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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.
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:

\[
SRISK_{i,t} = E_{t-1}(Capital\ Shortfall_{i} | Crisis)
\]

\[
= E_{t-1}(k(Debt + Equity) - Equity | Crisis)
\]

\[
= kDebt - (1 - k)(1 - LRMES_{i,t}) Equity_{i,t}
\]

- 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.
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
KEEP BAILING!

FINANCIAL INSTITUTIONS

TAXPAYERS

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6/19/2014
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.
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

\[
\begin{pmatrix}
    y_t \\
    x_t
\end{pmatrix}
\mid \mathcal{F}_{t-1} \sim N\left( \mu_t, H_t \right) = N\left( 
\begin{pmatrix}
    \mu_{y,t} \\
    \mu_{x,t}
\end{pmatrix},
\begin{pmatrix}
    H_{yy,t} & H_{yx,t} \\
    H_{xy,t} & H_{xx,t}
\end{pmatrix}
\right)
\]

- Then

\[
y_t \mid x_t, \mathcal{F}_{t-1} \sim N\left( \mu_{y,t} + H_{yx,t} H_{xx,t}^{-1} \left( x_t - \mu_{x,t} \right), H_{yy,t} - H_{yx,t} H_{xx,t}^{-1} H_{xy,t} \right)
\]

- Hence:

\[
\beta_t = H_{xx,t}^{-1} H_{xy,t}
\]
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 $\frac{h_{yx,t}}{h_{xx,t}}$ 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:

$$y_t = \phi' x_t + (\lambda \circ \beta_t)' x_t + \nu_t$$

- 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*
GLOBAL SYSTEMIC RISK
Time zones

Figure 1
Condition on $t-2$

$$\begin{pmatrix}
R_{i,t} \\
R_{m,t} \\
R_{m,t-1}
\end{pmatrix} \bigg| \mathcal{F}_{t-2} \sim N\left(0, H_t\right)$$

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:

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

- Where \( u \) will be an MA(1) GARCH
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 ratio of 5.5% to reflect the expanded balance sheet.
GLOBAL SRISK
SINCE 2000

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

Date Range: from 06/2000 to 05/2014
Window: 6m · 1y · 2y · 5y · all

VOLATILITY INSTITUTE 6/19/2014
Risk Analysis Overview - China Financials Total SRISK (US$ billion)
Risk Analysis Overview - Greece Financials Total SRISK (US$ billion)
<table>
<thead>
<tr>
<th>Company</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bank of America Co</td>
<td>1</td>
</tr>
<tr>
<td>JPMorgan Chase &amp; Co</td>
<td>2</td>
</tr>
<tr>
<td>Citigroup Inc</td>
<td>3</td>
</tr>
<tr>
<td>Prudential Financial</td>
<td>4</td>
</tr>
<tr>
<td>MetLife Inc</td>
<td>5</td>
</tr>
<tr>
<td>Morgan Stanley</td>
<td>6</td>
</tr>
<tr>
<td>Goldman Sachs Group</td>
<td>7</td>
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<tr>
<td>Lincoln National C</td>
<td>8</td>
</tr>
<tr>
<td>Hartford Financial</td>
<td>9</td>
</tr>
<tr>
<td>SLM Corp</td>
<td>10</td>
</tr>
<tr>
<td>Principal Financia</td>
<td>11</td>
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<tr>
<td>Genworth Financial</td>
<td>12</td>
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<tr>
<td>State Street Corp</td>
<td>13</td>
</tr>
<tr>
<td>Bank of New York M</td>
<td>14</td>
</tr>
<tr>
<td>Protective Life Co</td>
<td>15</td>
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<tr>
<td>E*TRADE Financial</td>
<td>16</td>
</tr>
<tr>
<td>First Niagara Fina</td>
<td>17</td>
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<tr>
<td>Zions Bancorporati</td>
<td>18</td>
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<tr>
<td>CNO Financial Grou</td>
<td>19</td>
</tr>
<tr>
<td>First Horizon Nati</td>
<td>20</td>
</tr>
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</table>
How can you validate a systemic risk model?
Global Systemic Risk Rankings

“A Look Back”
BAILOUT PREDICTION

[Graph showing financial data with various companies labeled and their positions on a grid.

Note: The graph illustrates the bailout prediction based on volatility and financial injection post-2008 crisis.]
## Systemic Risk Rankings for 2008-08-29

<table>
<thead>
<tr>
<th>Institution</th>
<th>SRISK%</th>
<th>RNK</th>
<th>SRISK ($ m)</th>
<th>MES</th>
<th>Beta</th>
<th>Cor</th>
<th>Vol</th>
<th>Lvg</th>
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<tbody>
<tr>
<td>Citigroup Inc</td>
<td>13.65</td>
<td>1</td>
<td>122,135</td>
<td>5.56</td>
<td>2.16</td>
<td>0.66</td>
<td>65.8</td>
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<td>JPMorgan Chase &amp; Co</td>
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<td>80,919</td>
<td>4.89</td>
<td>1.90</td>
<td>0.61</td>
<td>63.3</td>
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<td>Freddie Mac</td>
<td>7.69</td>
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<td>68,864</td>
<td>10.39</td>
<td>4.04</td>
<td>0.37</td>
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<td>Fannie Mae</td>
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<td>66,629</td>
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<td>4.27</td>
<td>0.41</td>
<td>213.4</td>
<td>115.68</td>
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<td>American International Group Inc</td>
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<td>8.05</td>
<td>3.13</td>
<td>0.58</td>
<td>97.2</td>
<td>17.62</td>
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<td>Bank of America Corp</td>
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<td>62,016</td>
<td>4.11</td>
<td>1.60</td>
<td>0.59</td>
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<td>Merrill Lynch</td>
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<td>Morgan Stanley</td>
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<td>1.80</td>
<td>0.61</td>
<td>54.5</td>
<td>23.01</td>
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<td>1.40</td>
<td>0.62</td>
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<td>3.80</td>
<td>0.61</td>
<td>132.3</td>
<td>55.88</td>
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### Systemic Risk Rankings for 2007-01-31

<table>
<thead>
<tr>
<th>Institution</th>
<th>SRISK%</th>
<th>RNK</th>
<th>SRISK ($)</th>
<th>MES</th>
<th>Beta</th>
<th>Cor</th>
<th>Vol</th>
<th>Lvg</th>
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</thead>
<tbody>
<tr>
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<td>22.09</td>
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<td>40,848</td>
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<td>Freddie Mac</td>
<td>15.73</td>
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<td>29,087</td>
<td>1.24</td>
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<td>Fannie Mae</td>
<td>13.42</td>
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<td>24,826</td>
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<tr>
<td>Merrill Lynch</td>
<td>9.61</td>
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<td>17,769</td>
<td>2.75</td>
<td>1.16</td>
<td>0.59</td>
<td>21.5</td>
<td>10.70</td>
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<tr>
<td>Goldman Sachs Group Inc/The</td>
<td>8.73</td>
<td>5</td>
<td>16,139</td>
<td>2.90</td>
<td>1.22</td>
<td>0.57</td>
<td>24.6</td>
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<td>Lehman Brothers</td>
<td>8.46</td>
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<tr>
<td>Bear Stearns</td>
<td>8.45</td>
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<td>15,634</td>
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<td>MetLife Inc</td>
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<td>0.47</td>
<td>15.6</td>
<td>11.10</td>
</tr>
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</table>
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

<table>
<thead>
<tr>
<th></th>
<th>SRISK</th>
<th>INDPRD</th>
<th>URATE</th>
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<tbody>
<tr>
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<td>0.02</td>
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<tr>
<td>INDPRD</td>
<td>20.65***</td>
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<td>8.99**</td>
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<tr>
<td>URATE</td>
<td>0.01</td>
<td>7.39***</td>
<td></td>
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</table>
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.