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"Learn how to see. Realize that everything connects to everything else."
— Leonardo da Vinci

July 9th 2018

FASANARA CAPITAL | SCENARIOS

| THEMATIC RESEARCH | positive feedback loops series

Analysis of Market Structure: Towards A Low-Diversity Trap

How The Market Structure Weakened Progressively In Recent Reaching The Point Where It Now Looks As Bad As After A Flash Crash

Abstract: part of our series supporting the case for a 'Critical Transformation Hypothesis' in global markets, this note further analyses the structure of the market, and how it weakened under the force of positive feedback loops between public flows and the private investment community. QE/NIRP created 'Fake Markets', within which passive and quasi-passive investors blossomed, under the cover of deceptive economic narratives. We look at asset managers and ETFs as a meaningful proxy for the broader financial system, as we think they represent the weakest links, the cracks in between tectonic plates in the market crust. **We find that, over recent years, measures of market diversity and resilience fell in lockstep with measures of entropy, all the while as size rose to record levels**. Entropy in the ETF market decayed at an average rate of 4.5% per year in the last ten years, and its trend-line has almost reached 2008 levels. Measured as 'average closeness centrality', concentration in the ETF market increased by a striking 12.1% year-on-year since 2008, and its trend-line too reached levels seen in 2008. Our analysis framework borrows from complexity theory and network modelling, we investigate phase transition from one state of the market to another by applying ideas from earthquakes prediction, information theory and pure mathematics. **Looking at systemic risk as a complexity problem, we attempt a visualization of how the market structure on passive ETFs evolved over time, using agent-based modeling.** This is the visual story of how the market structure weakened relentlessly in the last ten years, **becoming more concentrated, entropic-fragile, and ready to snap. We analyze the structure of the market network during good and bad times**, trying to identify the DNA of a market crash. **The current market exhibits the typical structure visible during flash crashes, yet despite not being in one. We conclude that the market system is full, stationing on paper-thin ice, ready to transition.**

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PREVIOUSLY, ON FASANARA CAPITAL:

1. Our framework of analysis for "**Complex Markets**" (systemic risk as a complexity problem: slide 14) points to high alert for systemic risk, and impending market crash risk.

2. **TIPPING POINT ANALYSIS**: it shows that enough is enough, points to abundance of systemic risks, unstable equilibrium and market fragility. Fault lines in the system, tightness in capacity constraints and their synchronicity. Our thoughts are expanded in this video slideshow.

3. **EARLY WARNING SIGNALS ANALYSIS**: if you have reasons to believe that a cliff is approaching, you then look for confirmation signals, or **crash hallmarks**. Many are in sight today! Frequency of VAR shocks/pressure points, 'critical slowing down', 'flickering', autocorrelation, skewness of fluctuations are all general properties of systems in phase transition zone (be it a natural ecosystem, a fishery, or a financial market). **The analysis of Early Warning Signals** (slide 30) **confirms the increasing likelihood of severe market ruptures**.

4. **BUTTERFLIES ANALYSIS**: If so, you should look for triggers. Normally a fragile system can run into disorder for small changes in initial conditions, the so-called butterfly effects. Here though, more than butterflies, you see "elephants", as risk are all too evident and tangible: slides 61-66.

5. Lesson from complex theory: not one trigger, no cause and effect. Human brain tends to look for one, forgetting system as a whole (Tyson lost not to Buster Douglas, but when he was ready to go). Subprime mortgages in 2007 were there, but the system was ready to transition beforehand, that was just the trigger jumpstarting the autolytic reaction function and chain effect. When the system is tight in all directions of potential expansion, hitting capacity constraints in synchronicity, it becomes brittle, it is acting weirdly, ready to snap.

THE CRITICAL TRANSFORMATION HYPOTHESIS: POSITIVE FEEDBACK LOOPS LED INTO PHASE TRANSITION ZONE

Ever since early-2017, our theory has been that multiple years of monumental **Quantitative Easing / Negative Interest Rates** monetary policies affected the behavioral patterns of investors and **changed the structure itself of the market,** in what accounts as **self-amplifying positive feedbacks**. Fake markets, where artificial money flows killed data dependency, affected market functioning and changed the structure itself of the market (May 2017). The positive feedback loop between fake markets and investors created system instability, and divergence from equilibrium (July 2017). That is the under-explored, unintended consequence of extreme monetary policymaking. A jammed-up, stuffed-turkey market system, where it is easy to detect heavy concentration risks, all the while as its size (i.e. valuations across both equities and bonds) got ginormous:

- **Concentration of size on few top players**: top 8 AM shops account today for $22trn, from $8trn in 2006
- **Size of 'passive' or 'quasi passive'**: considering leverage and turnover, ca. 90% of daily flows in equity today are passive
- **Correlation of risks across investment strategies**: ca. 90% of strategies today are either TREND-linked or VOLATILITY-linked

For those interested to dive deeper, here is the story of how $15trn of money printing by major Central Banks in the last ten years, of which $3.7trn in 2017 alone, were joined by total assets of $10trn managed into buying the same safe and risk assets across, with leverage, indiscriminately (slide 22): how **'market risk'** became **'systemic risk'.**

ANALYSIS OF THE MARKET STRUCTURE: WEAKEST LINKS

As we try to substantiate the view with hard data, we now further analyze the market structure across the two dimensions which may well represent its fault lines:

- Concentration of size on few top players**:** we use as proxy the top 22 asset managers globally
- Size of 'passive' or 'quasi passive': we use as proxy the top 2000 ETFs, as represented by their largest 350 since 2007

We focus on largest ETFs and largest Asset Managers as we believe them to be the cracks in the financial system, the fault lines that lead to market fragility, hence our focus on them as a meaningful proxy for the broader financial market. In so doing, we consider a static and a dynamic picture:

- Static snapshot of the structure of the market
- Dynamic evolution of the structure over time

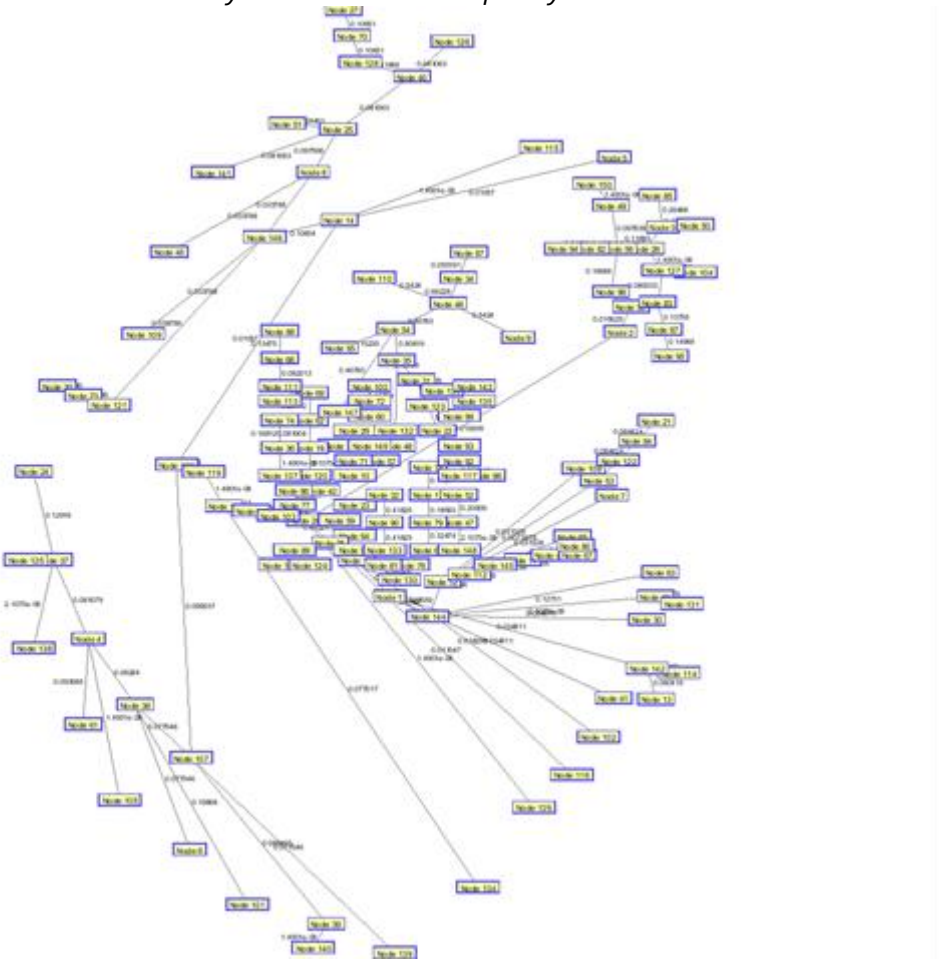
The analysis that follows is powered by our Fasanara Analytics team, a proud addition to the Fasanara family of late. It is not intended to be a finished product, but rather a work-in-progress, along the way of truth-seeking data mining. Any feedback/critique, please reach out, happy to collaborate and incorporate.

MEASURES OF HOW THE MARKET STRUCTURE WEAKENED OVER TIME

Our analysis framework borrows from complexity theory and network modelling, we investigate phase transition from one state of the market to another by applying ideas from earthquakes prediction, information theory and pure mathematics.

We model the market as a network of agents (the nodes of the figure below) whose strength of interaction (edges, distance) is computed using a non-linear transformation of the pairwise correlations; for details on the network construction please see Onnela et al. "Dynamics of market correlations: Taxonomy and portfolio analysis".

Figure 1 |
The Market As A Network Of Agents
Systemic Risk as a Complexity Problem



Source: Fasanara Analytics, Bloomberg
Data: Minimum spanning tree
Agents are the nodes, the strength of interaction are the edges
Computed using a non-linear transformation of the pairwise correlations

ANALYSIS OF LARGEST ASSET MANAGERS

The chart below is derived from the market structure as represented by nodes and edges. It measures the pairwise correlation across nodes for the largest Asset Managers globally.

In the chart, we observe recurrent spikes in average pairwise correlation, with a frequency of approximately 6 months, caused by variously meaningful price declines in the stock market (although never truly corrections, but rather speed bumps).

During market stress, correlation across asset classes and market players goes higher, reaching one at mayhem. This is no surprise and nothing new. Here instead, what we want to emphasize is the frequency of correlation flickering, which reminds of the early tremors occurring ahead of earthquakes - using insights from geophysics. The ripples may then be used as the Richter scale of a financial seismograph.

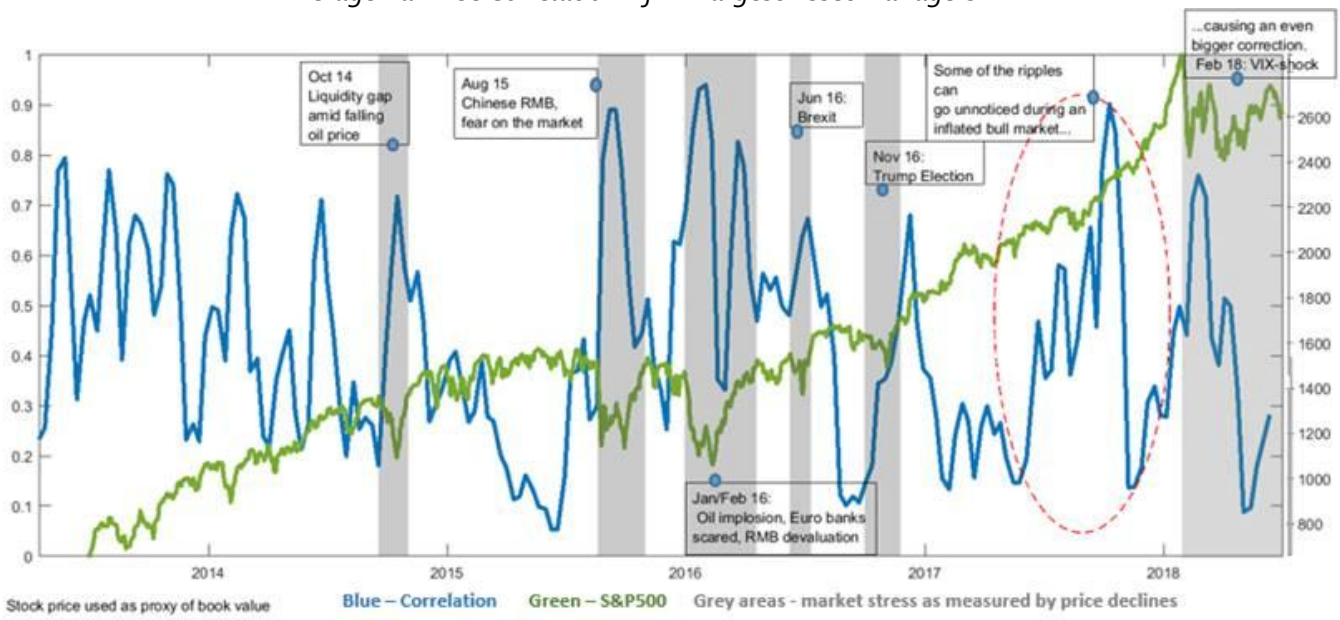
Borrowing from earthquake studies, in analogy, we allude that **each ripple weakens the market structure**, exposing fault lines, and nears the moment when full release of the energy in the system may occur, with severe effects. As ripples keep propagating across markets, the probability of a major reset increases: the instability is building up until eventually the pressure is released when the market structure falls under the weight of any new price correction, at some point along the way. Every new ripple manifesting itself may then represent a tick on the countdown clock towards phase transition.

Like tectonic plates do for the lithosphere, the market system can absorb latent energy, for long periods, in what physicist call a 'metastable state', until such point in time when it gets abruptly and devastatingly released.

Sheer-sized Asset Managers and passive and 'quasi-passive' vehicles (a broad category which includes ETFs, Risk Parity, Risk Premia / factor investing, Low-Vol vehicles, Short-Vol ETPs and option overwriting/variable annuities plans, AI / Quant funds, Trend-Chasing Algos, more on it here) are the cracks in between tectonic plates in the market crust, hence our focus on them as a meaningful proxy for the broader financial market.

As to when energy for markets may get released, this is an evolving idea. We give our take here (at slide 30).

Figure 2 |
Market System Absorbing Latent Energy, One Ripple At A Time: The Case of The Largest Asset Managers
Average Pairwise Correlation Of 22 Largest Asset Managers



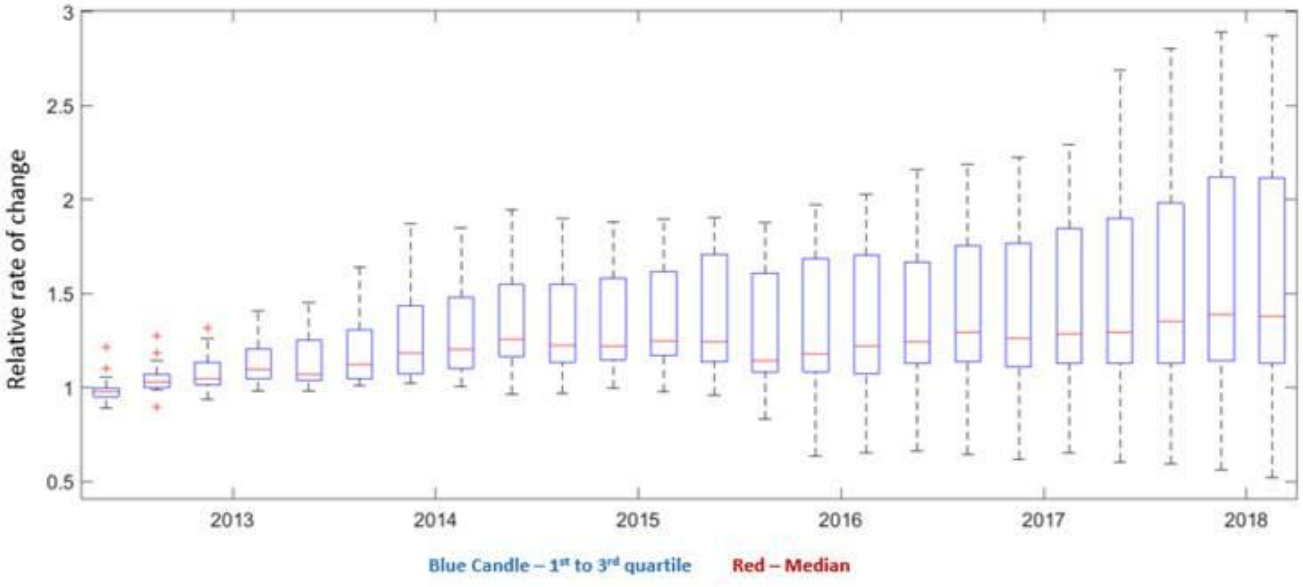
Source: Fasanara Analytics, Bloomberg

In our next chart we focus instead on the **ballooning size of the passive asset manager industry, and its progressive concentration**. We use a boxplot representation of the relative increase in Asset Under Management for the top 22 managers globally, since mid-2012. Two phenomena can be inferred: the mean size of the managers is increasing over time (50% over 5 years, within our sample of listed companies); the variability is increasing over time too. As some of the smaller managers are getting smaller, some big players are getting considerably bigger (between 100% and 400% in 5 years), suggesting a concentration of the passive industry in the hands of few strategic players.

The conclusion is hardly a surprise, if one considers that Blackrock, Vanguard and State Street alone today manage almost USD 15 trillions. Which is 22 times the total stock market capitalization of a G8 country like Italy, to put things in perspective. Praise be.

As numbers go out of whack, such concentration is under-researched, to say the least. Naturally, the 'too-big-to-fail' concept applied to banks in the aftermath of the Great Financial Crisis should be expanded to include asset managers, for some of them to be considered G-SIFI (Global Systemically Important Financial Institutions). But this is not happening - as we discuss in Systemic Risk is Not Just About Banks: Look at Funds. Not long ago, the Financial Stability Oversight Council commissioned a study on the matter, but no steps have since been taken to adapt the regulatory oversight for these institutions.

Figure 3 |
Asset Managers: Ever Bigger, and More Heavily Concentrated
Relative Size Increase Over Time for 22 Top Managers Globally



Source: Fasanara Analytics, Bloomberg

ANALYSIS OF LARGEST ETFs

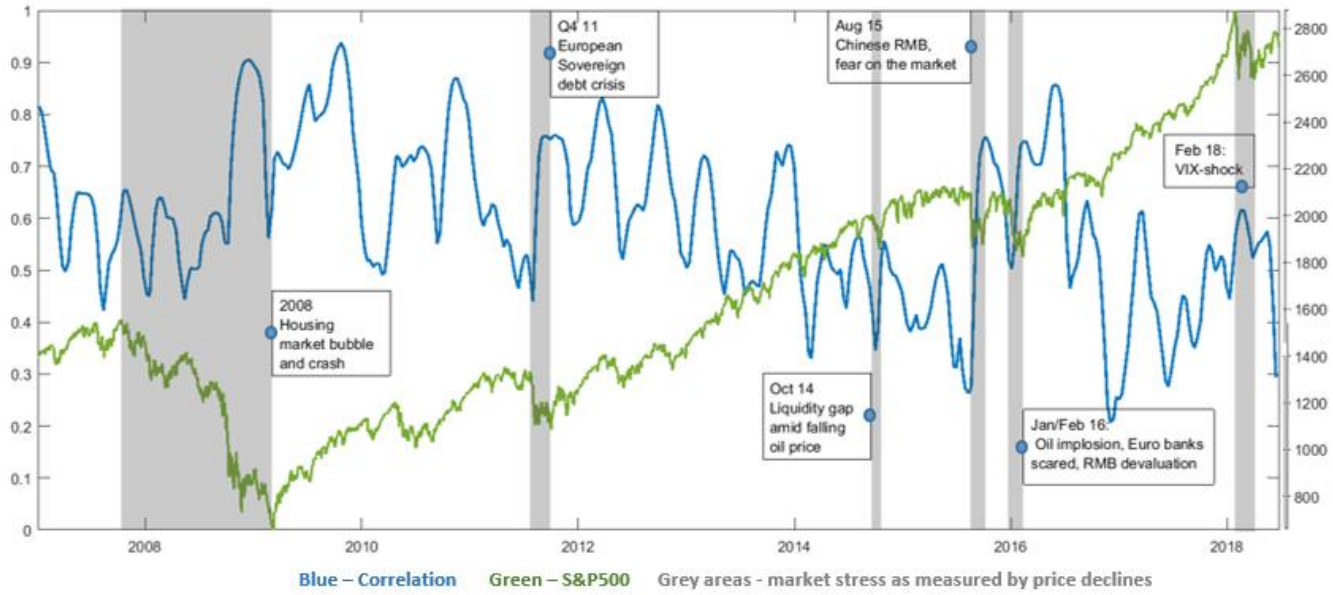
Having touched on the concentration of size on few top AM players, we now discuss the size and dynamics of the 'passive' and 'quasi passive' industry. We do this using the proxy of its largest 350 ETFs globally, as a first initial step in understanding.

Similarly to what shown in the previous model, we observe that the correlation structure among ETFs follows a similar behaviour, suggesting that **instability ripples are propagating through the passive-investment subset of the market too**.

Figure 4 |

Market System Absorbing Latent Energy, One Ripple At A Time: The Case of The Largest ETFs

Average Pairwise Correlation of 350 Largest Asset Managers

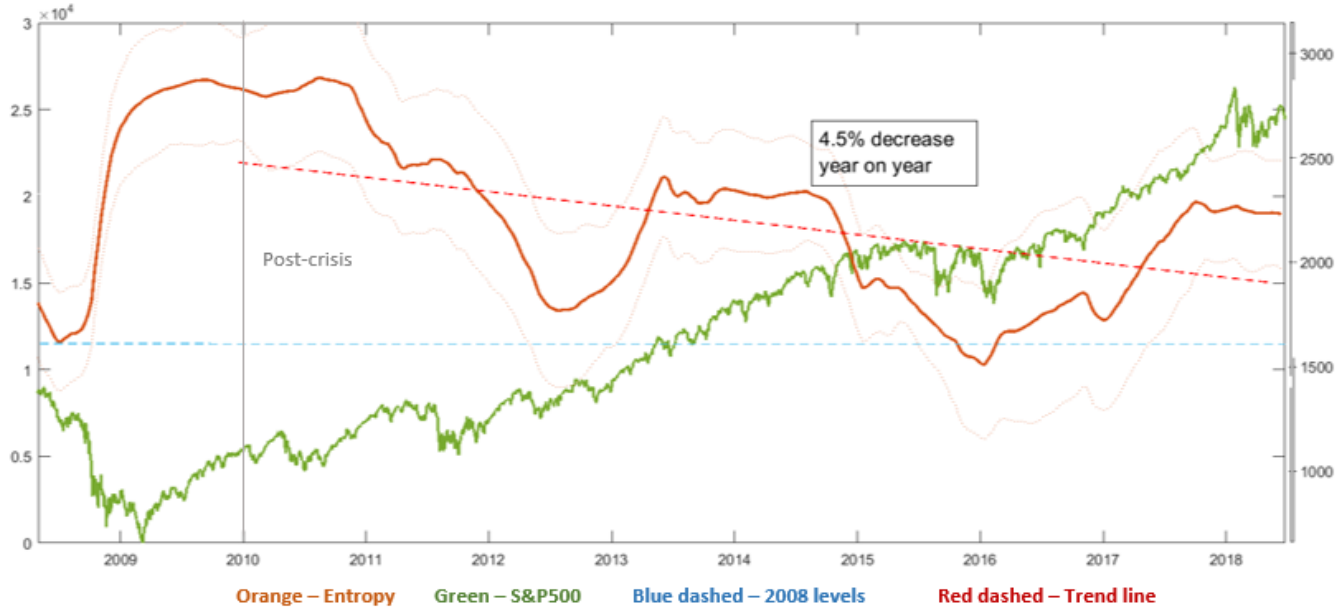


Source: Fasanara Analytics, Bloomberg

Inspired by a number of works on the information entropy as a measure of market risk (among which Pele et al. "Information entropy and measures of market risk"), we study the entropy on our network representation of the subset passive investment industry. The average information content in the system, or average entropy – computed on the edges of the graph, not to be confused with the entropy of prices – represents a local measure of unpredictability of the system, or equivalently, of its average information content. In this specific vein, when a tail-probability event occurs, it carries more "information" than an ordinary day, thereby causing a spike in entropy.

The second law of thermodynamics states that "**entropy always rises within an isolated system, over time**" (to be precise: cannot decrease). This is in contrast with empirical evidence in the market, as we analyse below that **average entropy is on a decade-long down-trend**. It may serve as a stark reminder that the market system is currently therefore not an 'isolated system'. Little surprise there, when we think of the exogenous factor of unprecedented/unorthodox Central Banks' manipulation, in the forms of Quantitative Easing and Negative and Zero interest Rate policies. Anti-gravity policies blow bubbles in valuations, drive positive feedback loops with private investors, divergence from equilibrium, spur system instability: latent energy accumulates in the market crust, ripple after ripple.

Figure 5 |
Declining Entropy In The ETFs Market Structure
Information Density Of The Network Of The 350 Largest ETFs

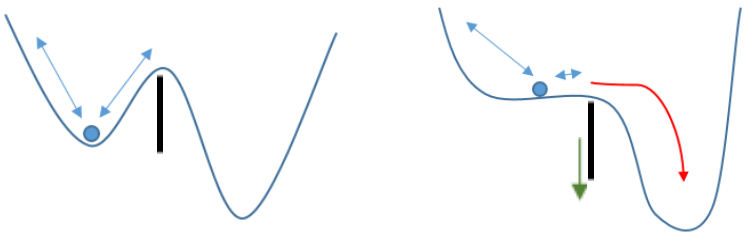


Source: Fasanara Analytics, Bloomberg

We find that information **entropy is decaying at an average rate of 4.5% per year** (**orange line** in the chart below below) and its trend-line (**dashed red line**) has almost reached 2008 levels (**dashed light blue line**).
To be sure, a low-entropy market is not necessarily a market ready to crash, no causality there. Said that, it is historically also true that long periods of low vol and, in this vein, declining entropy have preceded the market crashes of 1929, 1987, 2000, 2007, by tricking investors into a bull trap (Minsky's 'stability is destabilising' factor, which we most often discuss in our papers).

In order to further contextualise such claims we refer to the work of Risso (2008), Zunino et al. (2009) and Billio et al. (2016) among others, where the authors show how the entropy can be used as a measure of stock market efficiency. In particular it has been found that the probability of a market crash increases as the information efficiency of the market, measured by entropy, decreases. As also recently discussed by Howard Marks in a recent note, the flow of capital from active to passive investors helps weakening the process of price discovery in turn driving down the information efficiency of the market; in our study we find more mathematical evidence backing these ideas.

A market robust to instabilities is a dynamic market that can test price swings with confidence; in a low-noise condition, as we observe today, a small correction could cause the equilibrium to break down, inducing a phase transition from a metastable state to a stable equilibrium.

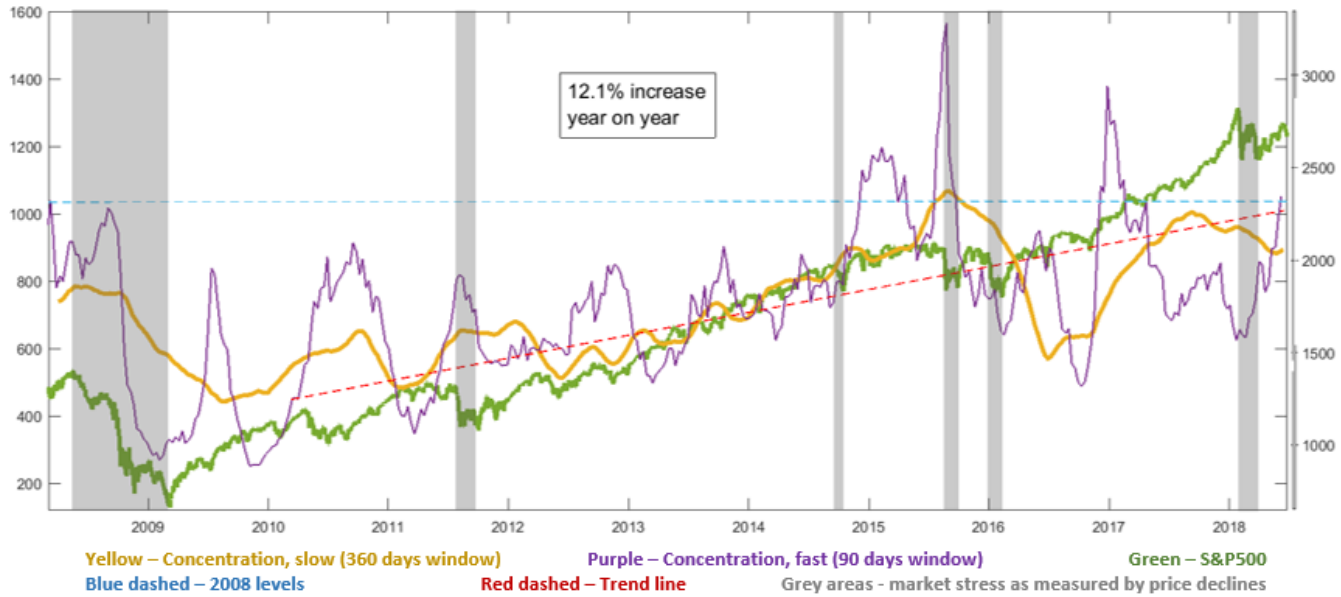


On the left we present a schematic representation of a stable equilibrium point, where entropy might be high and market participants compete in a normal market structure. On the right hand side, on the other hand, we observe a market with declining entropy, thereby inducing investors – the boiling frogs of slides 24-25 – to lower their defences (**black thick line** above), and cease to provide negative feedback loops. The context is then broader than just low and declining entropy, and it includes several fundamental factors acting in unison, such as QE, feedback loops, liquidity and easiness to grow debt/leverage, which altogether bring markets towards a low resilience state.

We now throw concentration in the picture of the low-entropy ETFs market. We again use a representation of the market structure on ETFs made of nodes and edges. We here measure concentration using the ''average closeness centrality measure'' (**purple** and **yellow** lines). The closeness of a node is a measure of centrality in a network, calculated as the reciprocal of the sum of the length of the shortest paths between a node and all other nodes in the graph, thus the more central a node is, the closer it is to all other nodes. **So measured, the concentration in the ETF market has been increasing by a striking 12.1% year-on-year since 2008**. Moreover its trend line (**dashed red line**) has reached the levels of concentration seen in 2008 (**dashed light blue line**), while our shorter-term estimation of market concentration (**purple** line) has spiked above such levels already twice: just before the market corrections during Aug '15 and Jan '16 and during the rally at the beginning of 2017, which ended in the VIX explosion.

Generally, **greater market concentration translates in stiffness of the market structure**, which then becomes fragile as a crystal glass, which in turn is less and less able to absorb idiosyncratic shocks. Following through on the analogy, it may allow the next ripple to compound and morph into a full blown quake, propagating across more easily given the concentration.

Figure 6 |
ETFs: Ever Bigger, and More Heavily Concentrated
Average Concentration Of The Network Of 350 Largest ETFs



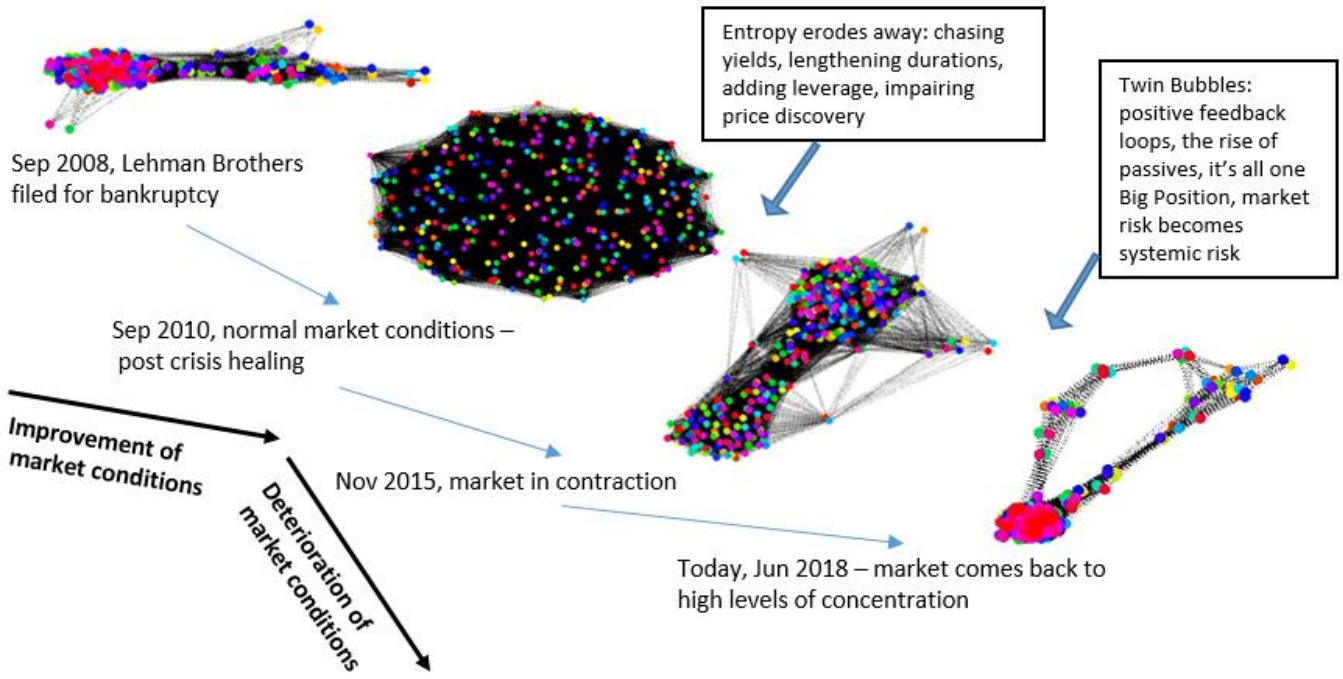
Source: Fasanara Analytics, Bloomberg

Contrary to previous indicators in this paper that had only inference power, we believe that this measure of market concentration may possess some predictive power (with the exception of VIX-driven sell-off,

possibly more idiosyncratically centred around the VIX complex). In particular, short-term concentration (narrower estimation windows) seems to peak before price declines, while longer-term concentration (wider estimation windows) may provide a signal that fragility is increasing and a full phase transition approaching.

To corroborate this take, we provide a **visualisation of the market structure** as modelled by a graph where each node represents an ETF, and the length of the edge represent the strength of interaction (inversely proportional). Please note the density/crowding of the nodes (market concentration) in September 2008, and how it looks after the pressure is released, in the healthier conditions of 2010. **The stiffness of the market increases again after 2015, leading to a current situation of high density and potential danger as the market is no longer able to absorb shocks.**

Figure 7 |
Market Structure Over Time, With Agent-Based Modeling:
Healthy vs Unhealthy Market Structures
Average Concentration Of The Network Of 350 Largest ETFs



Source: Fasanara Analytics, Bloomberg, Method IT

All in all, we observe signals that a phase transition in the passive investment industry might be approaching, as shown by our analysis of the Asset Management and ETFs segments of the industry, which give similar results. When coupled with their size, and the tight ties with financial markets at large, we believe systemic risk are at or close to the cliff, ready to transition.

Similar levels of fragility, as defined and measured in this paper, were visible in the most recent proper crash of 2007/2008.

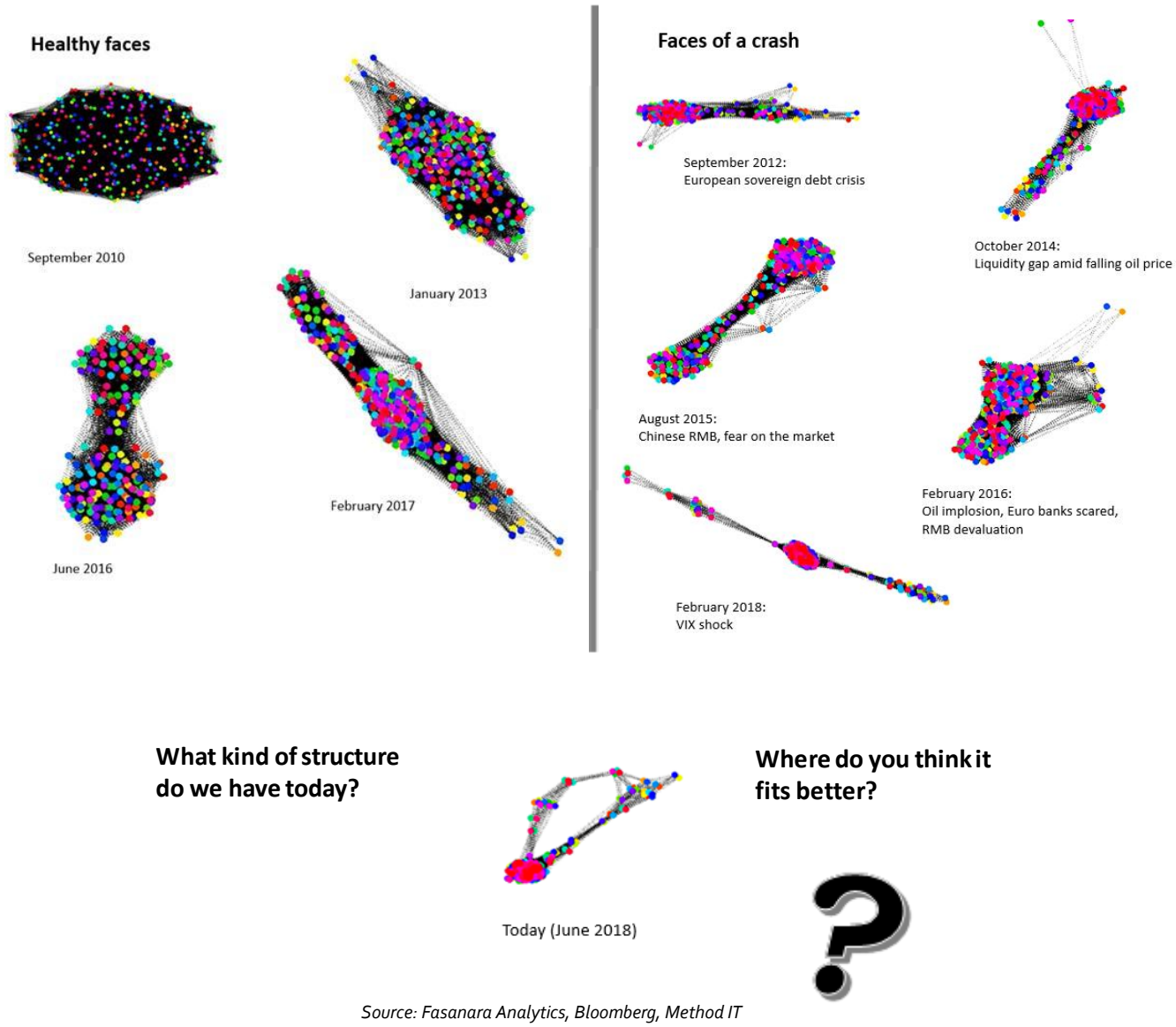
IDENTIKIT OF A CRASH

How does a crashing market looks like in terms of market structure?

Here below we pit the healthy faces of the market, in peaceful blue-sky environments, against the ugly faces revealed during periods of stress.

One big annotation: no truly meaningful crash occurred ever since the Lehman-moment. Here we only see timid, tepid, shallow, fleeting market sell-offs. None of them lasted, if anything they got more and more irrelevant over the years as the buy-the-dip mentality compounded. Most importantly, none of them look even remotely like the one we expect in the not-so-distant future for markets. Still, they can be analysed as 'small-scale rehearsals' for the Big One approaching, and certain general properties of their structure can be learned.

Figure 8 |
Structure Of The Market Network During Good and Bad Times
Sequencing The DNA Of A Market Crash



Source: Fasanara Analytics, Bloomberg, Method IT

ATTRIBUTES OF TODAY'S MARKET STRUCTURE

Where does the current market structure belong? It may belong to the list on the right, the ugly faces of the market in the midst of a stress period.

With one notable difference: there is no crash today. Today's market structure looks like the market structures visible during flash crashes, without being in one.

It may be yet another signpost, in a long list of early warning signals, that the market system is full, stationing on paper-thin ice, ready to transition.

CONCLUDING REMARKS - FOOD FOR THOUGHT

As background material of our 'Critical Transformation Hypothesis' for global markets, this note further analyses the structure of the market, and how it weakened under the force of positive feedback loops between public flows and the private investment community. We looked at largest asset managers and largest ETFs globally as a meaningful proxy for the broader financial system, as we think they represent the weakest links in the market lithosphere. **We find that, over recent years, measures of market diversity fell in lockstep with measures of entropy, all the while as concentration rose to record levels**. Entropy in the ETFs market decayed at an average rate of 4.5% per year in the last ten years, and its trend-line has almost reached 2008 levels. Measured as ''average closeness centrality'', concentration in the ETF market increased by a striking 12.1% year-on-year since 2008, and its trend-line reached levels only seen in 2008. **Looking at systemic risk through the lens of complexity theory, we attempt a visualization of how the market structure on passive ETFs evolved over time.** We visualized how the market structure weakened progressively over the last ten years, **becoming more concentrated, entropic-fragile, and ready to snap. We analyzed the structure of the market network during good and bad times**, trying to identify the DNA of a market crash. **The current market exhibits the typical structure visible during flash crashes, yet despite not being in one. We conclude that the market system is full, stationing on paper-thin ice, ready to transition.**

Again, the analysis is a work-in-progress, a live project on systemic risk as a complexity problem, which forms the conceptual framework around our 'Fat Tail Risk Hedging Programs'. Looking forward to any feedback/support in taking this analysis further ahead.

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