Why Stock Markets Crash

Critical Events in Complex Financial Systems

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FOREWORD

Society has never been more complex, as illustrated by the failure of economics during the 2008 financial crisis, misled for a decade by the mirage of the "Great Moderation" whose demise led to the "Great Recession". The collapse of Lehman Brothers in Sept. 2008 resulted directly in more than US $600 billion losses and triggered the global financial and economic crisis in 2008-2009 causing the loss of over US $30 trillion worldwide in stock market capitalization. This led to extraordinary measures by the US central bank to bail out banks and corporations considered "too-big-too-fail" and to support the economy by unprecedented monetary policies.

This crisis was considered by many, including central bankers, treasury secretaries, prominent policy makers as well as most pundits and academics, as a rude awakening, a great shock that was not foreseen. However, in June 2005, with my post-doc Dr. Wei-Xing Zhou, now a professor at the East China University of Science and Technology in Shanghai, I published on the international Science archive (arXiv.org) a clear diagnostic of the existence of a massive bubble developing in the real-estate sector of the US, with a specific forecast of its peak to occur in the middle of 2006 [1]. The forecast turned out to be accurate, with the peak in the real-estate sector becoming the forerunner of the resulting stress on a variety of financial derivatives such as CDO (collaterised debt obligations), which eventually erupted in the crisis [2].

"Gouverner, c'est prévoir" ("Governing is the art of planning and predicting"- Émile de Girardin). In our complex world, projecting oneself in the future provides immense benefits in making strategic decisions and acting efficiently: being prepared for exploiting potential upside opportunities, as well as preventing or being ready for adverse developments and crises. Indeed, the most momentous events in many complex natural and social systems are the greatest source of dramatic change in such systems for good or for ill; yet these events are often poorly understood, predicted or controlled. Unfortunately, the science of forecasting complex systems is still at a rudimentary stage, if not fully neglected perhaps due to misguided claims of inherent unpredictability from fields such as algorithmic complexity theory in mathematics and computer sciences, self-organised criticality in physics, Knightian uncertainty in the epistemology of science as well as an exaggerated faith in the efficiency of financial markets by economists.

It is often advanced that, because many phenomena in the physical, natural, environmental, economic and social sciences can be characterized in large part by power law statistics, large events are inherently unpredictable since they are undistinguishable from their smaller siblings and reflect the same underlying generating mechanism(s). In this view, major catastrophes are just events that started small but did not stop growing and are thus unpredictable, in the sense that the timing as well as final size of a future event cannot be forecasted in advance. If the 2008 financial crisis was a "black swan", nobody is responsible and we just have to prepare for the random occurrence of such unknown unknowns.

A fundamentally different view of the world of risks is captured by the message of this book, written in 2002, but whose relevance remains as vivid for understanding the 2008 crisis as well as the very special present times, as it was almost 15 years ago. The key concept has been fleshed out under the colorful concept of "Dragon Kings" that I introduced later in 2009 to make more explicit the emphasis on the special nature of extreme events. Dragon Kings embody a double metaphor implying that an event is both extremely large (a King) and born of unique origins (dragon) relative to its peers, in a precise statistical and mechanistic sense. The key hypothesis is

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[1] http://arxiv.org/abs/physics/0506027

[2] W.-X. Zhou and D. Sornette, Is There a Real-Estate Bubble in the US? Physica A 361, 297-308 (2006)

that most extreme events and crises may not be due to the same mechanisms acting on the rest of the distribution of events, and may require specific amplifying processes that are activated intermittently. This gives rise to specific properties and signatures that may be unique characteristics of Dragon Kings. In fact, the 2008 financial crisis provided one of the most prominent examples of Dragon Kings, spreading across continents and affecting the world economy until today, with clear precursors and preparatory processes that the theory and methodology explained in this book allowed to identify unambiguously. Another example of Dragon Kings is the flash crash of May 6, 2010 when the Dow Jones Industrial Average dropped almost 10% in less than one minute, amplified by high-frequency trading.

This book presents a general conceptual framework and methodology to understand why, how and when financial bubbles appear and develop, often ending in ruinous crashes. In general, bubbles follow a universal scenario, starting with a new investment opportunity, which can be a new technology or the access to a new market. An initial strong demand from first-movers and "smart money" leads to a first price appreciation. This often goes together with an expansion of credit, which further pushes prices up. A positive feedback mechanism is generated as new participants enter the market, its behavior then no longer reflects any real underlying value and a bubble is born, eventually ending in collapse. The key concept presented in the book is the faster than exponential growth patterns of prices that characterize bubbles, resulting from amplified growth due to positive feedback among traders

Since the publication of the first edition in 2002, with my collaborators, I have pursued the systematic application of the theory and methodology explained in the present book to monitor financial markets worldwide, to diagnose the presence of bubbles in real time and to forecast their burst ex-ante. In addition, in response to the general mistaken (in my opinion) notion that the 2008 crisis could not have been predicted, I created in August 2008 the Financial Crisis Observatory [3] (FCO) at ETH Zurich as a scientific platform that aims at testing and quantifying rigorously, in a systematic way and on a large scale the hypothesis that financial markets exhibit a degree of inefficiency and a potential for predictability, especially during regimes when bubbles develop. Since then, we monitor about 25'000 assets worldwide (indices, stocks, bonds, commodities, currencies, derivatives) and construct a daily update of a number of bubble indicators, based on the analyses of price time series with the LPPLS (log-periodic power law singularity) model presented in this book. In a public version of the FCO, we share the results on 21 major assets of the behavior of our financial bubble indicators, with the goal of helping develop a science and culture of dynamical crisis risk monitoring, which I have come to call "time-at-risk" (T@R), in particular targeting large downward losses (as well as large potential upward gains).

Because back-testing is subjected to a host of possible biases, in November 2009, the Financial Bubble Experiment (FBE) was launched within the FCO. Our motivation was to develop real-time advanced forecast methodology that is constructed to be free, as much as possible, of all possible biases plaguing previous tests of bubbles. The FBE was based on an innovative framework to perform secure, verifiable ex-ante forecasts on financial crises using a creative digital fingerprint system to ensure authenticity of forecasts released six months later for verification. In the FBE, forecasts were revealed only after the predicted event has passed but where the original date when we produced these same results could be publicly, digitally authenticated (see the reports and ex-post analysis of our diagnostics performed ex-ante on the FCO website). The FBE experiment ran until 2009 and has since been replaced by real-time trading experiments in a "financial trading experiment" with real money, with excellent results (unpublished). Since October 2014, with a collaborator and two PhD students, I have offered the "monthly cockpit", which analyses the dynamical evolution of bubbles in different asset classes, sectors and geographic locations. It is the result of an extensive analysis done on the historical time series of 431 systemic assets and 898 single stocks worldwide. The systemic assets are bond,

[3] https://www.ethz.ch/content/specialinterest/mtec/chair-of-entrepreneurial-risks/en/financial-crisis-observatory.html

equity and commodity indices and a selection of currency pairs. The single stocks include US and European, as well as Asian equities. Each month, the report presents the state of the world, based on the analysis of the systemic assets. Then, the report zooms in on the bubble behavior of single stocks and discuss some specific noteworthy cases. For the global 898 stocks, bubble warning indicators are calculated, which are complemented by two financial strength indicators, which indicate the fundamental value of the stock and the growth capability respectively. The stocks are the constituents of the Stoxx Europe 600, the S&P 500 and the Nasdaq 100 indices and others from world markets. My goal is to establish a track record and, as mentioned above, a culture of dynamical risk forecast and management.

In addition to the correct call on the US real-estate bubble mentioned above, since the first publication of this book, we have published a number of remarkably successful predictions based on its methodology. Let me just mention a few as appetizers.

In early September 2007, Wei-Xing and I performed a LPPLS analysis of the Shanghai index that led to (i) a diagnostic of an on-going bubble and (ii) the prediction of the end of the bubble in early 2008. I communicated this prediction on October 18,2007 at a prominent global-macro hedge-fund conference in Stockholm. The Hang Seng China Enterprises Index (HSCEI) reached the historical high 20609.10 on Nov. 2, 2007. Afterwards, the first valley HSCEI=15460.72 (-25% from historical high) was reached on Nov. 22, 2007 and the bottom HSCEI=4792.37 (-77% from historical high) was on 29 Oct. 2008. On 19 Mar. 2008, HSCEI=11379.91 was another deep valley. These drops occurred after a six-fold appreciation of the Chinese market from mid-2005 to October 2007 (see [4] for a detailed account).

On July 10, 2009, my group jointly with a team at the Bank Fortis submitted a prediction online on arXiv.org of a coming crash on the Chinese market, in which we estimated a 60% (respectively 80%) probability that the end of the bubble would occur in the interval 7-27 July 2009 (respectively 10 July - 10 August 2009). Redoing the analysis 5 days later on 14 July 2009, the predictions tightened up with an 80% probability for the change of regime to start between 19 July and 3 August, 2009. On July 29, 2009, Chinese stocks suffered their steepest drop since November 2008, with an intraday bottom of more than 8% and an open-to-close loss of more than 5%. The market rebounded with a peak on August 4, 2009 before plummeting the following weeks. The SSEC slumped 22 percent in August, the biggest decline among 89 benchmark indices tracked world wide by Bloomberg, in stark contrast with being the no. 1 performing index during the first half of that year (see [5] for a detailed account)..

On June 6, 2008, we published on arXiv.org our LPPLS analysis of the oil prices in USD and in other major currencies [6], which confirmed the start of a bubble between the last quarter of 2005 and the first quarter of 2006, beyond which a net unsustainable faster-than-exponential acceleration could be observed. We estimated an 80% probability that the Oil bubble would burst between 17 May 2008 and 14 July 2008. The actual peak oil price was observed on 3 July and the steep descent in price began on 11 July [7].

From 2014 to June 2015, the Chinese domestic market accelerated tremendously, more than doubling within a year. From June 15, 2015, it started to crash, in a series of very large drawdowns. This was the catalyst of the largest one-day gap open in US equity markets since the end of the financial crisis. My team and I demonstrated how our LPPLS metrics correctly flagged the growing risks of a sharp correction in the Shanghai stock market index, initially in early 2015 and then repeatedly in April-June 2015 [8]. This last example demonstrates the power of our theoretical model and our computational methodology, giving interested readers a clear illustration of our log-periodic power-law singularity model and a direct path to learning about it,

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[4] Z.-Q. Jiang, W.-X Zhou, D. Sornette, R. Woodard, K. Bastiaensen and P. Cauwels, Bubble Diagnosis and Prediction of the 2005-2007 and 2008-2009 Chinese stock market bubbles, Journal of Economic Behavior and Organization 74, 149-162 (2010)

[5] Ibid

[6] http://arXiv.org/abs/0806.1170

[7] D. Sornette, R. Woodard and W.-X. Zhou, The 2006-2008 Oil Bubble: evidence of speculation, and prediction, Physica A 388, 1571-1576 (2009)

[8] D. Sornette, G. Demos, Q. Zhang, P. Cauwels, V. Filimonov and Q. Zhang, Real-time prediction and post-mortem analysis of the Shanghai 2015 stock market bubble and crash, Journal of Investment Strategies 4 (4), 77-95 (2015)

as explained in this book.

In summary, these examples and developments provide significant evidence that the material of this book has not aged a day and that its fundamental conceptual underpinning has only improved as a good French Bordeaux wine!

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