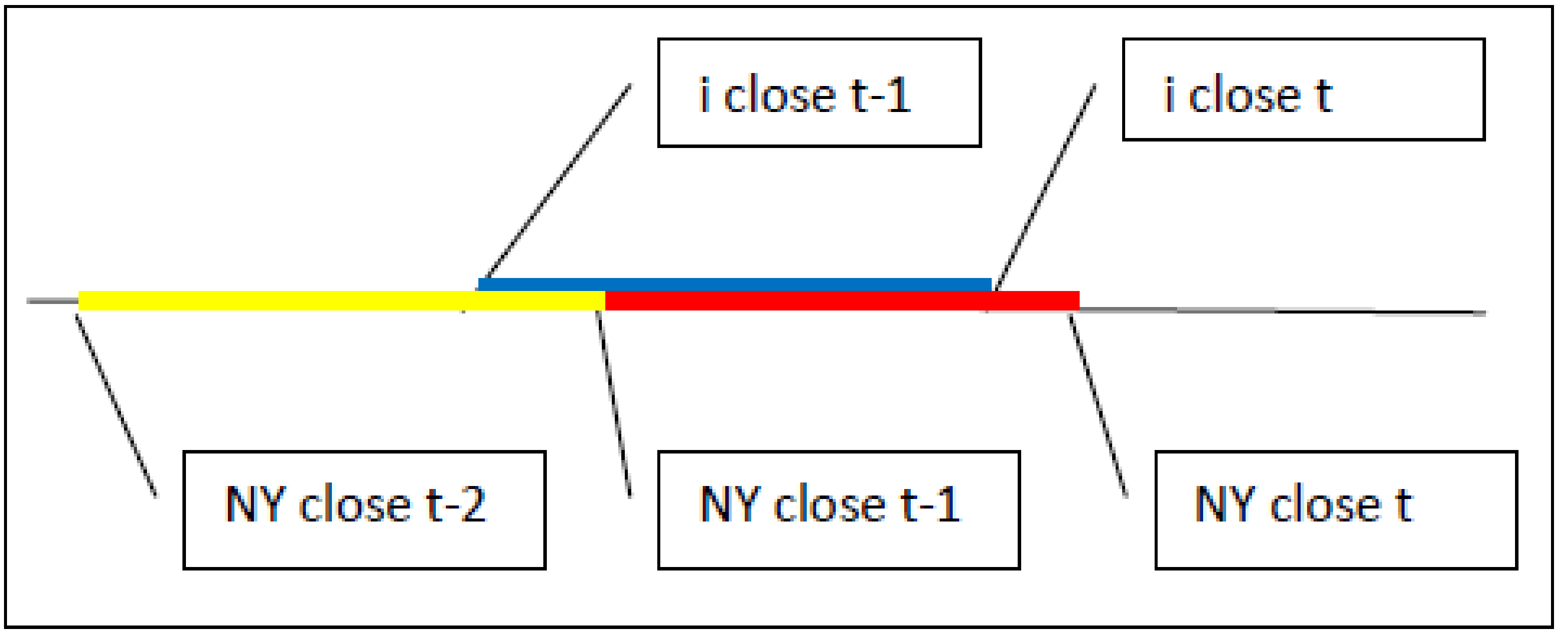


Figure 1

model

- Condition on t-2 $$\begin{pmatrix} R_{i,t} \\ R_{m,t} \\ R_{m,t-1} \end{pmatrix} \Big| \mathbb{F}_{t-2} \sim N\left(0, H_t\right)$$
- The equation $$R_{i,t} = \beta_{i,t} R_{m,t} + \gamma_{i,t} R_{m,t-1} + u_{i,t}$$
- But u can be an MA(1) and GARCH. In fact, it must have MA(1) if R_i is to be a Martingale difference.

Nested model

- Combining the constant beta and dynamic conditional beta into one regression:

$$R_{i,t} = \left(\phi_1 \beta_{i,t} + \phi_2\right) R_{m,t} + \left(\phi_3 \gamma_{i,t} + \phi_4\right) R_{m,t-1} + u_t$$

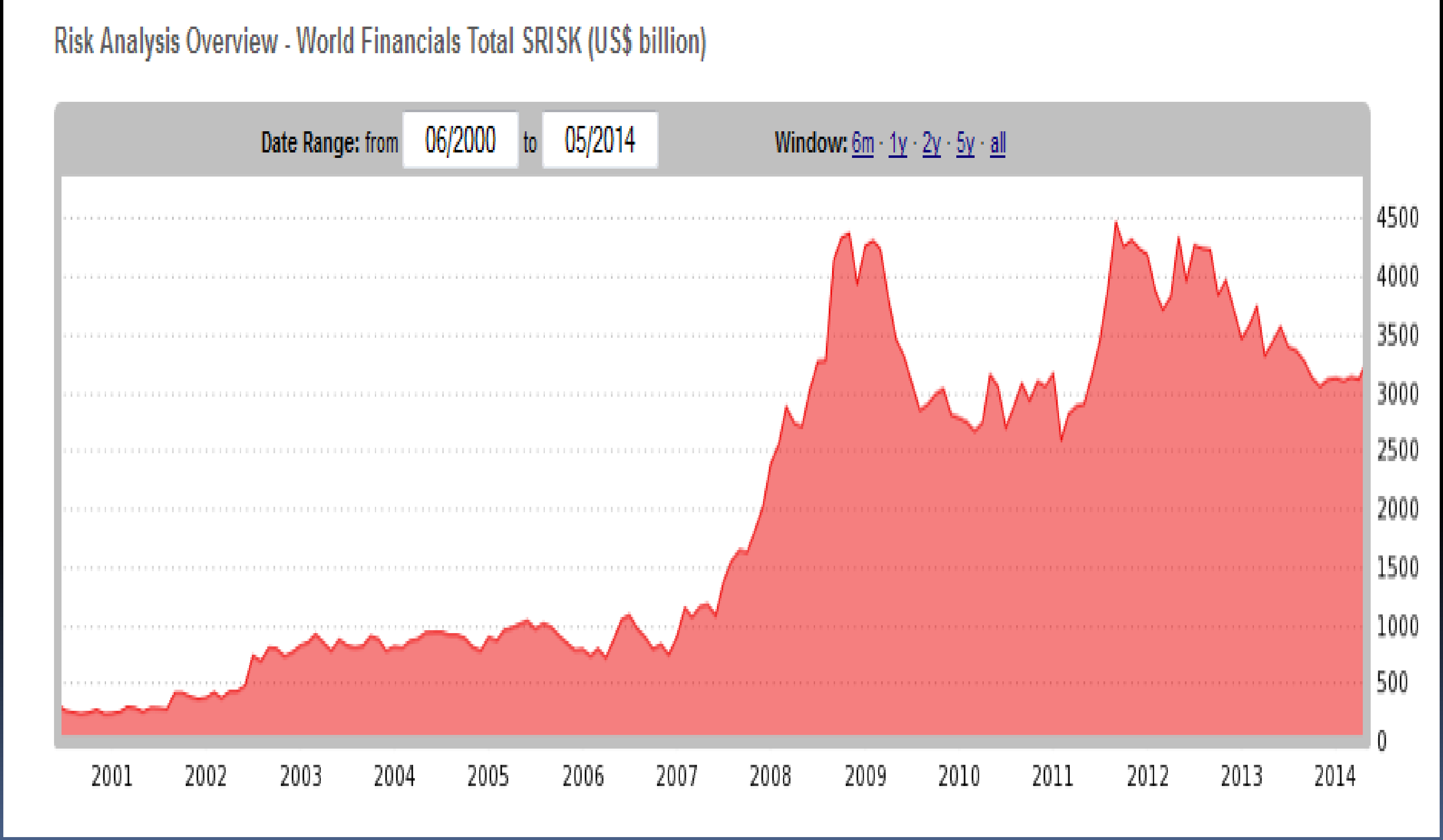
- Where u will be an MA(1) GARCH

V-LAB

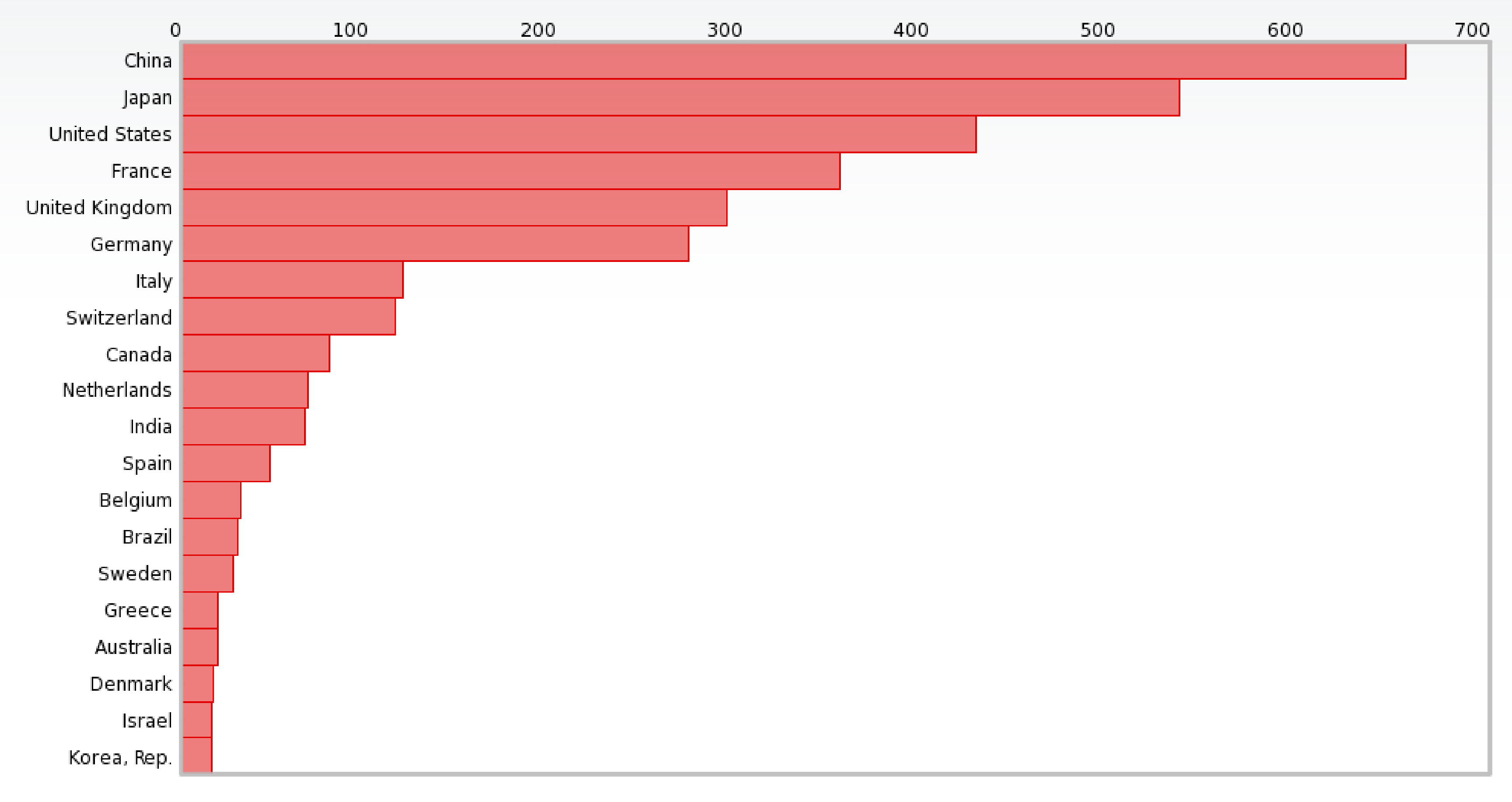
NEW YORK UNIVERSITY NYU STERN LEONARD N. STERN SCHOOL OF BUSINESS

- For 1200 global financial institutions we update weekly estimates of SRISK. These now use Nested Dynamic Conditional Beta with MA(1) and GARCH.
- http://vlab.stern.nyu.edu
- These are adjusted for differences between GAAP and IFRS accounting by using a lower capital adequacy ration of 5.5% to reflect the expanded balance sheet.

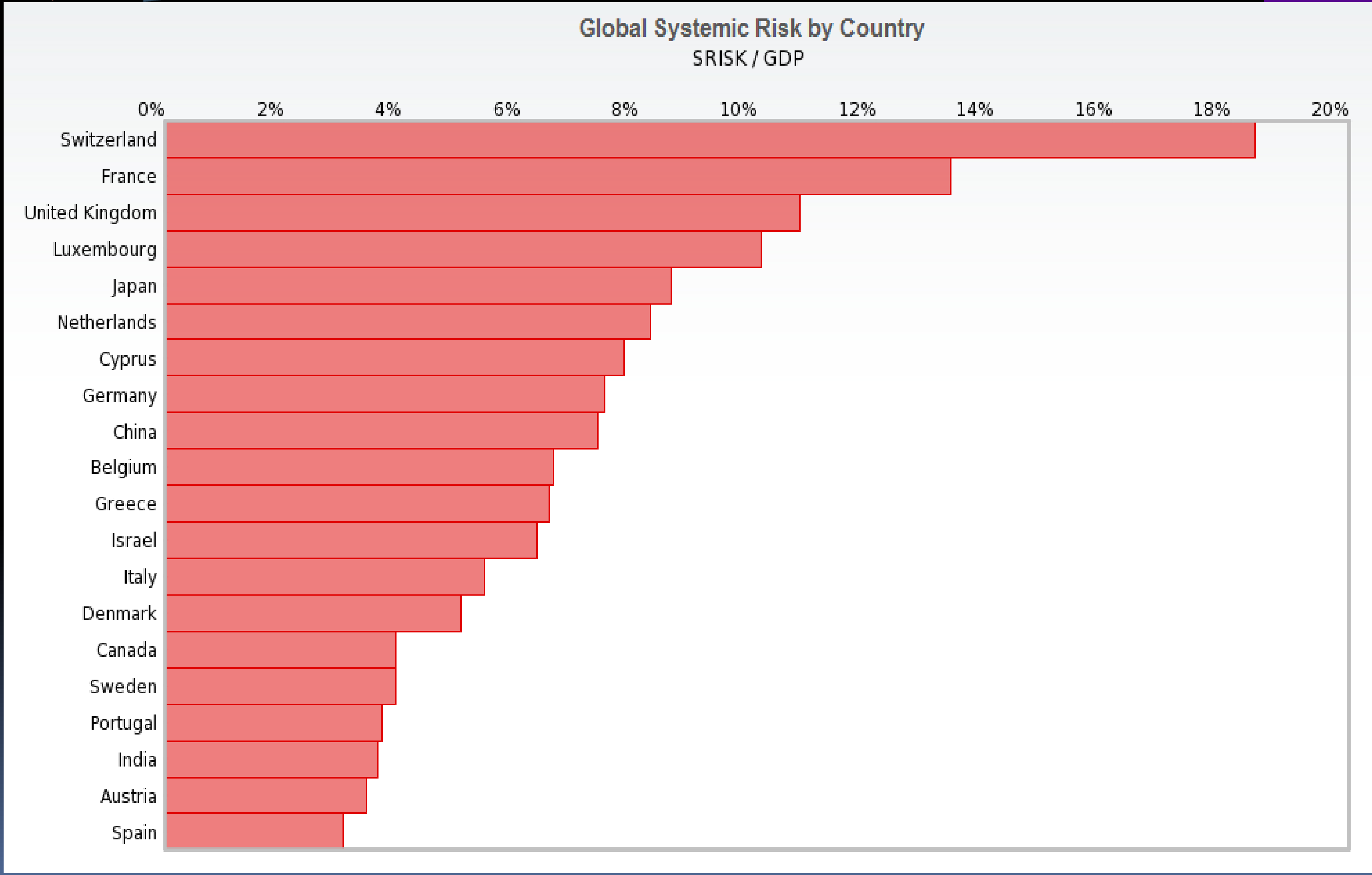
GLOBAL SRISK SINCE 2000



WHERE IS THE RISK *today*?

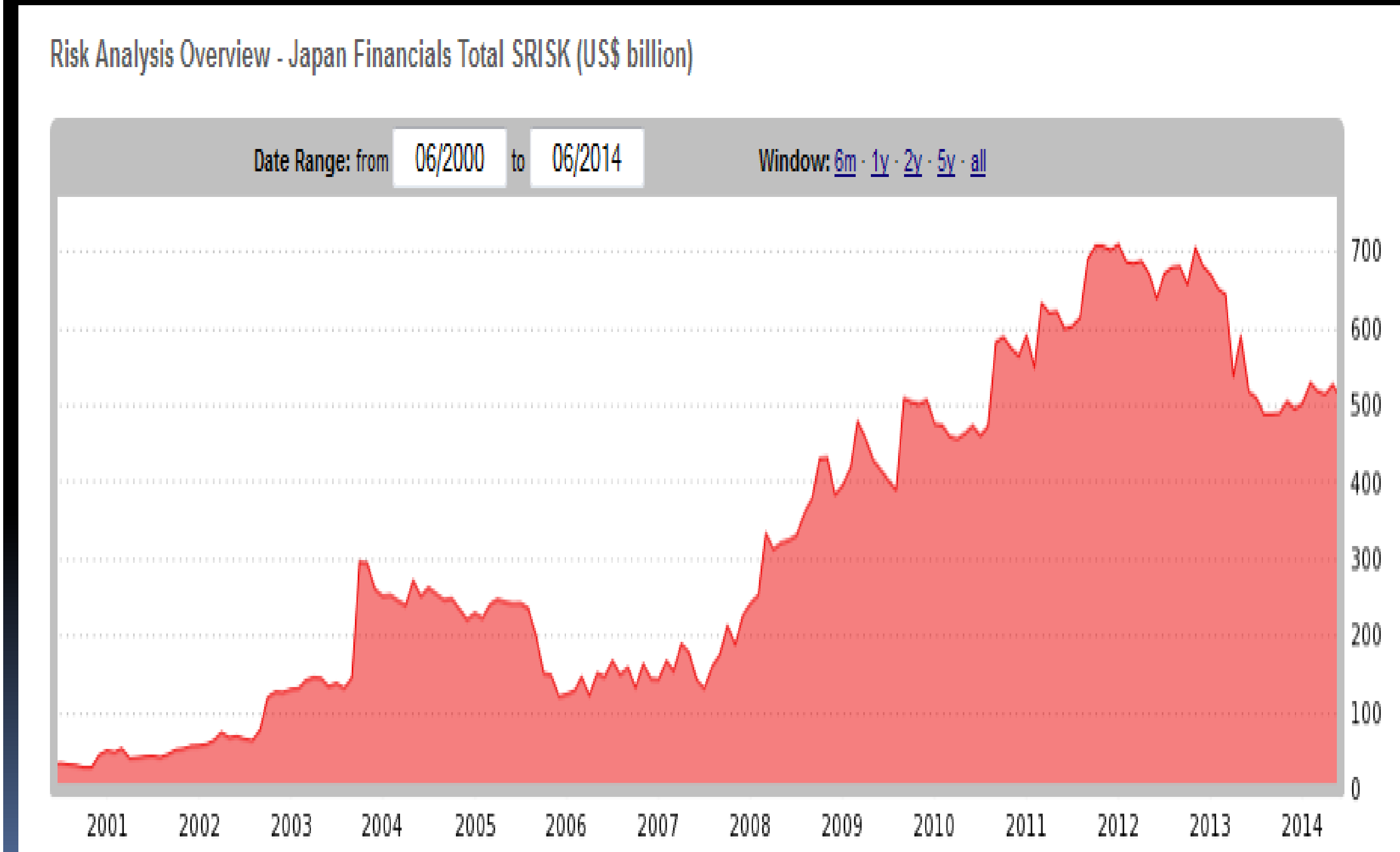


SRISK/GDP



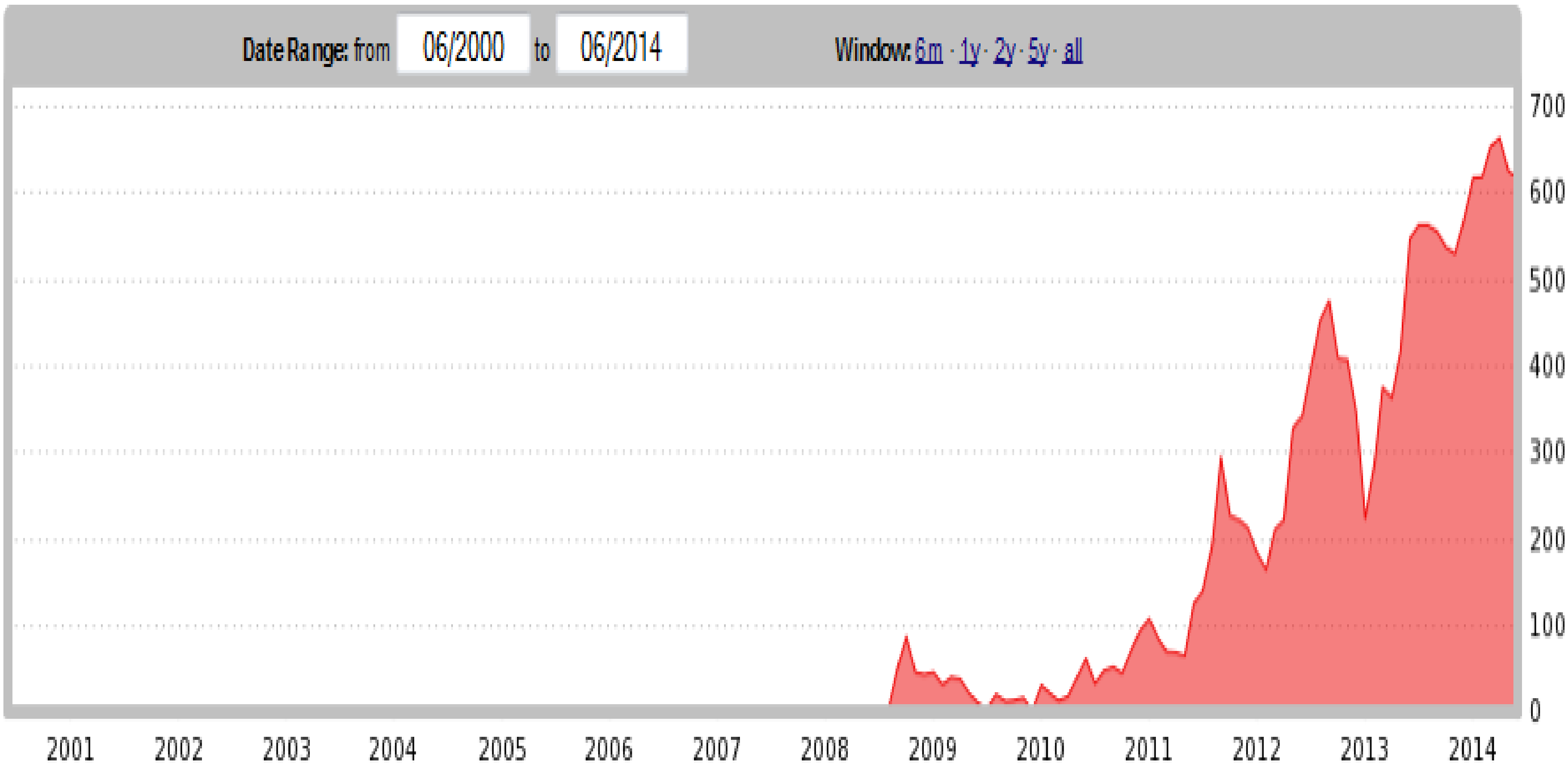
Global Systemic Risk by Country
SRISK / GDP
0%
2%
4%
6%
8%
10%
12%
14%
16%
18%
20%
Switzerland
France
United Kingdom
Luxembourg
Japan
Netherlands
Cyprus
Germany
China
Belgium
Greece
Israel
Italy
Denmark
Canada
Sweden
Portugal
India
Austria
Spain

JAPAN

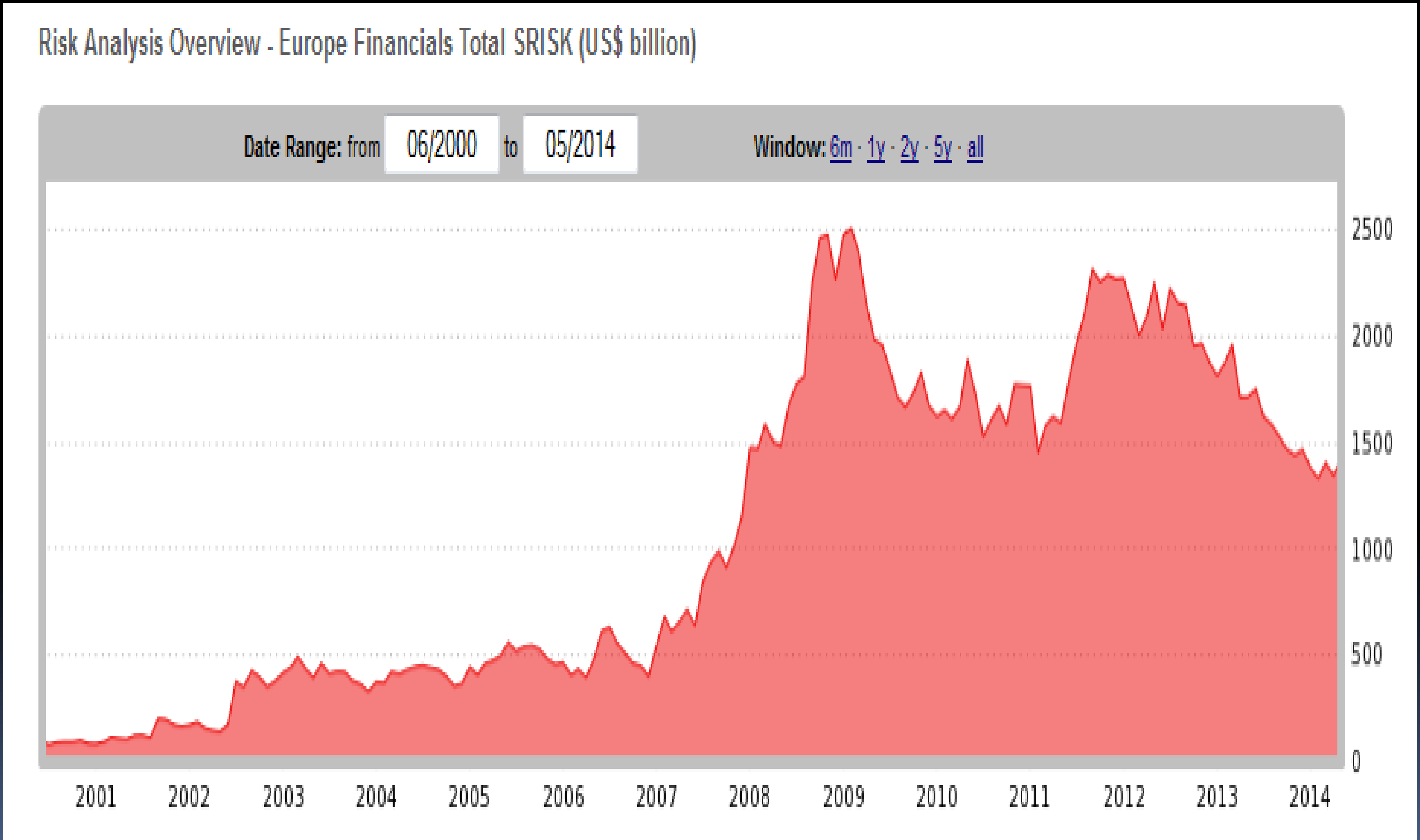

Risk Analysis Overview - Japan Financials Total SRISK (US$ billion)
Date Range: from 06/2000 to 06/2014
Window: 6m · 1y · 2y · 5y · all
700
600
500
400
300
200
100
0
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014

CHINA

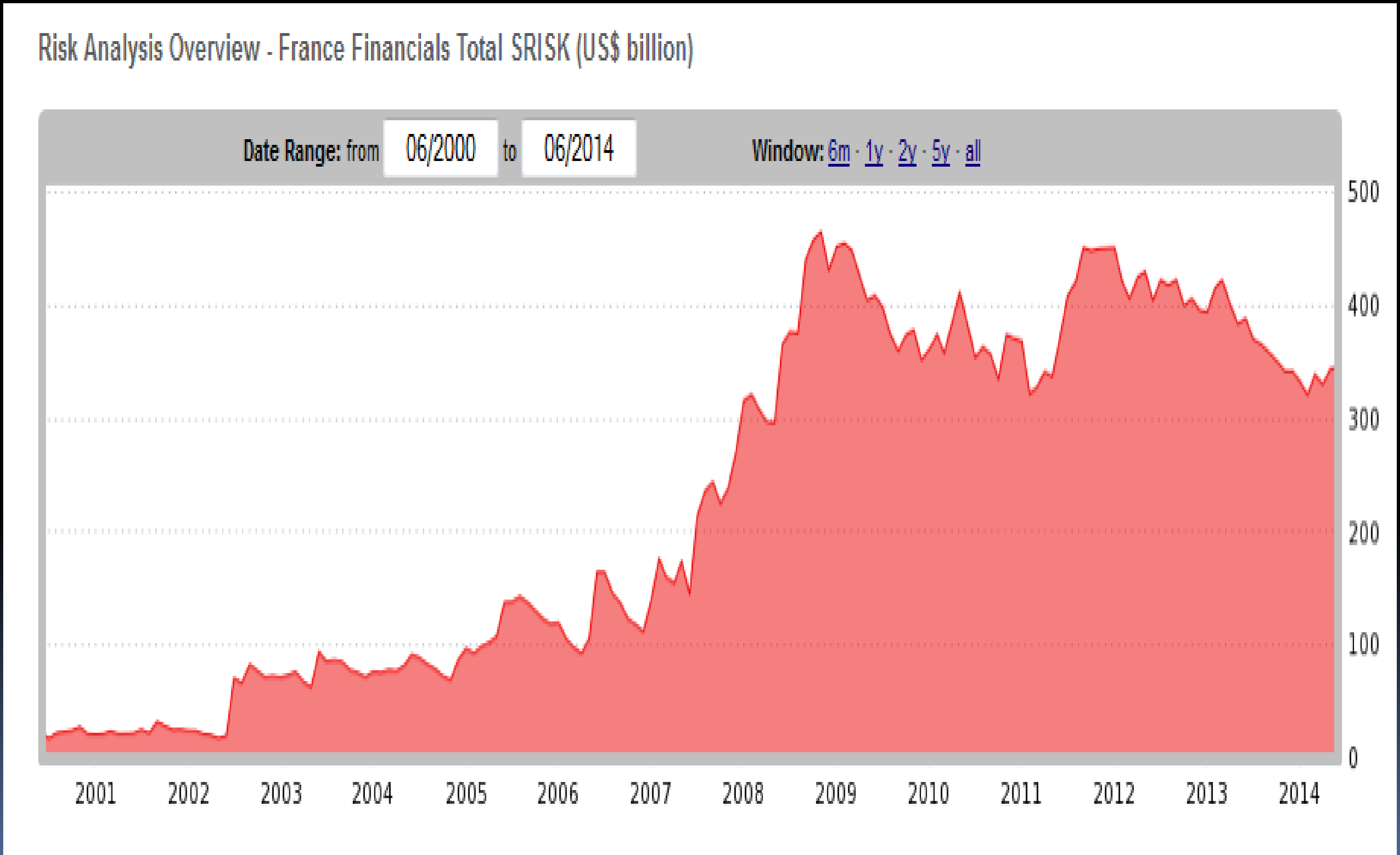
Risk Analysis Overview - China Financials Total SRISK (US$ billion)



EUROPE SINCE 2000

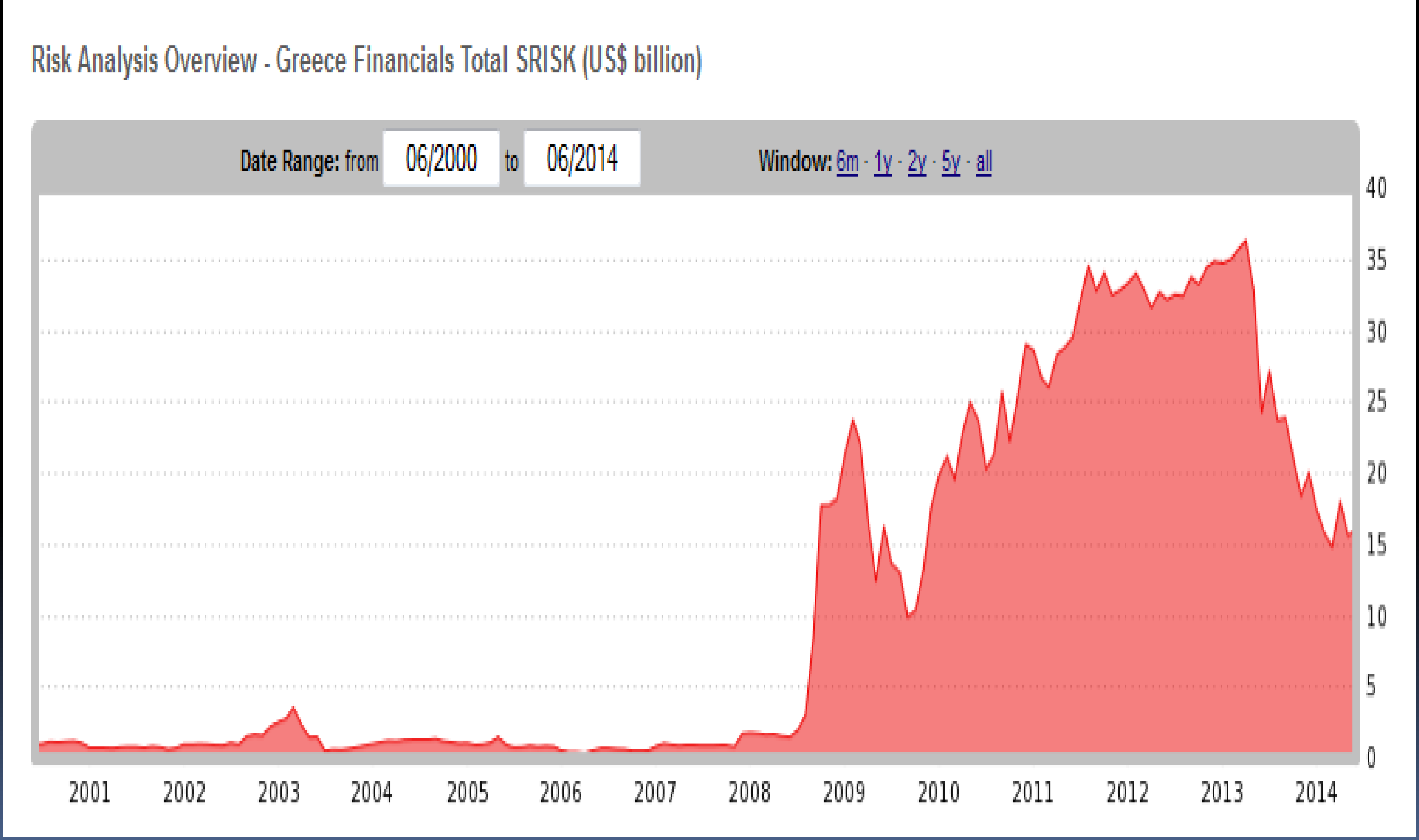


FRANCE



Risk Analysis Overview - France Financials Total SRISK (US$ billion)
Date Range: from 06/2000 to 06/2014
Window: 6m · 1y · 2y · 5y · all
500
400
300
200
100
0
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014

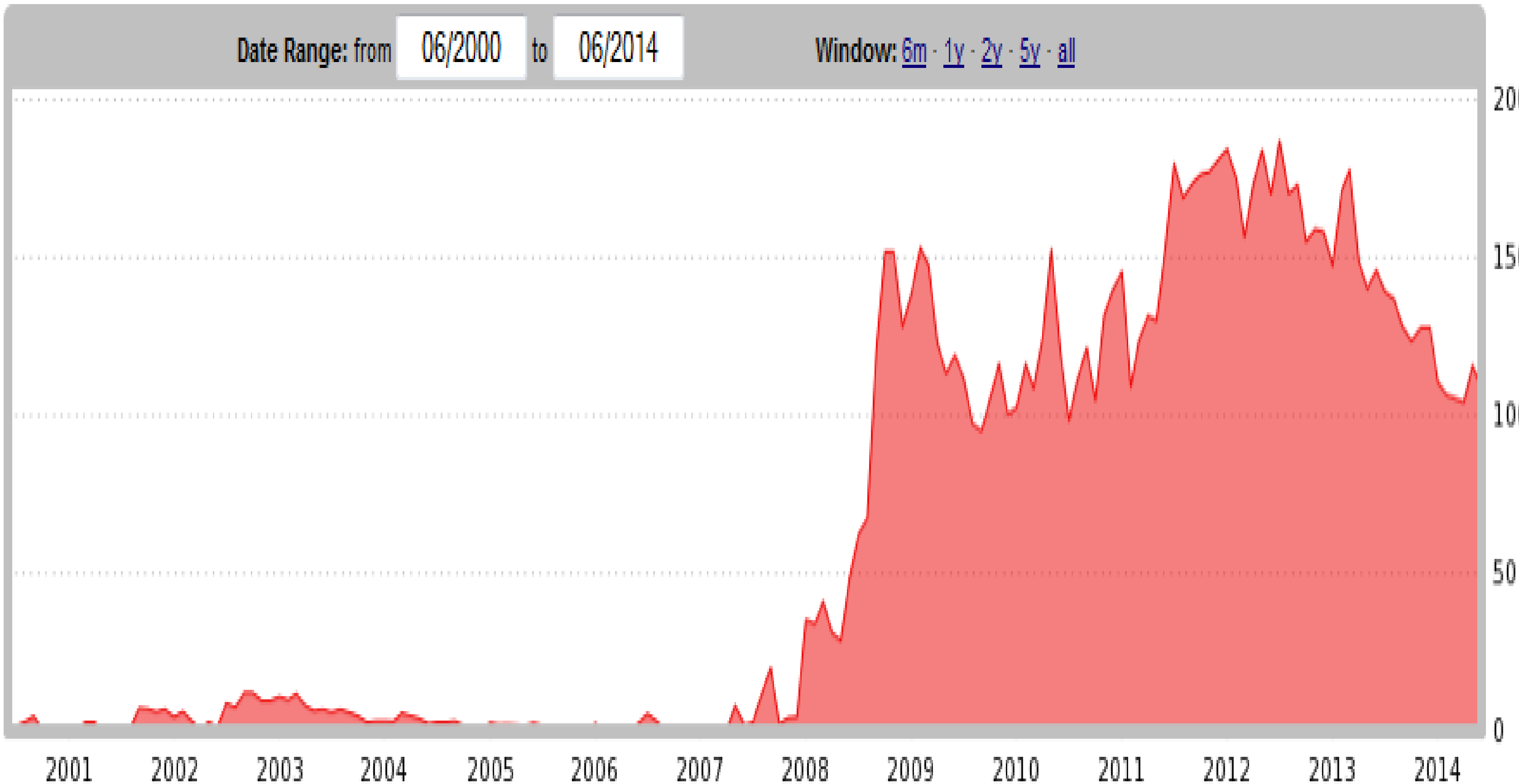
GREECE



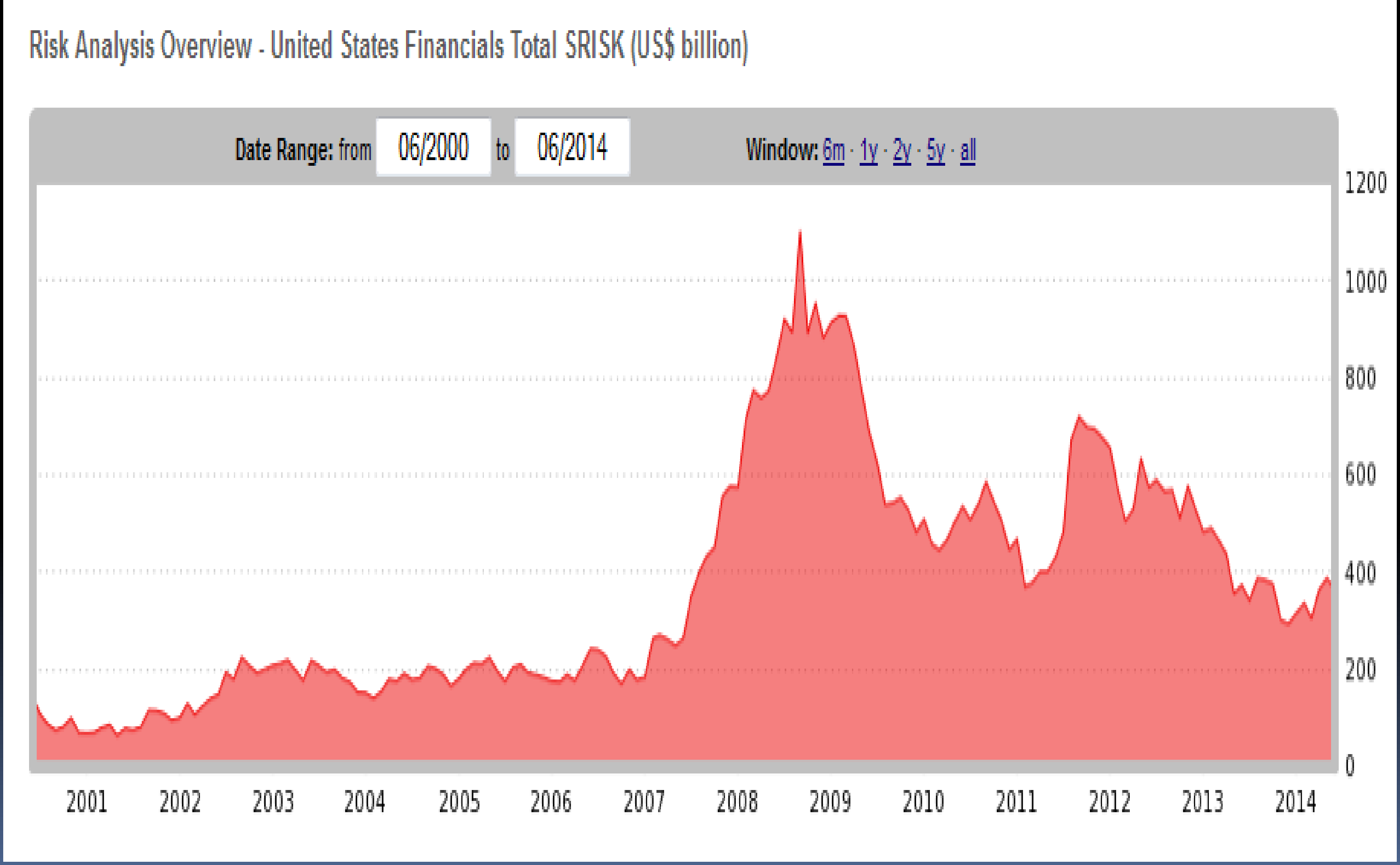
Risk Analysis Overview - Greece Financials Total SRISK (US$ billion)
Date Range: from 06/2000 to 06/2014
Window: 6m · 1y · 2y · 5y · all
40
35
30
25
20
15
10
5
0
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014

ITALY

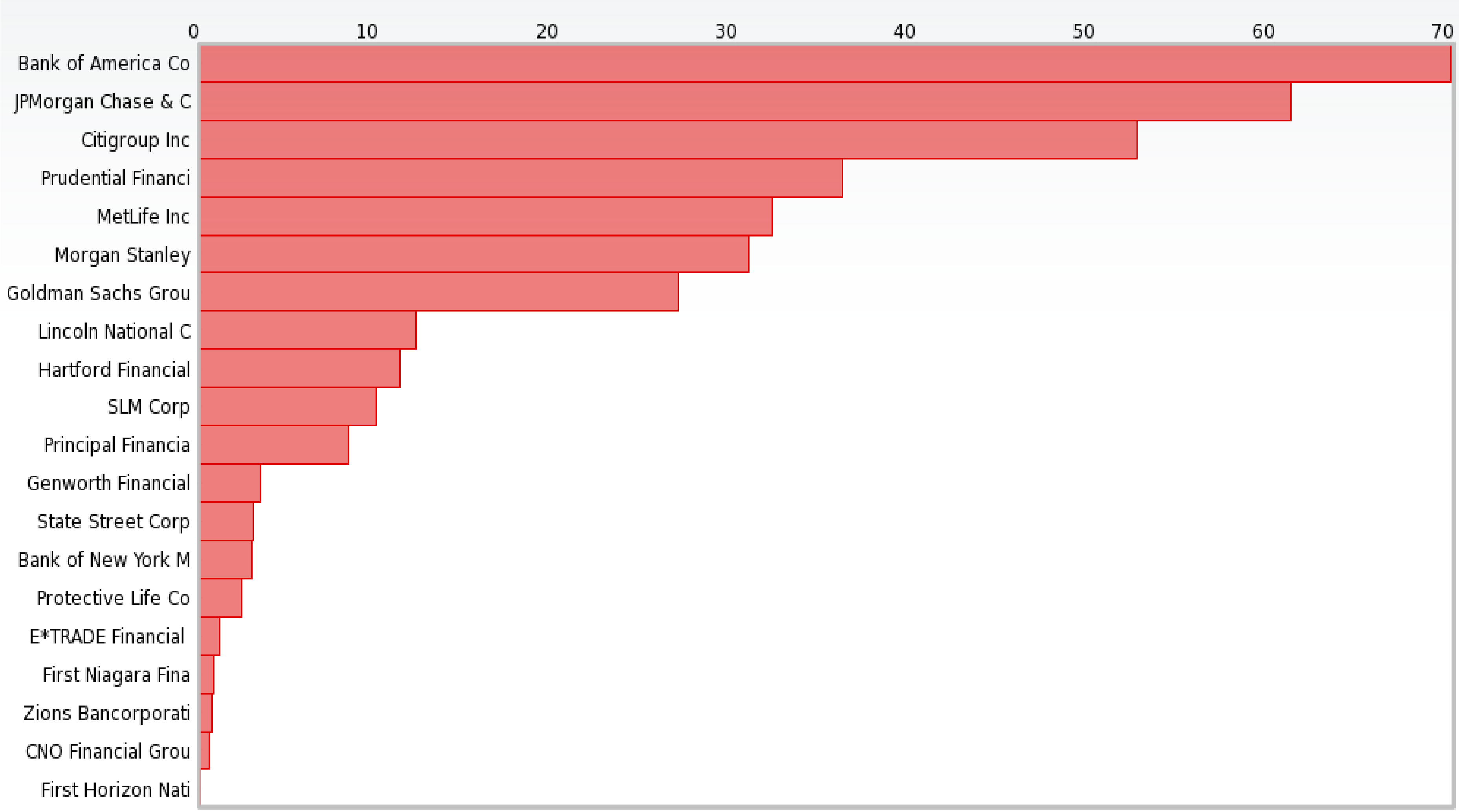
Risk Analysis Overview - Italy Financials Total SRISK (US$ billion)



US SINCE 2000



US FIRM SRISK



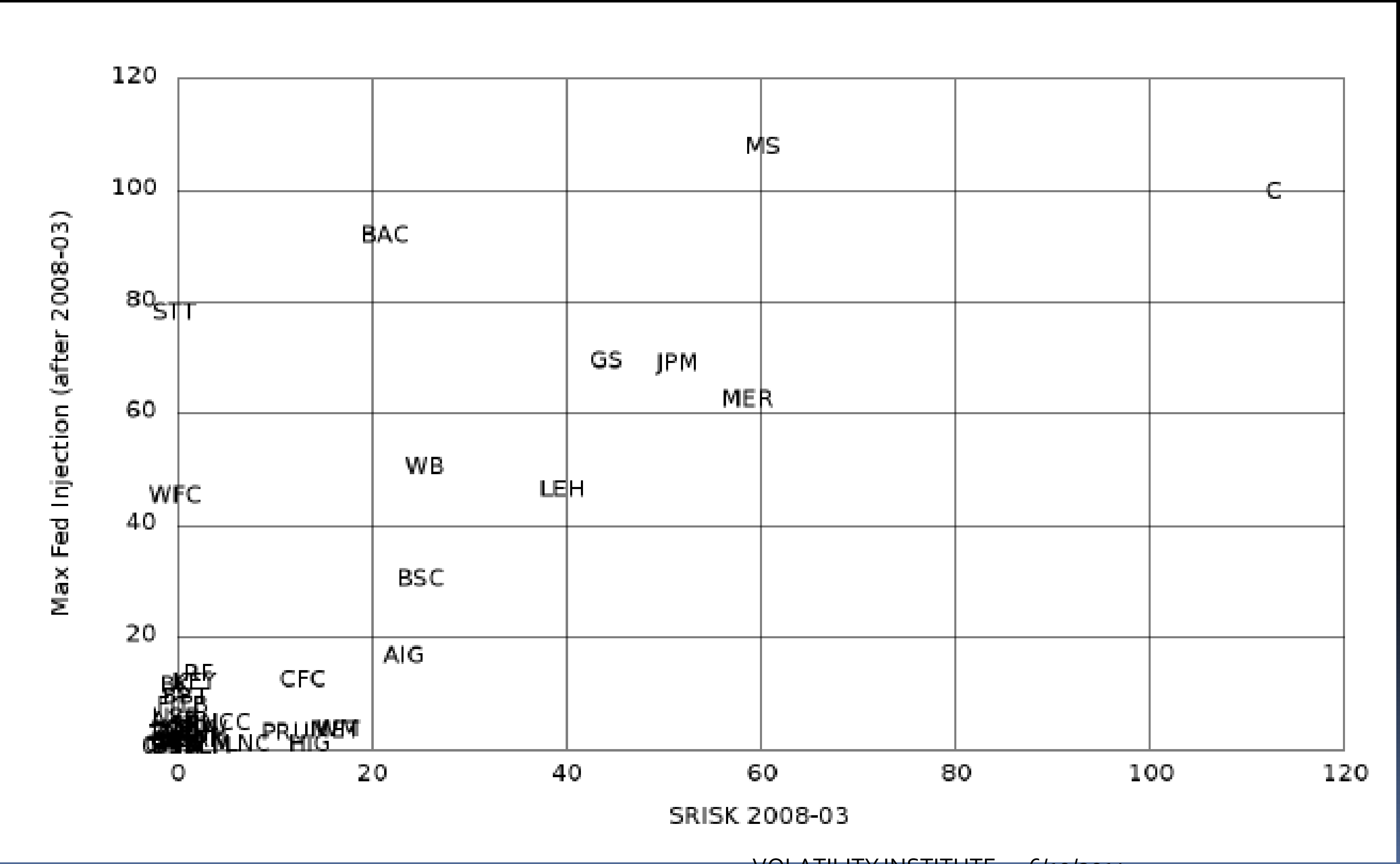
ANALYSIS OF THE RESULTS

How can you validate a systemic risk model?

Global Systemic Risk Rankings

“A Look Back”

BAILOUT PREDICTION



Risk Rankings Before Lehman

Systemic Risk Rankings for 2008-08-29 View changes

Institution	SRISK%	RNK	SRISK ($ m)	MES	Beta	Cor	Vol	Lvg
Citigroup Inc	13.65	1	122,135	5.56	2.16	0.66	65.8	19.99
JPMorgan Chase & Co	9.04	2	80,919	4.89	1.90	0.61	63.3	13.42
Freddie Mac	7.69	3	68,864	10.39	4.04	0.37	221.8	297.76
Fannie Mae	7.44	4	66,629	11.01	4.27	0.41	213.4	115.68
American International Group Inc	7.19	5	64,352	8.05	3.13	0.58	97.2	17.62
Bank of America Corp	6.93	6	62,016	4.11	1.60	0.59	77.6	11.94
Merrill Lynch	6.90	7	61,793	6.36	2.47	0.65	84.3	22.45
Morgan Stanley	6.88	8	61,621	4.63	1.80	0.61	54.5	23.01
Goldman Sachs Group Inc/The	5.75	9	51,487	3.59	1.40	0.62	43.3	16.99
Lehman Brothers	5.28	10	47,283	9.78	3.80	0.61	132.3	55.88

RISK RANKINGS 1/2007

Systemic Risk Rankings for 2007-01-31 View changes

Institution	SRISK%	RNK▲	SRISK ($ m)	MES	Beta	Cor	Vol	Lvg
Morgan Stanley	22.09	1	40,848	3.07	1.29	0.63	23.1	13.50
Freddie Mac	15.73	2	29,087	1.24	0.52	0.40	14.3	18.29
Fannie Mae	13.42	3	24,826	1.41	0.59	0.39	19.4	15.56
Merrill Lynch	9.61	4	17,769	2.75	1.16	0.59	21.5	10.70
Goldman Sachs Group Inc/The	8.73	5	16,139	2.90	1.22	0.57	24.6	10.14
Lehman Brothers	8.46	6	15,650	3.07	1.29	0.62	25.6	12.11
Bear Stearns	8.45	7	15,634	2.46	1.04	0.57	23.5	18.48
MetLife Inc	5.15	8	9,528	2.08	0.88	0.46	17.9	11.43
Hartford Financial Services Group Inc/The	3.23	9	5,971	2.19	0.92	0.53	18.6	11.23
Prudential Financial Inc	3.12	10	5,769	1.74	0.75	0.47	15.6	11.10

GRANGER CAUSALITY TESTS

- A small piece of evidence.
- Monthly SRISK, calculated recursively at the end of each month and summed over all US financial institutions.
- Tested with monthly industrial production and unemployment.
- All variables log differenced, 3 lags of all variables, OLS estimation

RESULTS:
– COLUMNS CAUSE ROWS

	SRISK	INDPRD	URATE
SRISK		4.31	0.02
INDPRD	20.65***		8.99**
URATE	0.01	7.39***	

GLOBAL RISK

- November 4, 2011 BIS with FSB of the G-20 released its list of Global Systemically Important Financial Institutions GSIFIs.
- They listed 17 European Banks
- November, our list of the top 17 banks is identical with one exception:
  - We have Intesa Sanpaolo instead of Dexia
- Furthermore, we have ranked these
- It took BIS two years and many meetings. We have now updated many times.