Stress Testing Correlation Networks

Financial Risk and Network Theory

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Stress Testing is at the forefront of the banking regulatory agenda

Regulators are increasingly relying on Stress Tests to assess if the national or regional banking system is sufficiently capitalised to maintain the supply of bank lending in the face of adverse shocks.
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Transactions & Similarity Based Networks

Transaction: payment, trade, exposure, supply, flow, ...

Similarity: correlation, partial correlation, granger causality, transfer entropy, ...
Stress Testing Correlation Networks

We need ability to:

- Understand correlations structures of much larger scale
- Conveniently develop plausible but severe correlation scenarios
Correlation Network

We can view any matrix as a network.

We encode correlations as links between the correlated nodes/assets.

Red link = negative correlation
Black link = positive correlation

However, this simple encoding does not give us much.
Significant Correlations

Not all correlations are statistically significantly different from 0.

Absence of link marks that asset is not significantly correlated (here at 95% level).

Due to the large number of estimates, we also need for multiple comparisons correction. Eg. Bonferroni or FDR.
We can use network layouts to better detect patterns from noise.

Eg we can try a Force-Directed network layout to identify clusters.
Next, we identify the Minimum Spanning Tree and filter out other correlations (Mantegna, ‘99).

We need a distance function, here we look at maximum spanning tree with distance function: $\text{abs}(\text{cor})$

This shows us the backbone correlation structure.
Radial Tree layout

We use a radial tree layout algorithm (Bachmeier et al. ‘05) that places the assets so that:

Shorter links in the tree indicate higher correlations

Longer links indicate lower correlations

As a result, we also see how the assets cluster by asset class.
Filtering

Focus on the links in the Spanning Tree to highlight clustering structure.

Node color indicates last daily return
Green = positive
Red = negative

Node size indicates magnitude of return
Bright colors are VaR exceptions
Brexit, Friday 24 June 2016
Financial Cartography

Coordinate system

-> layout algorithm

System for visual encoding of map data

-> node sizes & colors

Dimensionality reduction & filtering

-> minimum spanning tree

Eratosthenes' map of the known world c. 194 BC
Example US Housing
In this example we look at US house prices across states. We see the US states as nodes and strong correlation between house prices as link. In 2000 the tree is very spread out and prices are going slightly up. This is a time when ABS are developed with the assumption that real-estate risk can be diversified across US states.
In 2003 we start to see some strong upward movements in prices in states like Nevada and we see a big cluster of bumper returns in Florida and states that have strong correlations with it.
As we move into 2004, into the peak of the housing bubble we see that most states now have outlier price changes and Nevada for example has an almost 12% rise in house prices in one quarter.
As we move into 2005 we look at the length of the tree. It measures the overall correlations in this system. The shorter (smaller value) the tree, the stronger the correlations. We see that the tree has been getting shorter and shorter. The assumptions behind diversification of ABS getting eroded.
In summer 2007 the housing bubble is over and we see the first negative outlier in Florida. Most of the system has become red, except a green branch on the left. We also see that the tree has been getting shorter and shorter, reaching new lows each quarter. The system is becoming highly coupled.
In 2009 we reach the peak crisis. The system has become largely red with many central states as negative outliers.

We can look at another metric on the left. Systematic risk measures how much changes in the system are driven by the largest single factor, and how much by idiosyncratic - state level - factors. We see that the system is quickly becoming governed by a single factor affecting all states.
The same dynamics continue with the “double dip” in 2011.
In Spring 2012 we see the first positive outlier in North Dakota, likely drive by the fracking boom. The rest of the system is still mostly negative.
If we fast forward to the latest observation, July 2015, we see a period of positive changes in prices with outliers scattered across the network.

We also see both systematic risk and correlations at their peak. We have not returned to the pre-bubble system state but are in a very risky territory still.
We can see this clearly by looking at the size of the tree.

First in 2010.
Then at the peak of the bubble in 2005.
Then at the peak of the crisis in 2009.
And now.
The tree has shrunk during the whole period. The correlations are now stronger than ever.

Such slow moving change is hard to notice when focusing on daily events. Like in the story of the frog put in water that is gradually heated.
Example: China hard landing
Here we see a correlation map showing the broad global markets. We see different asset classes cluster together, e.g. oil-energy, precious metals, bonds and equities clustered in the center.
Many people are worried about China. Here we do a stress test shocking Chinese equity markets 4.5% down.

We see the impact in the network. A shock like this would, based on currently observed correlations, be accompanied by large downward movements in many markets - with VIX futures and Japanese Yen having strong positive moves.
The impact would have been worse during the time period of strongest correlations, the August sell-off.
And even worse if we also increase overall correlations from 0.53 to 0.58.
However, had we done this stress test with the correlation structure experience in early 2015, the impact would have been mostly contained to Asian markets.

China became very central in the global markets during 2015.
And even less if we detach China from emerging markets.
Conclusions

Visual methods based on networks allow us to:

* understand correlations structures of much larger scale than often done before.
* conveniently develop correlation scenarios based on historical structures
* create new correlation structures

-> Correlations become a subjective variable in the stress test