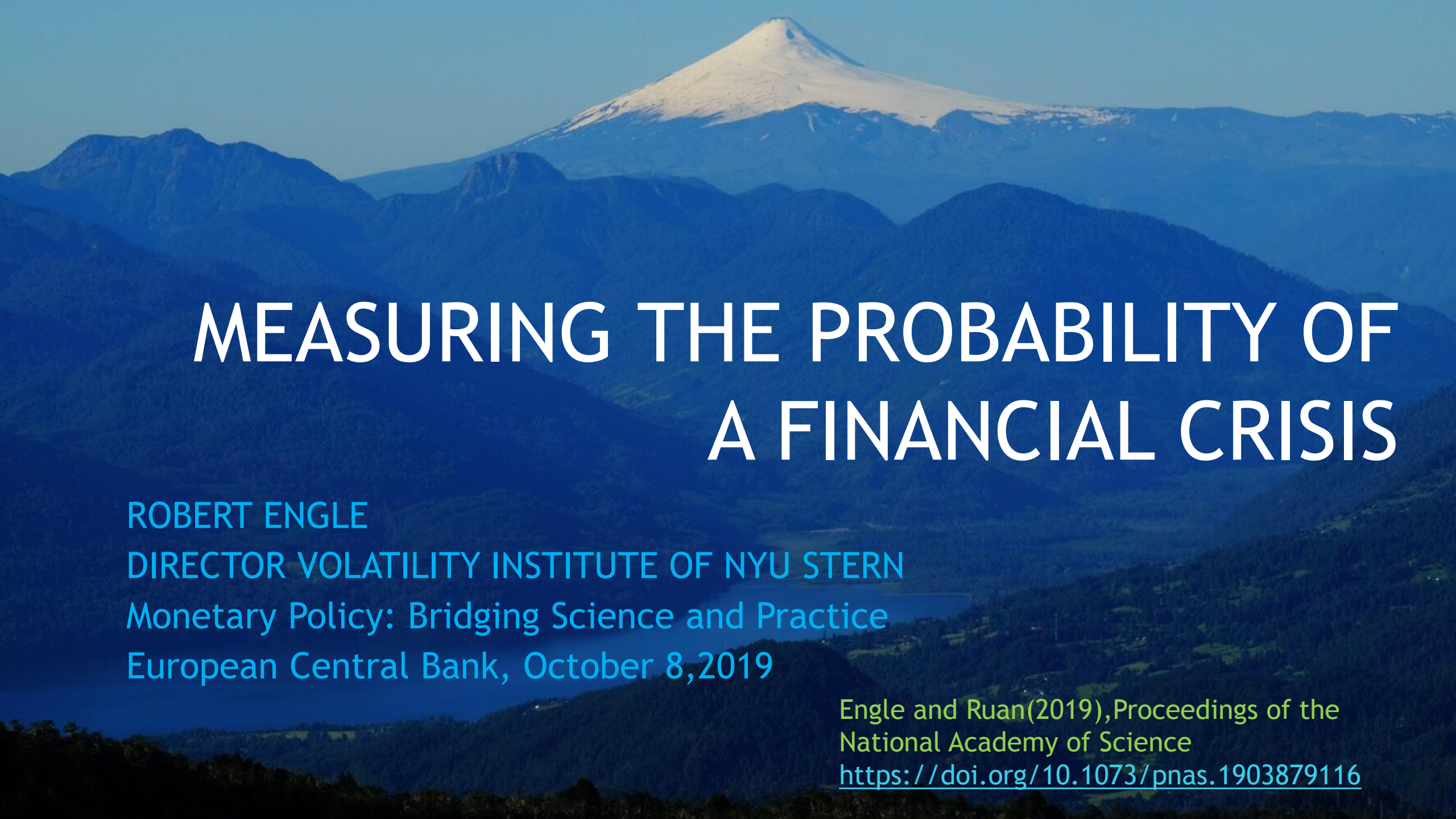
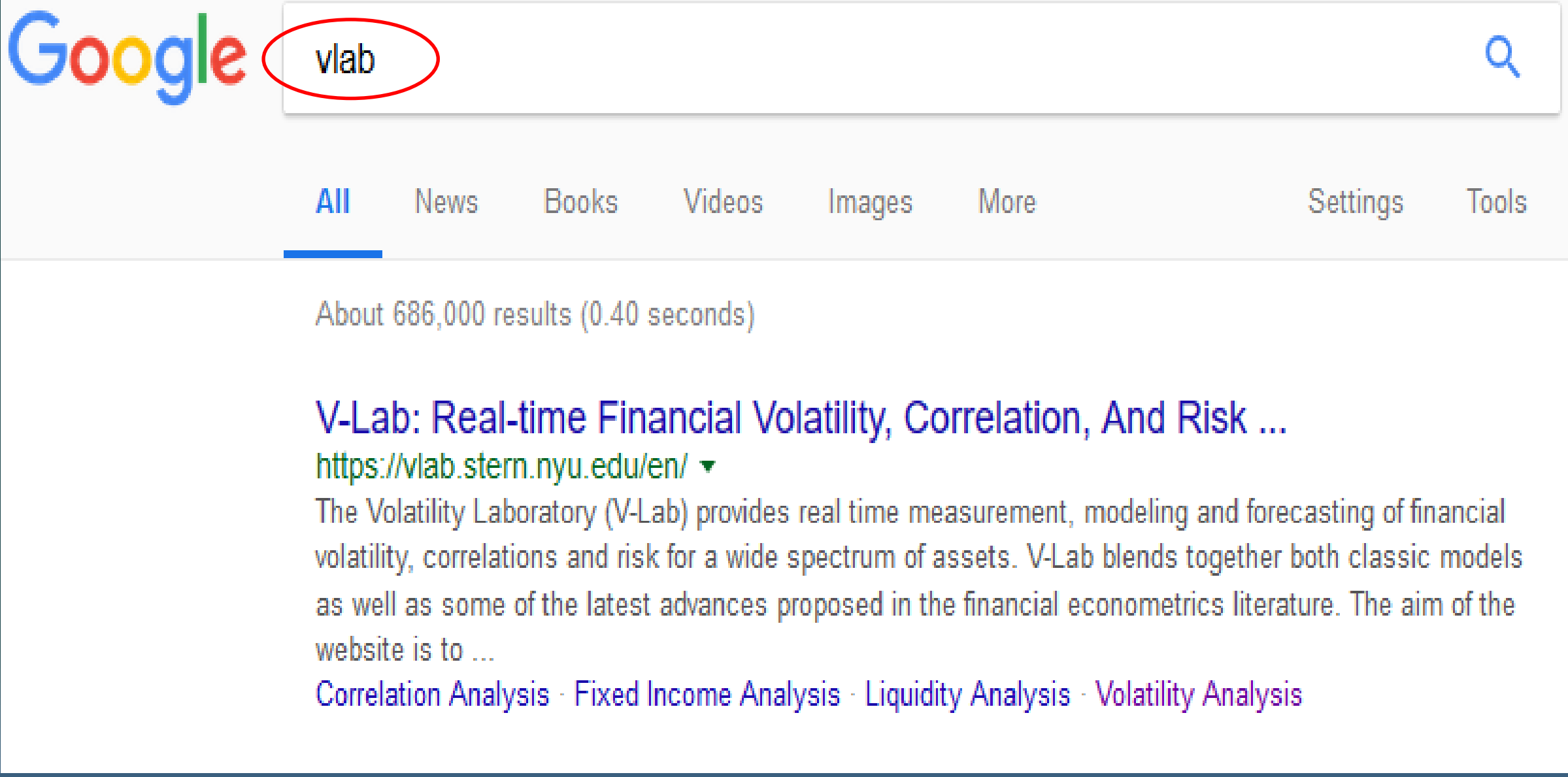


MEASURING THE PROBABILITY OF A FINANCIAL CRISIS

ROBERT ENGLE
DIRECTOR VOLATILITY INSTITUTE OF NYU STERN

Monetary Policy: Bridging Science and Practice
European Central Bank, October 8,2019

Engle and Ruan(2019),Proceedings of the National Academy of Science
https://doi.org/10.1073/pnas.1903879116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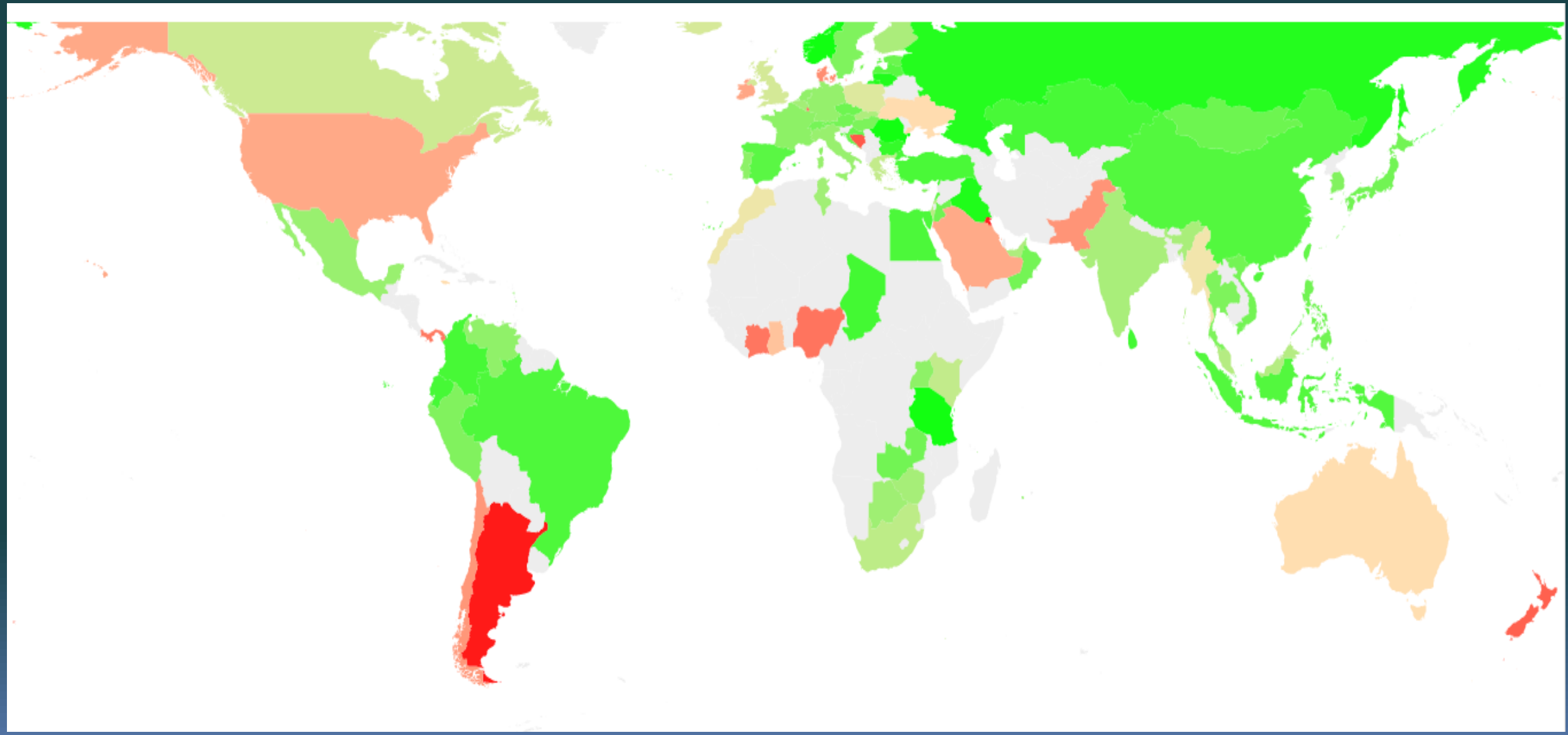
V-Lab: Real-time Financial Volatility, Correlation, And Risk ...
https://vlab.stern.nyu.edu/en/
The Volatility Laboratory (V-Lab) provides real time measurement, modeling and forecasting of financial volatility, correlations and risk for a wide spectrum of assets. V-Lab blends together both classic models as well as some of the latest advances proposed in the financial econometrics literature. The aim of the website is to ...
Correlation Analysis · Fixed Income Analysis · Liquidity Analysis · Volatility Analysis

GLOBAL VOLATILITY 9/13/19



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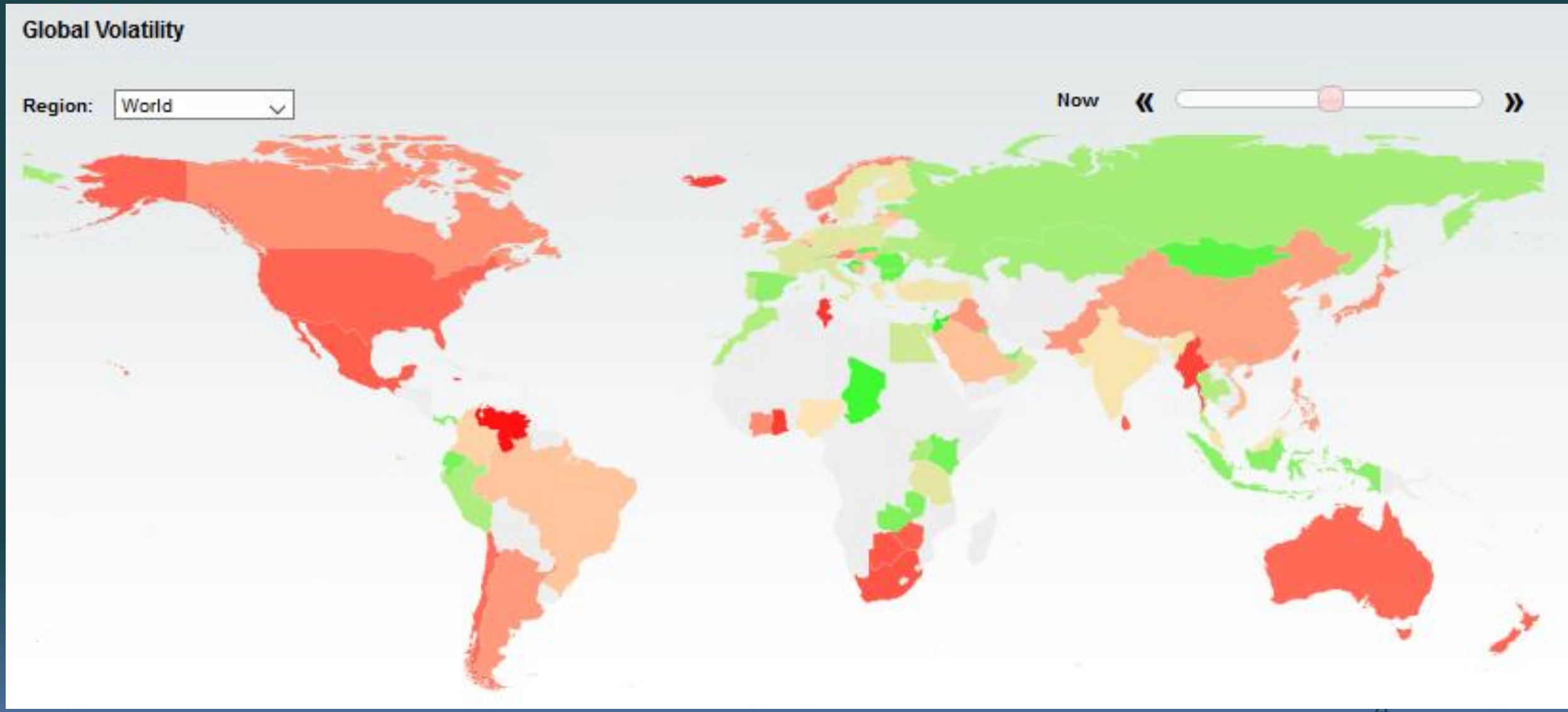
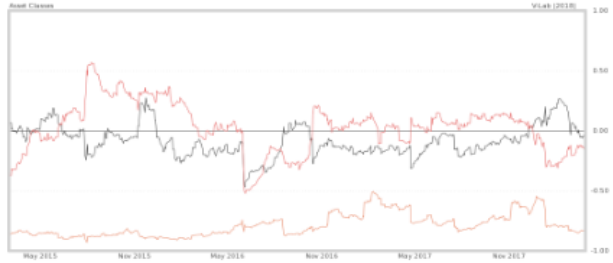


Volatility Analysis

There are few guarantees in financial markets. However, we do know that volatility clusters and mean-reverts. But how long will it take to mean revert and, on average, to what level? Where are the 'host spots' of volatility in the world and in what sectors? We attempt to answer these questions and more in our Volatility Analysis section of V-Lab. Come see the many models meant to explain volatility and explore volatility dynamics.

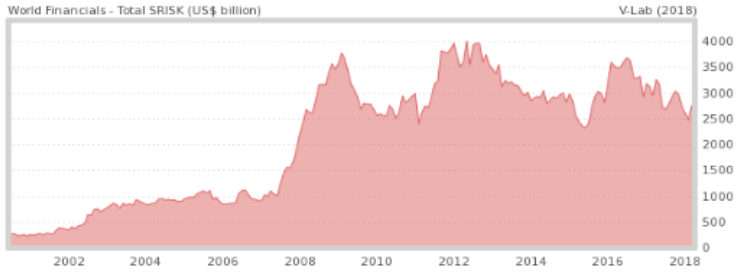
Correlation Analysis

The co-movement of asset prices is important in many financial market decisions, such as portfolio allocation, diversification, and hedging. In our Correlation Analysis section, we use econometric models to determine how these time series co-move, which assets are particularly correlated, and which are diverging in direction.



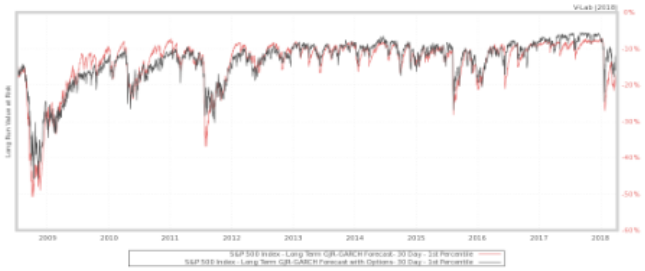
Systemic Risk Analysis

The Global Financial Crisis of 2008 revealed the degree of interconnectedness and fragility of the global financial system at the time. How badly would the equity values of financial institutions decline if there were another crisis today? What degree of capital shortfall would financial institutions suffer? Our Systemic Risk Analysis section of V-Lab simulates crises in domestic markets, as well as another global financial crisis, in an attempt to answer these questions.



Long-Run VaR Analysis

Often, volatility is assumed to grow with the square root of time. However, this assumes independence between observations each day (i.e. today's volatility has no bearing on what volatility will be tomorrow). Since this is not the case, one must defer to more sophisticted methods in order to estimate long-run volatility. Our Long-Run Value-at-Risk section simulates the 1 month and 1 year risk of holding financial assets, both using only returns and also conditioning average future volatility on current options market data.

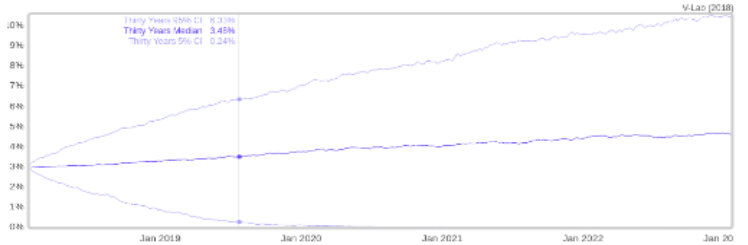


Liquidity Analysis

The liquidity of a financial asset reflects transaction costs and the ability to unwind large trades at reasonable prices. 'Liquidity spirals' often exacerbate stock market declines, such as what we saw in the last Global Financial Crisis. In the liquidity section we estimate and forecast the liquidity of a broad spectrum of financial assets.

Fixed Income Analysis

The future direction of interest rates has large implications for the the determination of discount rates, asset pricing, and firm capital structure. In addition, interest rates and their term structure are often used to infer economic forecasts of inflation, recession, and other key indicators. But where are rates headed in the long term? We forecast the distribution of treasury rates up to 5 years ahead from a 6-month bill to 30-year bond in the Fixed Income Section. We show upper and lower confidence intervals for future rates.



Climate Risk Analysis

Climate change is effecting the world via stronger, more severe weather events, rising sea levels, and in many other ways. Are these events and the risks imposed by climate change properly reflected in asset prices? Environmental risks can be thought of as long run risks which influence portfolio decisions. In our Climate Risk Analysis section. We examine the performance of publicly traded environmental portfolios, which can serve as a measure of the new information on environmental risk and a mechanism to hedge these risks.

HOW DO WE CONCEIVE OF THE RISK OF A FINANCIAL CRISIS?

- When the banking sector is undercapitalized, it is vulnerable to external shocks. We measure this by regulatory stress tests and by market measures such as SRISK. External Shocks

- However, when banks are undercapitalized, the deleveraging may be exactly what causes a financial crisis. Internal Shocks.
- In this case, the probability of a financial crisis depends on how extreme are the economic conditions.

EXCESSIVE CREDIT GROWTH

1. It is widely believed that excessive credit growth is the fundamental cause of financial crises.
2. See for example Reinhart and Rogoff(2009) "This Time Is Different" or Borio(2012)"the financial cycle", Adrian and Shin(2011)"Leverage"
3. But credit growth is typically procyclical as increased credit is a natural component of growth.
4. Schularick and Taylor argue that a financial crisis is a "credit boom gone bust." How can we see this in data?

A MORTGAGE EXAMPLE

- Here is an example of excessive credit growth: A bank may issue mortgages to underqualified borrowers or overvalued houses.
- These mortgages will have market values that may be less than the accounting value and if the housing market declines, their market values will fall further as the collateral weakens.
- A portion of the bank's capital will be needed to cover these losses.
- If it does not have a sufficient capital cushion, then it will face bankruptcy or will seek a bailout.
- *Credit growth is excessive if the financial sector does not have sufficient capital to cover losses in a downturn*.

DEFINITION of SRISK

- *How much capital would a financial institution need to raise in order to function normally if we have another financial crisis?*
- **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 Pierret, Emil Siriwardane.**
- **References: Acharya, Pedersen, Philippon, Richardson "Measuring Systemic Risk (2010); Acharya, Engle, Richardson "Capital Shortfall, A New Approach to Ranking and Regulating Systemic Risks, AEAPP (2012), Brownlees and Engle, "Volatilities, Correlations and Tails for Systemic Risk Measurement" and "A conditional Capital Shortfall Measure of Systemic Risk," RFS(2017)**

SRISK or Systemic Risk

$$Capital\ Shortfall = k\left(\underset{QUASI\ \ ASSETS}{Debt + Equity}\right) - Equity$$

$$SRISK = median\left(Capital\ Shortfall \,\middle|\, Crisis\right)$$

$$\log\left(Equity_{t+n} / Equity_t\right) = \beta_t \log\left(World\ Equity_{t+n} / World\ Equity_t\right) + \varepsilon_{t+n}$$

$$median\left(Equity_{t+n} \,\middle|\, \frac{World\ Equity_{t+n}}{World\ Equity_t} - 1 = \theta\right) = Equity_t \exp\left(\beta_t \log\left(1+\theta\right)\right)$$

ESTIMATE BETA WITH DCB

- Beta is a correlation with the market times the ratio of the standard deviation of the firm over the market.
- Dynamic Conditional Beta (DCB) estimates these inputs and adjusts for noise and for asynchronous returns.
- Beta is different every day and is forecast from day t-1.

MODELING THE COMPONENTS

We can construct DCB from

$$\beta_{i,m,t} = \rho_{i,m,t}\sqrt{\frac{h_{i,t}}{h_{m,t}}}$$

Estimation of Dynamic Conditional Beta involves

- GJR GARCH model of the volatility of market returns
- GJR GARCH model of the volatility of firm returns
- DCC estimation of the correlation between these

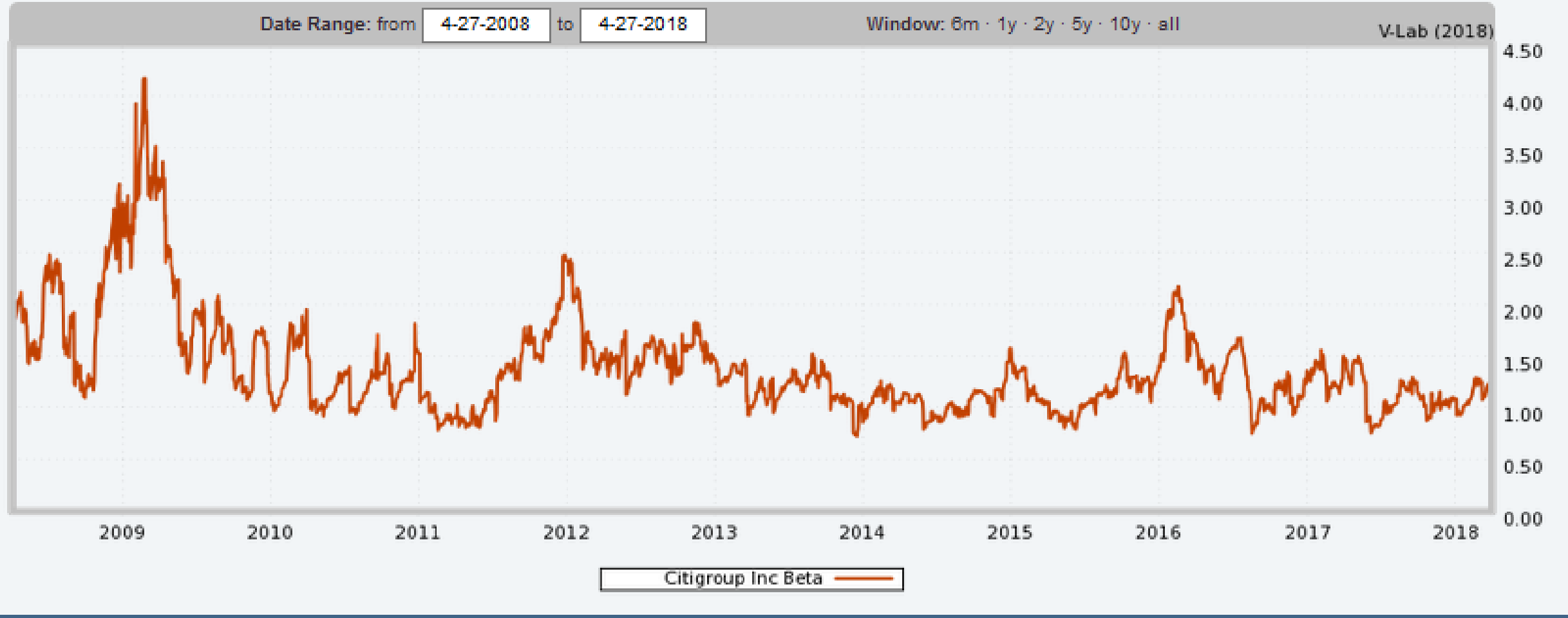
IS BETA CONSTANT?

- Test beta=constant with artificially nested model

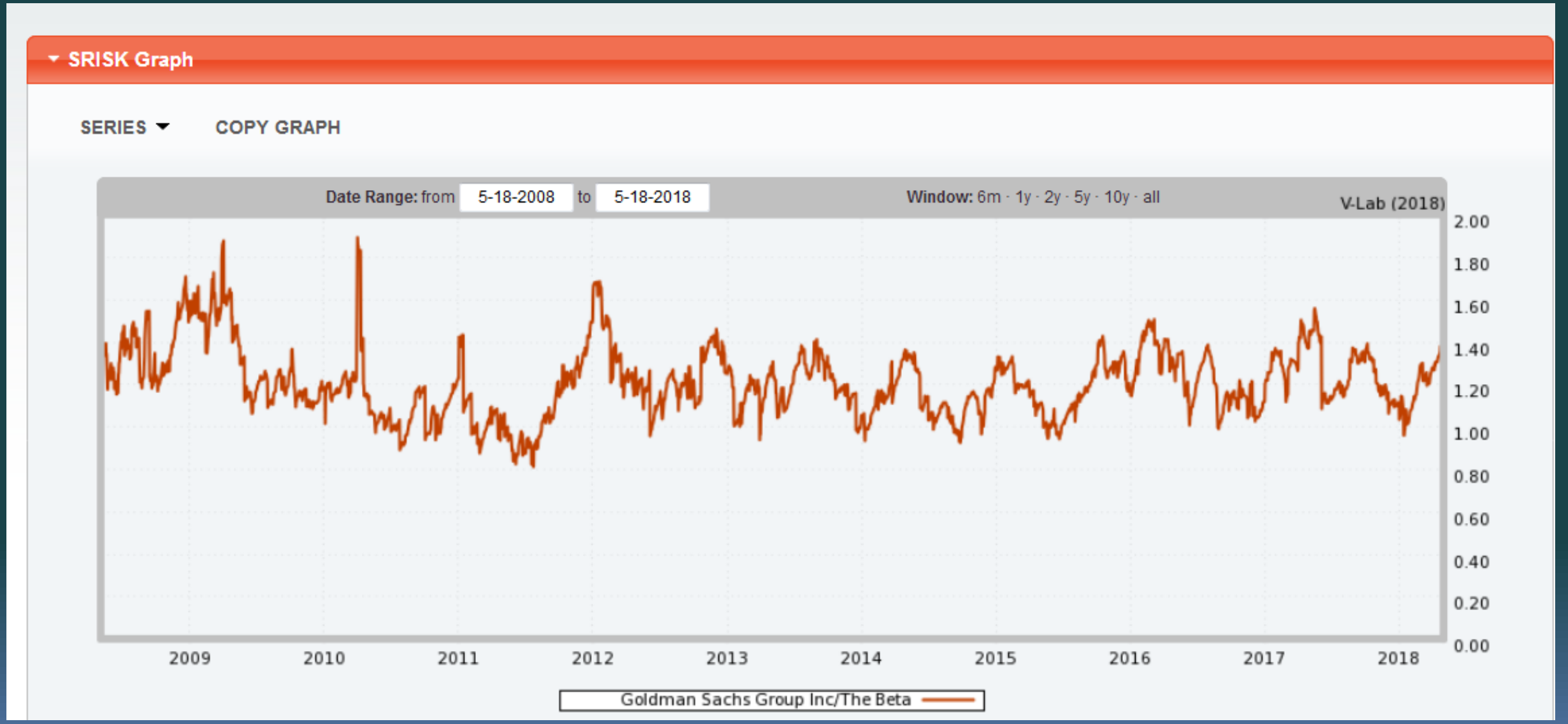
$$r_t^j = \phi r_t^m + \theta\left(\beta_t^j r_t^m\right) + \sqrt{h_t}\,\varepsilon_t^f$$

- Use $\hat{\phi} + \hat{\theta}\beta_t^j$ as the estimate of beta

BETA FOR CITIGROUP

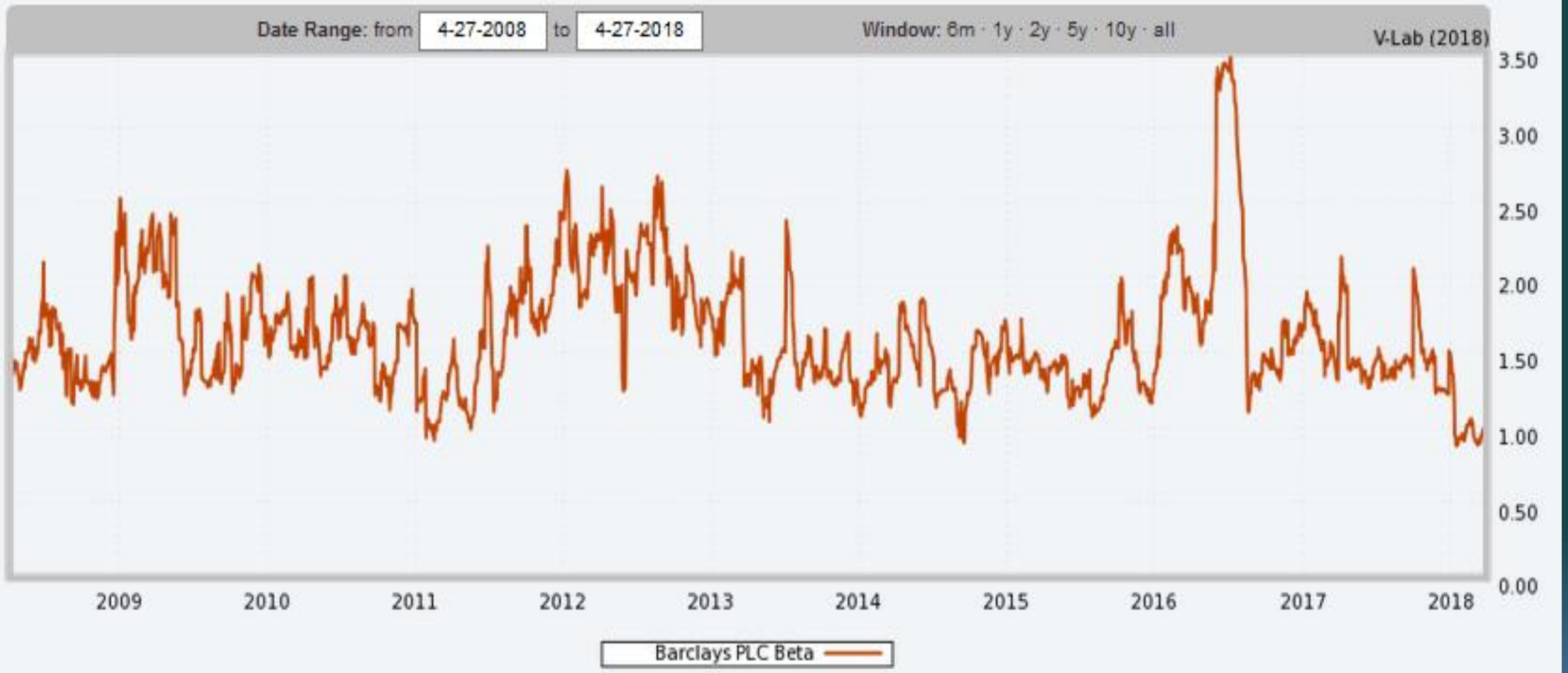


BETA FOR GOLDMAN SACHS

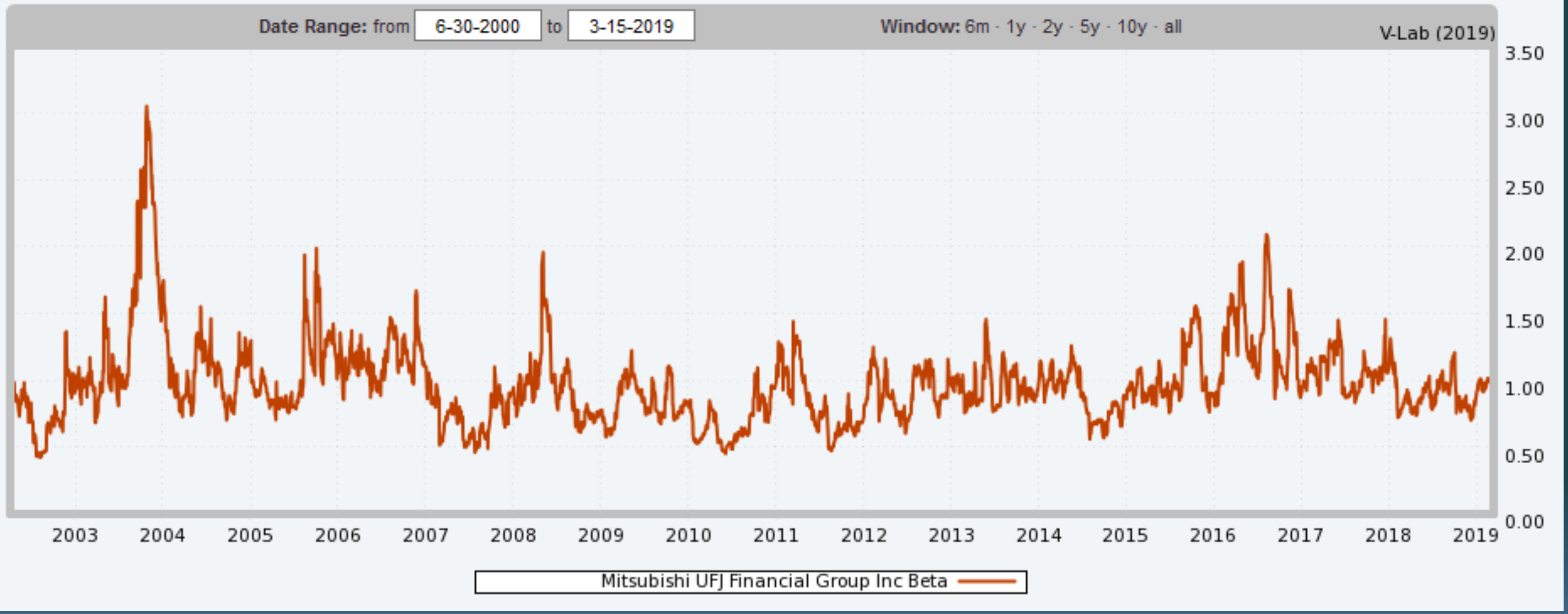


BETA FOR BNP PARIBAS

BETA FOR BARCLAY'S



BETA FOR MITSUBISHI UFJ




WHERE IS THE SRISK?

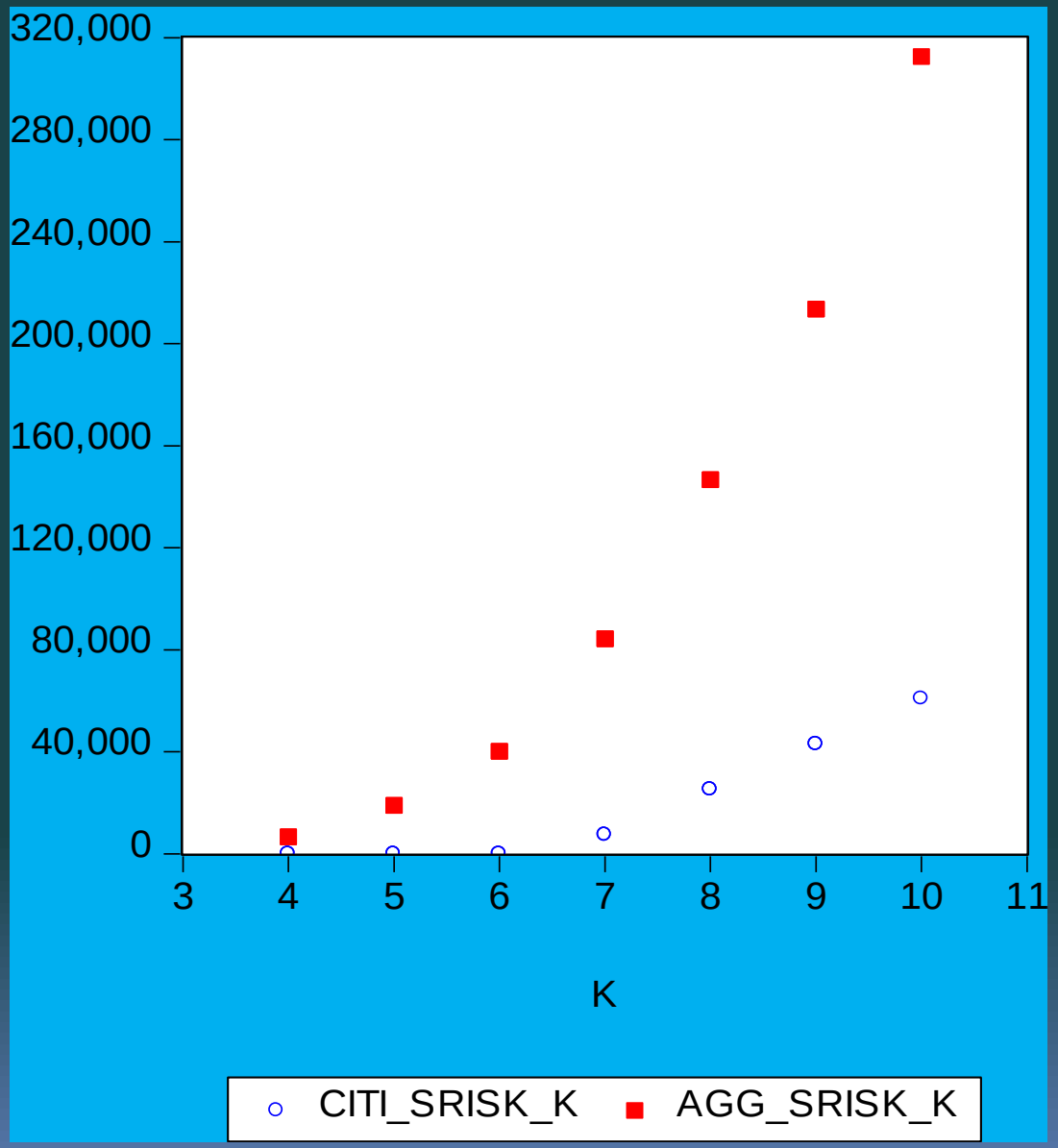
PARAMETERS IN SRISK

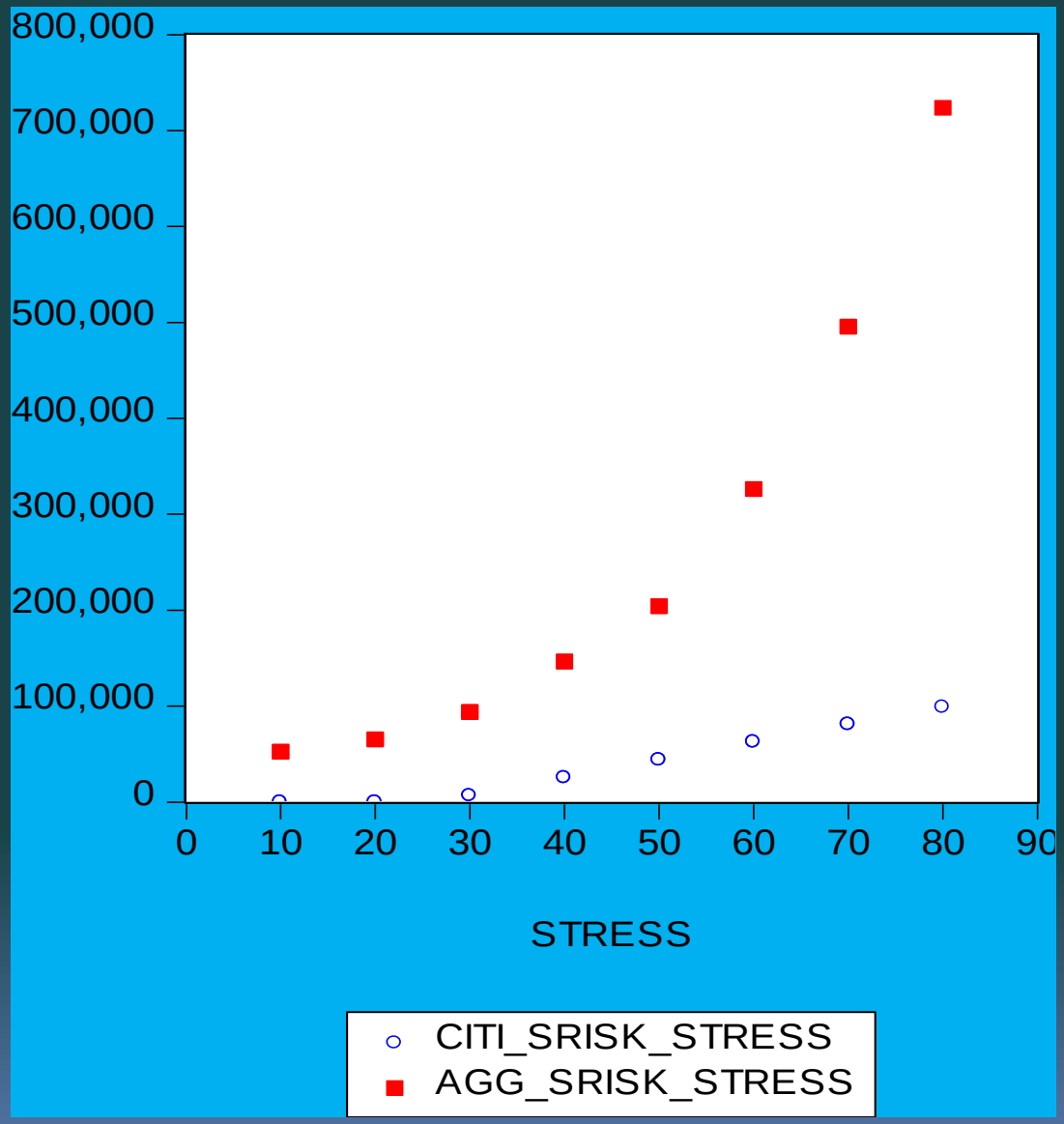
Stress is 40% decline over six months

Capital requirement is total leverage ratio of 8% with IFRS firms (European firms) at 5.5%

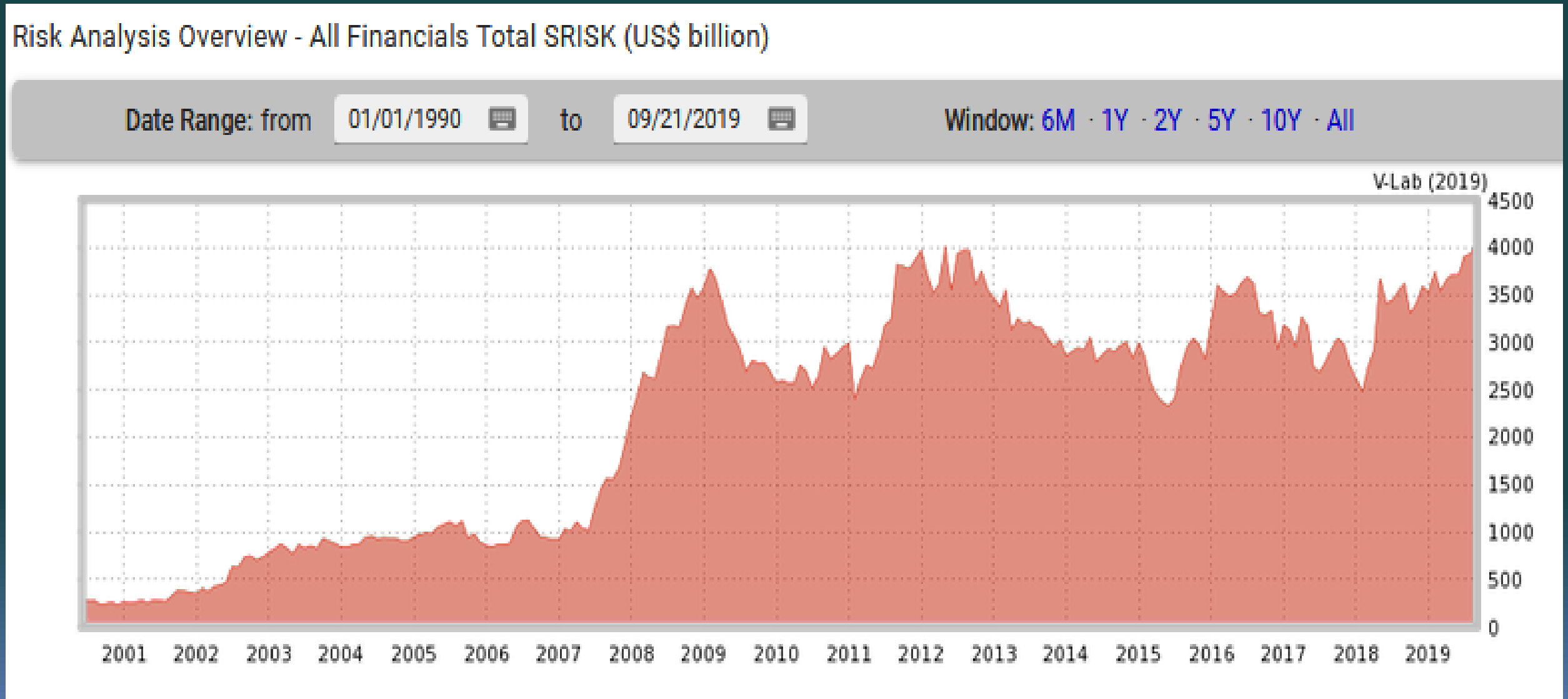
Fraction of separate accounts included as liabilities is 40%

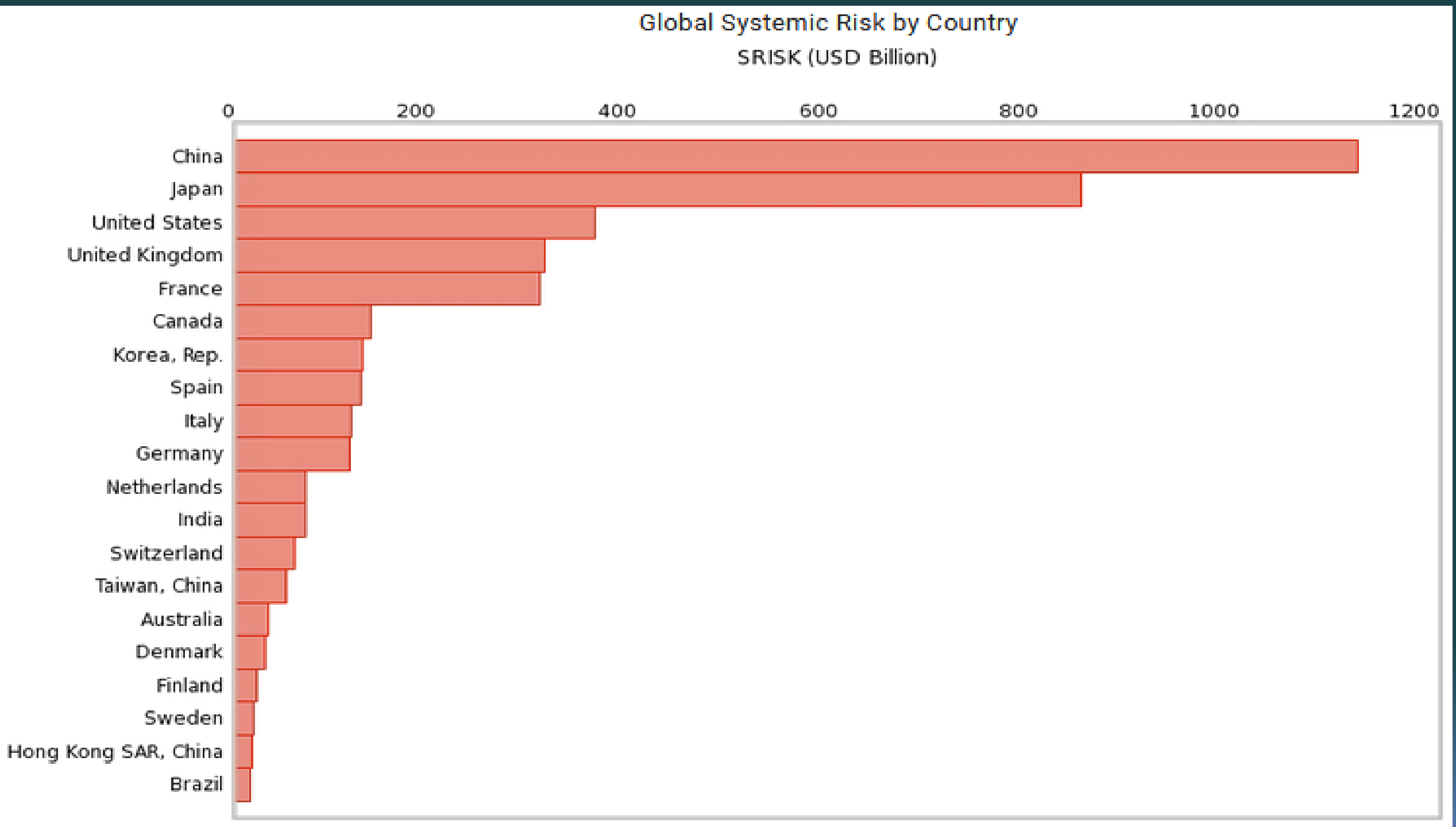
CHANGING THE INPUT PARAMETERS



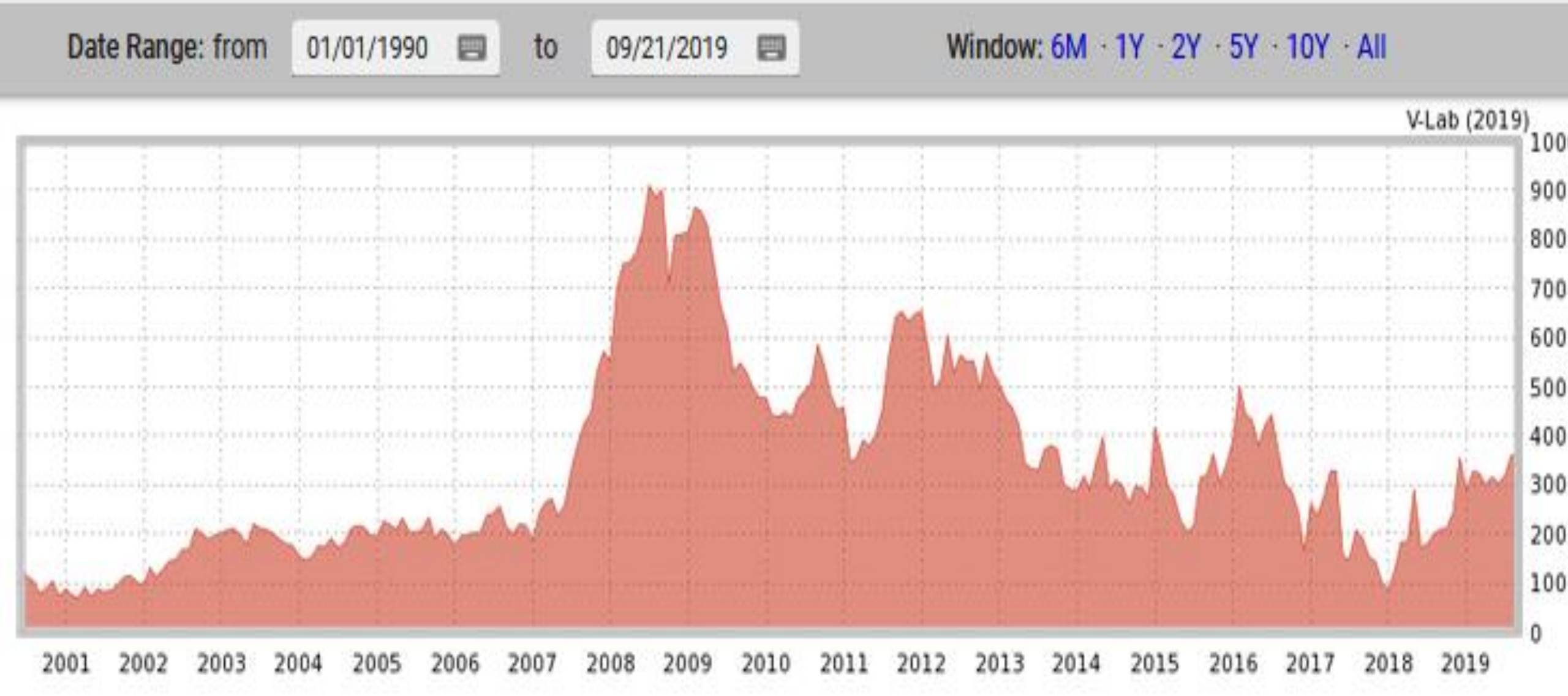


GLOBAL SRISK SINCE 2000

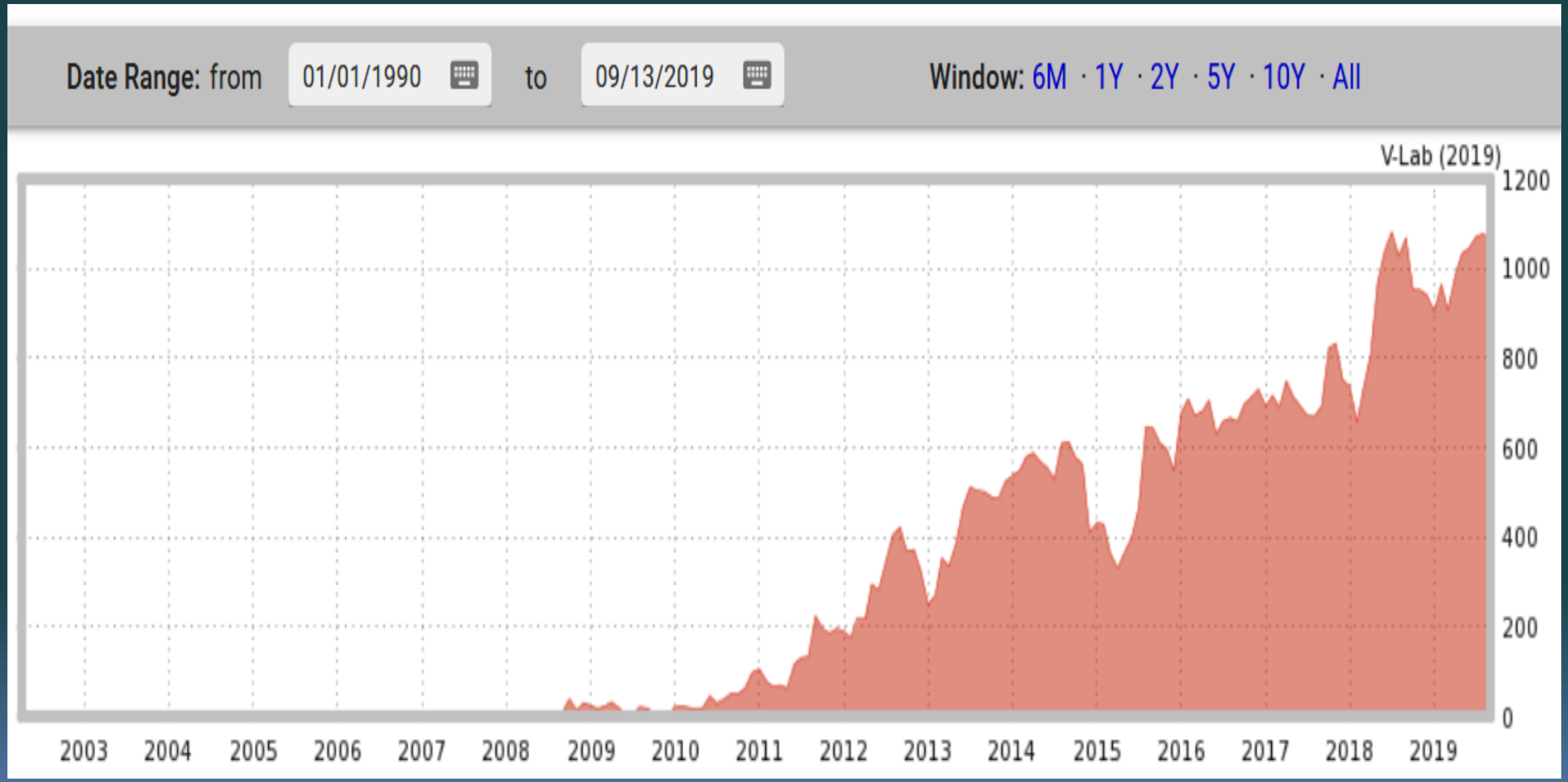



Global Systemic Risk by Country
SRISK (USD Billion)
0
200
400
600
800
1000
1200
China
Japan
United States
United Kingdom
France
Canada
Korea, Rep.
Spain
Italy
Germany
Netherlands
India
Switzerland
Taiwan, China
Australia
Denmark
Finland
Sweden
Hong Kong SAR, China
Brazil

US SINCE 2000



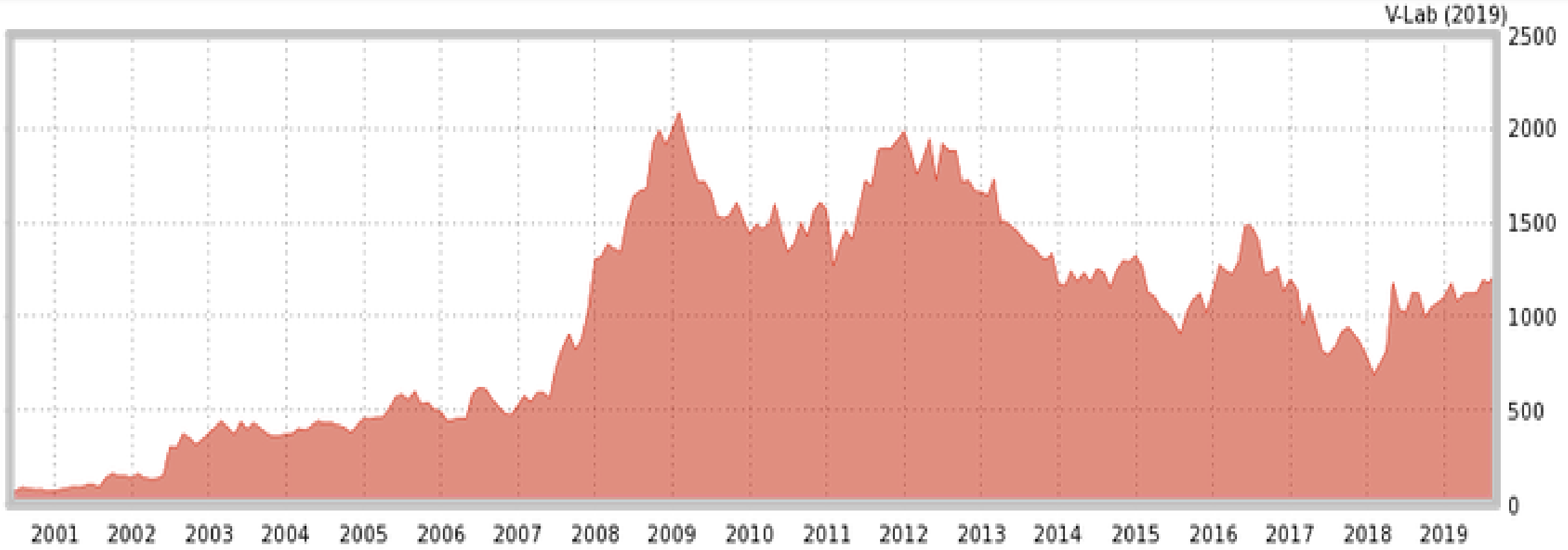
CHINA SINCE 2000



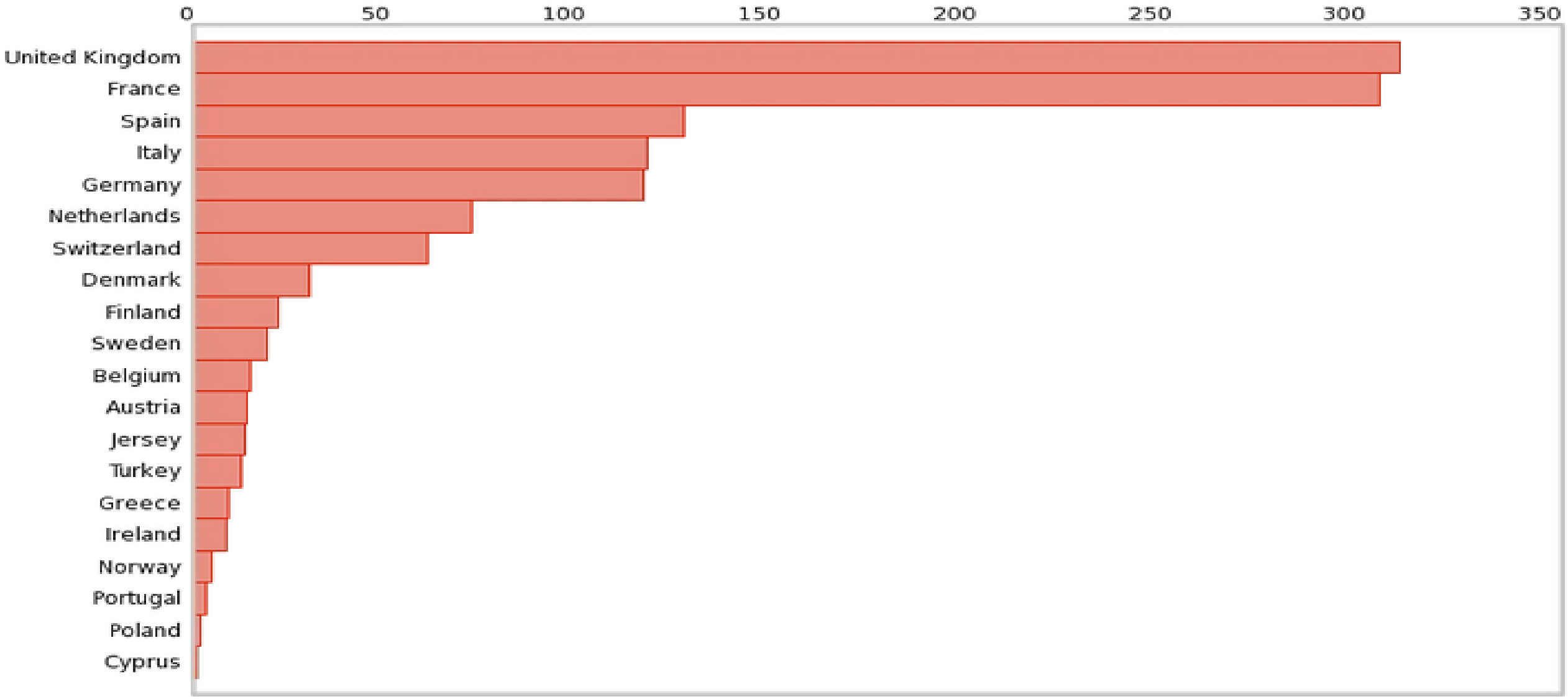
EUROPE SINCE 2000

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

Date Range: from 01/01/1990 to 09/21/2019 Window: 6M · 1Y · 2Y · 5Y · 10Y · All



WHERE IS EUROPEAN SRISK



TOP 10 FINANCIALS IN EUROPE

Institution	SRISK %	↓ SRISK ($ m)	LRMES	Beta	Cor	Vol	Lvg
BNP Paribas SA	7.64	94296.5	52.68	1.46	0.52	25.94	36.64
Credit Agricole SA*	7.10	87677.3	54.10	1.52	0.48	27.44	53.38
Deutsche Bank AG	6.49	80173.6	61.94	1.89	0.56	35.63	95.20
Societe Generale SA	5.88	72609.5	56.38	1.62	0.52	28.28	62.08
Barclays PLC	5.46	67393.1	54.68	1.55	0.39	33.46	46.58
Banco Santander SA	4.89	60317.9	55.39	1.58	0.52	29.69	24.69
HSBC Holdings PLC	4.43	54719.2	41.35	1.04	0.52	21.03	17.49
London Stock Exchange Group PLC	3.88	47878.0	43.14	1.11	0.24	39.06	38.27
UniCredit SpA	3.09	38195.6	58.76	1.73	0.48	38.03	33.30
ING Groep NV	2.98	36810.3	57.33	1.67	0.50	27.83	24.47

CHANGE OVER THE LAST YEAR

Institution	↓ SRISK (t)	SRISK (t - 1)	Δ SRISK	Δ DEBT	Δ EQUITY	Δ RISK
BNP Paribas SA	94296.5	104714.0	-10417.4	-15147.6	4992.9	-262.7
Credit Agricole SA*	87677.3	80973.7	6703.6	4218.6	1559.7	925.3
Deutsche Bank AG	80173.6	78554.5	1619.1	-971.8	2436.0	154.9
Societe Generale SA	72609.5	64919.6	7689.9	3480.0	3589.2	620.8
Barclays PLC	67393.1	61973.1	5420.1	2389.1	2867.0	164.0
Banco Santander SA	60317.9	51205.5	9112.4	3794.8	5111.7	205.9
HSBC Holdings PLC	54719.2	27841.7	26877.5	7890.3	10427.9	8559.4
London Stock Exchange Group PLC	47878.0	47573.8	304.2	5451.8	-5928.9	781.3
UniCredit SpA	38195.6	36685.5	1510.1	-660.9	1865.1	305.9
ING Groep NV	36810.3	34367.8	2442.4	-1385.5	4530.7	-702.8

HOW MUCH SRISK IS TOO MUCH?

MEASURING THE PROBABILITY OF A FINANCIAL CRISIS

- Engle and Ruan, (2019), Proceedings of the National Academy of Science
- When a country has a certain level of SRISK; what is the probability that it is in a crisis? Probability of Crisis
- Can we identify a level of SRISK_Capacity that keeps the probability of a crisis below 50%?

MANAGING SRISK

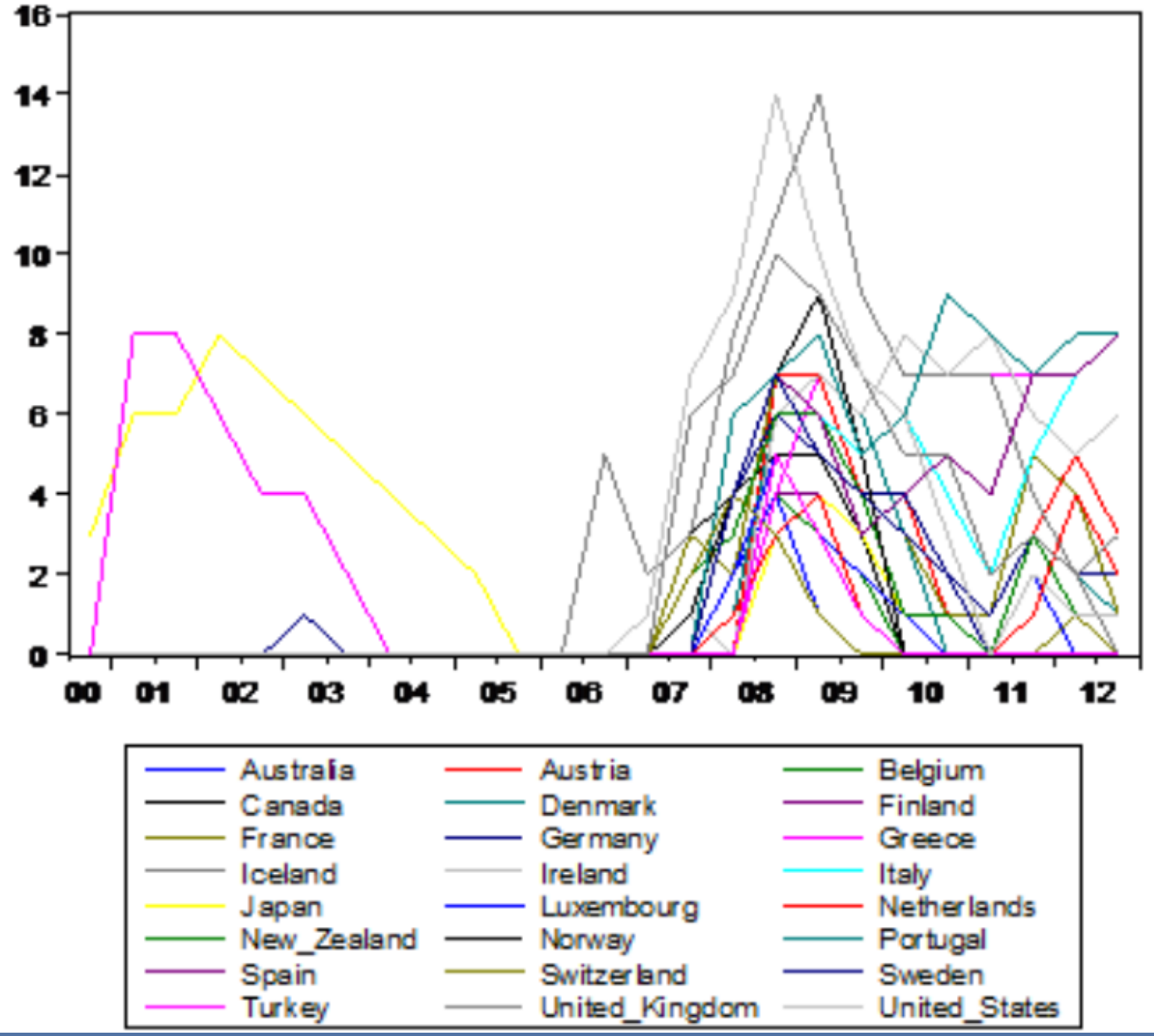
- If SRISK is a large fraction of Total Assets, then asset sales will be costly and will be likely to lead to a fire sale spiral.

- Appropriate risk measure is : rSRISK/TA/K

ROMER AND ROMER(2016) CRISIS INDICATOR

- For 24 industrial countries a semi-annual indicator of crisis intensity is extracted from OECD Reports 2000-2012.
- Measure ranges from 0 to 15 as a measure of credit disruption.
- Below 4 is called "minor credit disruption."

Figure SI-1: **Romer-Romer crisis severity over time by country**



TOBIT ECONOMETRICS

- Panel regression with country and (in first model) time fixed effects.
- Model is fit by Tobit as there are many zeros in dependent variable.
- For each country and time, calculate the probability that
- Crisis Indicator > "minor credit event"
- Calculate the Capacity which is the
  - SRISK that will bring the probability of a crisis above .5

TOBIT ECONOMETRICS

- $$y = \begin{cases} yl & if \quad yl > 0 \\ 0 & otherwise \end{cases}$$
$$yl = X\beta + \sigma\varepsilon \qquad \varepsilon \sim N(0,1)$$

- For some positive number q,

$$P(y > q|X) = P(yl > q|X) = P\left(\varepsilon > \frac{q - X\beta}{\sigma}|X\right) = 1 - \Phi\left(\frac{q - X\beta}{\sigma}\right)$$

- Implement with six monthly moving average and extrapolate to the present.

SRISK_CAPACITY

$$P\left(y > 4 \middle| X\right) = 1 - \Phi\left(\frac{4 - X\beta}{\sigma}\right) = 50\% \ when \ 4 = X\beta$$

$$SRISK\_CAPACITY = SRISK + TA * k * \frac{4 - X\hat{\beta}}{\hat{\beta}_1}$$

- Compute for Country Model and Global Model

Table 5: **Equation 3c: Tobit Model (Using leave-one-out sum for world variables)**
Standard errors are reported in parentheses. ***, ** and * represent 1%, 5% and 10% significance, respectively.

	Dep Var: CRISIS			
	(1)	(2)	(3)	(4)
SRISK/(TA*k)	18.179***	12.997***	12.681***	15.398***
	(1.209)	(1.375)	(1.315)	(1.392)
D.SRISK/(TA*k)	6.822***		4.118**	
	(1.947)		(1.894)	
World SRISK/(TA*k)		14.300***		
		(2.413)		
D.World SRISK/(TA*k)		8.245***		
		(2.808)		
World SRISK/MV			9.921***	
			(1.551)	
World log SRISK				1.845***
				(0.364)
D.World log SRISK				4.095***
				(1.012)
var(e.CRISIS)	11.185***	9.964***	9.924***	10.716***
	(1.273)	(1.123)	(1.119)	(1.214)
Country FE	Yes	Yes	Yes	Yes
Pseudo R^2	0.260	0.290	0.285	0.281
Observations	561	561	561	561

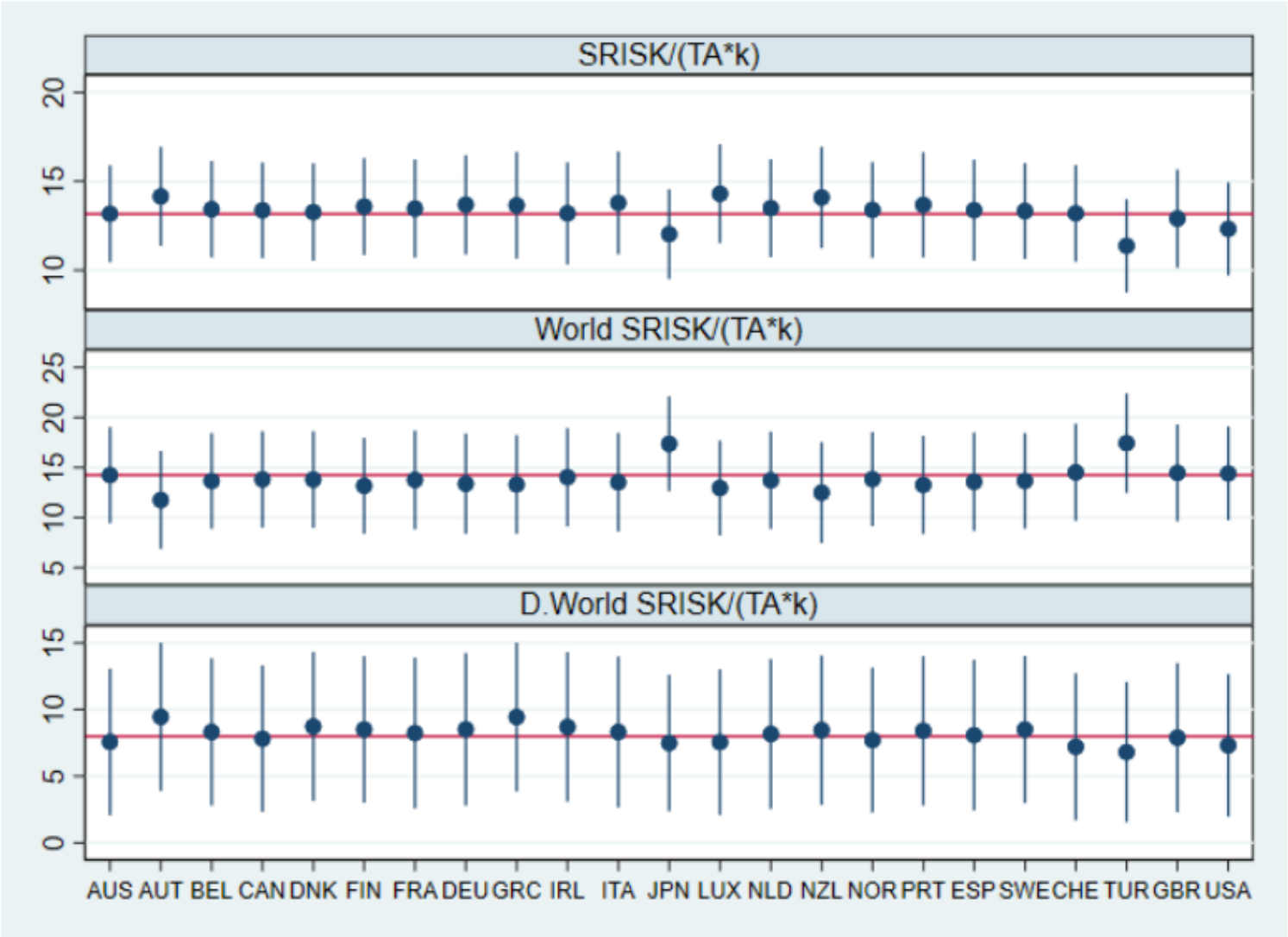
MODEL FEATURES TWO EXTERNALITIES

THE RISK OF AN UNDERCAPITALIZED FIRM DEPENDS UPON THE UNDERCAPITALIZATION OF OTHER FIRMS IN THE SAME COUNTRY

THE RISK OF AN UNDERCAPITALIZED COUNTRYS FINANCIAL SYSTEM DEPENDS UPON THE UNDERCAPITALIZATION OF THE REST OF THE WORLD

PROVIDES A MOTIVATION FOR COUNTRY AND GLOBAL COORDINATION AND REGULATION

Figure SI-27: Estimates for global model: Dropping one country at a time



This graph shows the stability of coefficient estimates in the global model by plotting the coefficients and the 95% confidence intervals estimated with one country dropped from the sample at a time. The horizontal axis lists the country that is dropped. The horizontal line in each subgraph indicates the level of the coefficient obtained from the full sample of 23 countries.

CAN WE DO BETTER WITH DIFFERENT STRESS TEST PARAMETERS?

We reestimate the model using stress of 30% to 60%

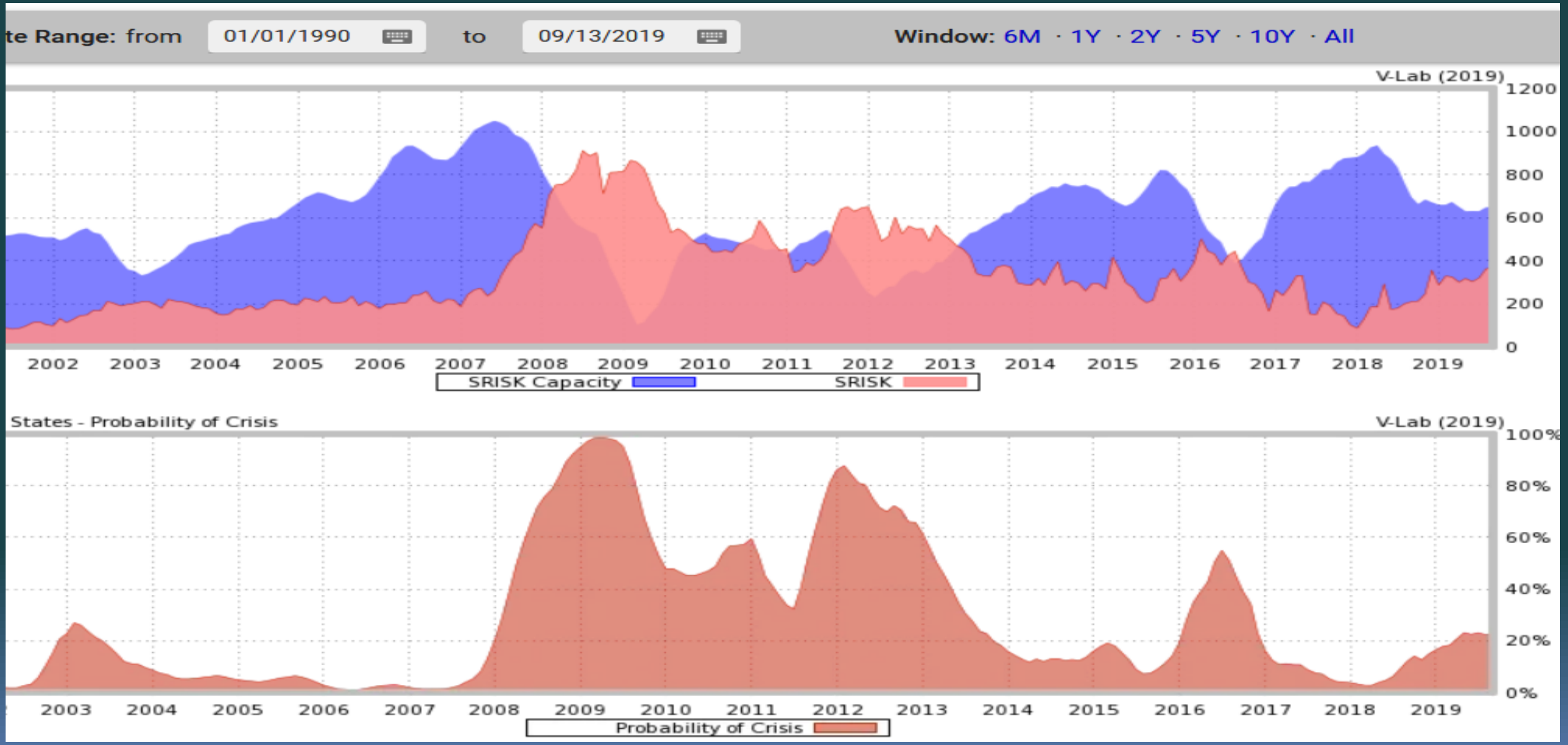
We use capital ratios from 4% to 10%, with and without the IFRS discount for European financials

We use proportions of separate assets for life insurers from 0 to 100%

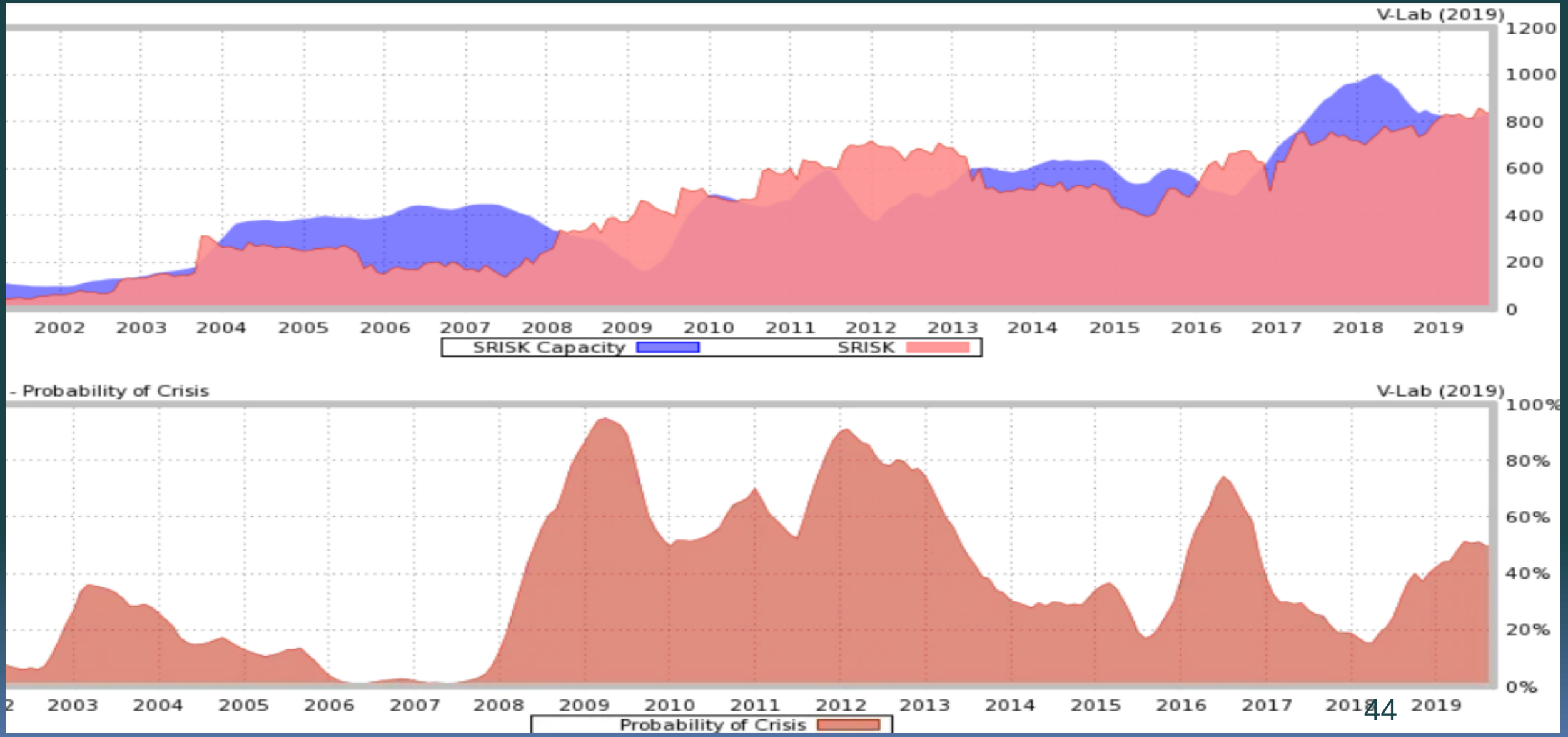
Then reestimate the two models. This is over 200 additional Tobit panel regressions.

The highest log likelihood for the global model is when stress=60%, k=4% and separate assets are at 0%. However the improvement is not significant by a Diebold Mariano test.

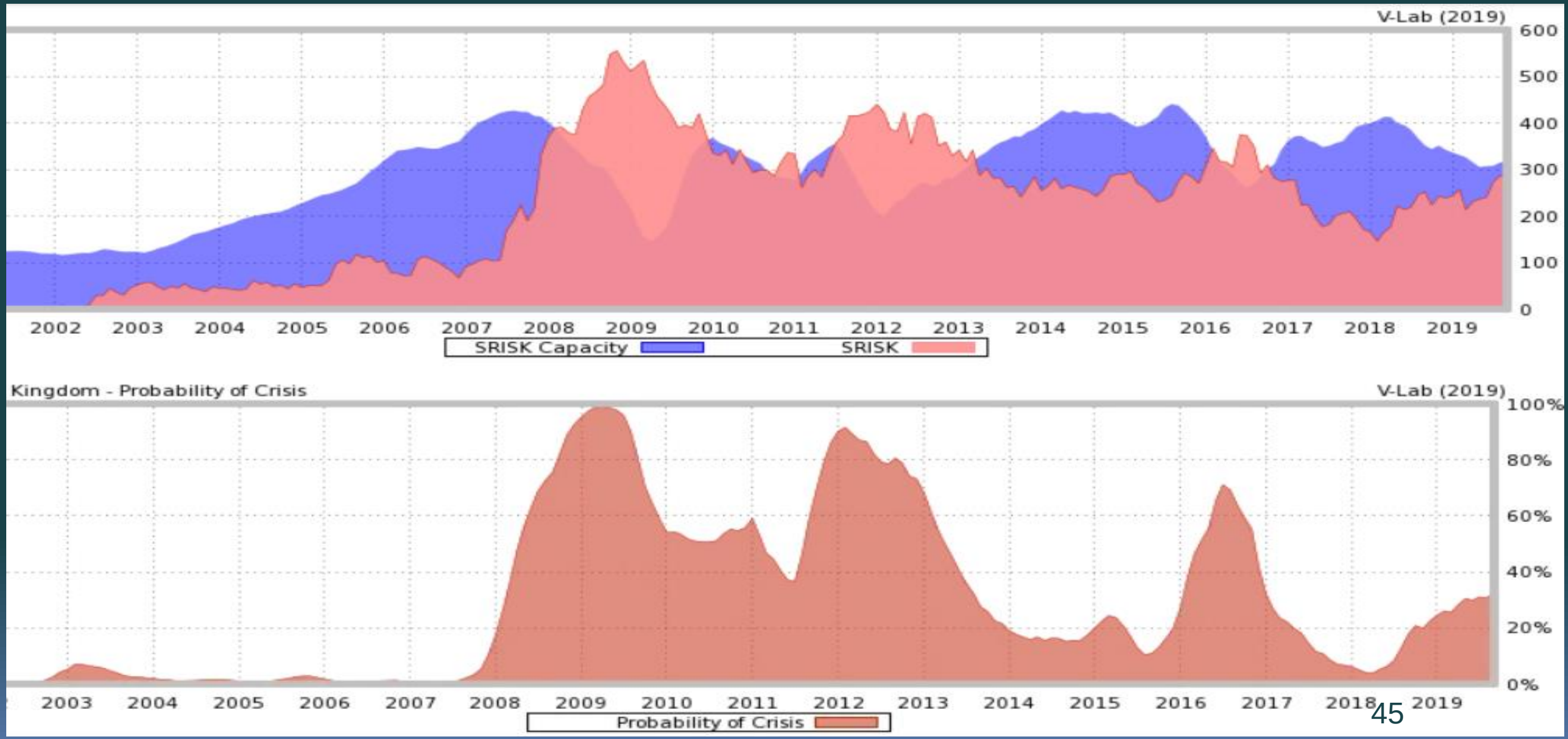
US SRISK Capacity and Probability of Crisis



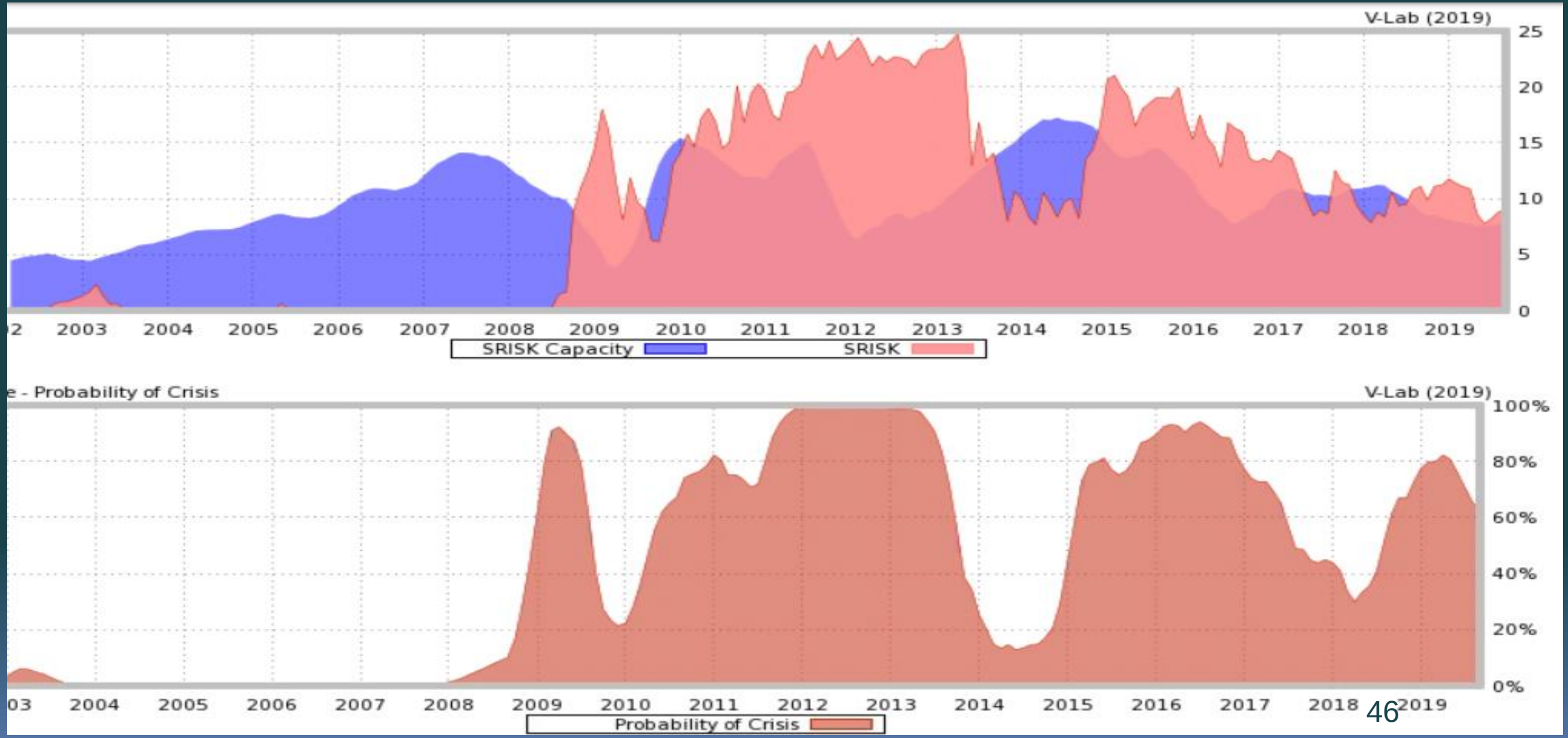
Japan SRISK and Probability of Crisis



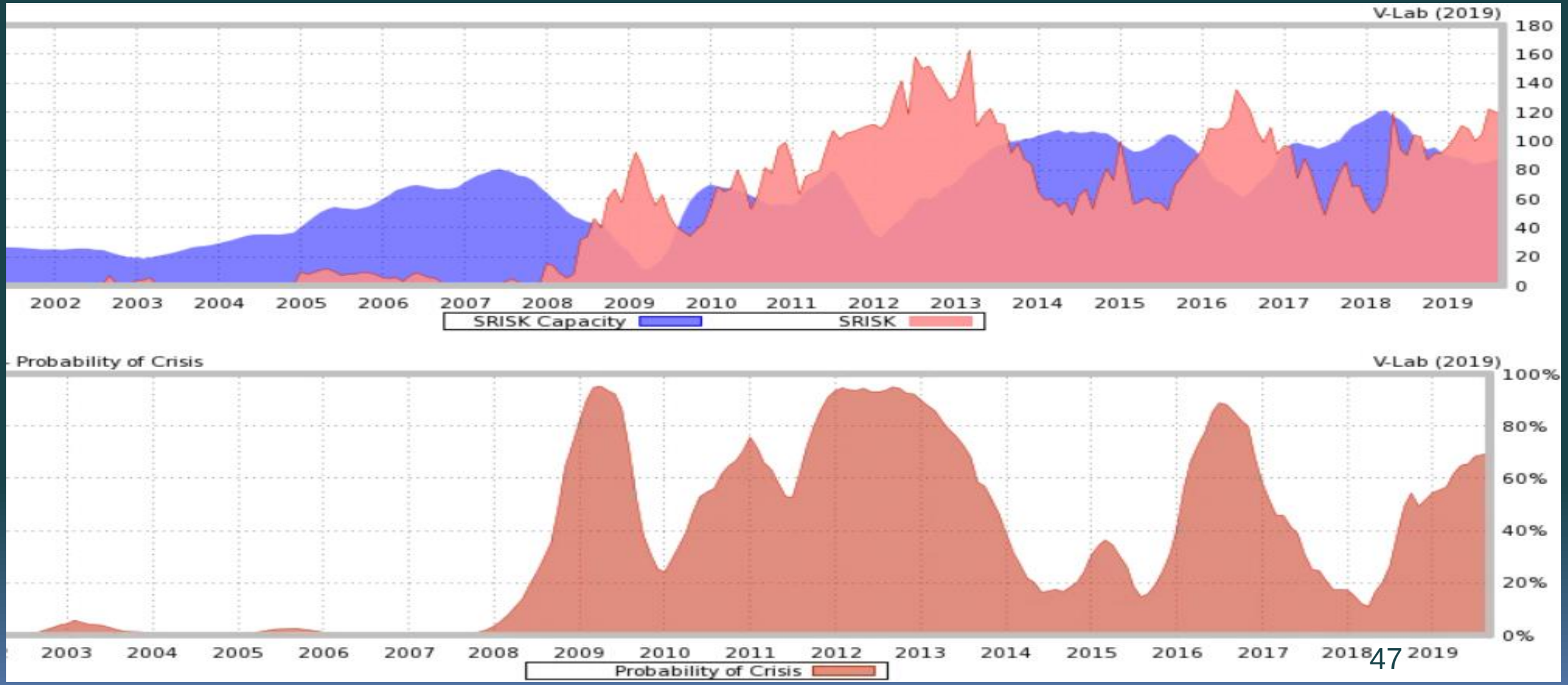
UK SRISK and Probability of Crisis



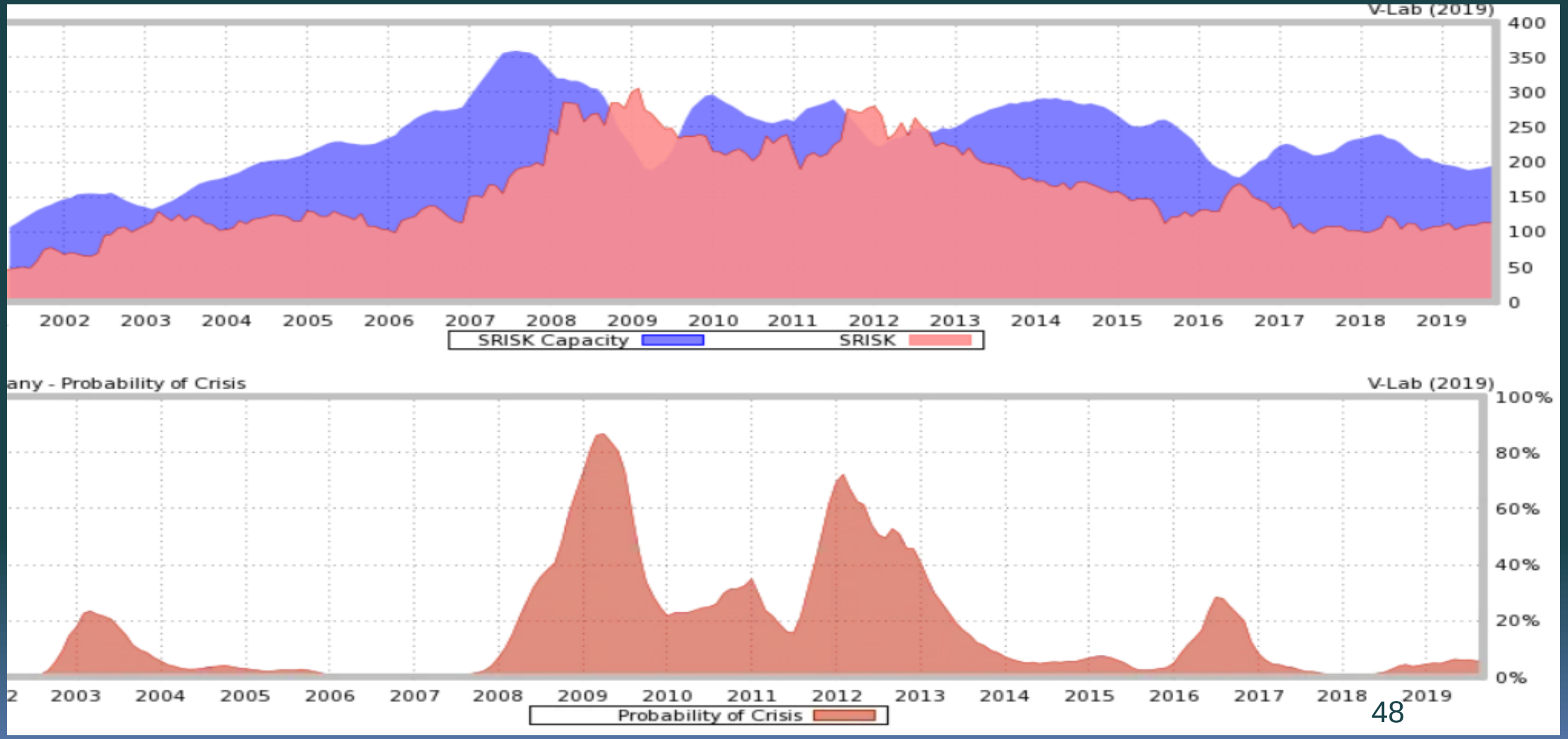
Greece SRISK and Probability of Crisis



Spain SRISK and Probability of Crisis



Germany SRISK and the Probability of Crisis



What is in their future?