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LPPLS bubble indicators over two centuries of the S&P 500 index

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HIGHLIGHTS

- Novel tests for early causal diagnostic of bubbles in the US S&P 500 index.
- Large testing period of more than two hundred years.
- Construction of efficient end-of-bubble signals.
- Horse-race between LPPLS versus exponential curve fitting and generalized sup ADF test approaches.
- Detection of eight positive bubbles and two negative bubbles from January 1814 to August 2014.

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ABSTRACT

The aim of this paper is to present novel tests for the early causal diagnostic of positive and negative bubbles in the S&P 500 index and the detection of End-of-Bubble signals with their corresponding confidence levels. We use monthly S&P 500 data covering the period from August 1791 to August 2014. This study is the first work in the literature showing the possibility to develop reliable ex-ante diagnostics of the frequent regime shifts over two centuries of data. We show that the DS LPPLS (log-periodic power law singularity) approach successfully diagnoses positive and negative bubbles, constructs efficient End-of-Bubble signals for all of the well-documented bubbles, and obtains for the first time new statistical evidence of bubbles for some other events. We also compare the DS LPPLS method to the exponential curve fitting and the generalized sup ADF test approaches and find that DS LPPLS system is more accurate in identifying well-known bubble events, with significantly smaller numbers of false negatives and false positives.

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1. Introduction

The US market capitalization of firms rose from $2.8 trillion in the end of 1988 to $18.7 trillion in the end of 2012 in current prices and hence increased 6.7 times in 15 years or 13.5% per year in average compounded growth. Correspondingly, $1.8 trillion in the end of 1998 and $9.6 trillion in the end of 2012 of corporate equities was held by households and non-profit organizations in the US.[1] Given the level of penetration of the stock market investment in US, a boom or a bust in the market has widespread effects on US economy, beyond its effect on the wealth of households and the value of firms. Therefore, it is vital to diagnose booms and busts before they hit the stock market.

The S&P 500 (S&P500) is one of the most frequently used stock market index in gauging the US stock market performance. The S&P price index, like many other assets, shows positive and negative bubbles in certain periods, which seems to contradict with the Efficient Market Hypothesis. Since Sornette et al. [1], there is a growing research using critical points with log-periodic corrections, borrowed from statistical physics, aiming at identifying bubbles.[2] This methodology (later started to be called Johansen–Ledoit–Sornette (JLS) model or Log-Periodic Power Law Singularity (LPPLS) analysis) proposes that a bubble can emerge intrinsically out of the natural functioning of the market. A brief survey of this literature is as follows.[3] To further test the methodology, Sornette and Johansen [5] used the two largest historical crashes of the century, the October 1929 and October 1987 crashes, and showed that the methodology identifies the two crashes by analysing bubbles developing over an interval of 8 years prior to when they happened. Sornette and Johansen [6] presented a simple hierarchical model of traders in stock markets, e.g., currency blocks at the highest level of the hierarchy, the countries at the next level, major banks and institutions within a country then, and so forth, all exhibiting herd behavior. Sornette and Johansen [6] showed that this hierarchical organization was sufficient to produce log-periodic oscillations and that a systemic instability could lead to a crash. Sornette and Zhou [7] presented a systematic algorithm, which was implemented on the Dow Jones Industrial Average index (DJIA) and on the Hong Kong Hang Seng composite index (HSI). The algorithm detected in advance significant drops or changes of regimes. Sornette et al. [8] analyzed the 2006–2008 oil prices run-up by using several implementations of the LPPLS methodology and evidenced that oil prices exhibited a bubble-like dynamics.[4] Jiang et al. [14] applied the LPPLS model to detect two bubbles and subsequent market crashes in two important indexes in the Chinese stock markets between May 2005 and July 2009, the Shanghai stock exchange composite index and the Shenzhen stock exchange component index and successfully predicted time windows for both crashes in advance. Johansen and Sornette [15] presented a systematic analysis of drawdown outliers and showed that they are either preceded by a (super-exponential) power law price appreciation decorated by log-periodic oscillations or by exogenous shocks. Yan et al. [16], using the JLS model, developed an alarm index based on an advanced pattern recognition method with the aim of detecting bubbles and performed forecasts of market crashes and rebounds. Testing their methodology on 10 major global equity markets, they showed quantitatively that an alarm method performs much better than chance in forecasting market crashes and rebounds. Filimonov and Sornette [17] proposed a revision of the LPPLS formulation convenient for more stable calibrations, by transforming it from a function of 3 linear and 4 nonlinear parameters into a representation with 4 linear and 3 nonlinear parameters. This transformation significantly decreases the complexity of the fitting procedure and improves its stability. In addition to this, they developed an additional subordination procedure that allows one to detect the critical time, the end of the bubble and the most probable time for a crash to occur. This further decreases the complexity of the search. Filimonov and Sornette [17] used the Shanghai Composite index (SSE) from January 2007 to March 2008 to test the modified LPPLS model. The research team at ETH Zurich further developed an LPPLS based bubble detection system, which is described by Sornette et al. [18] and Zhang et al. [19]. Three indicators used in this system are the Bubble Status (DS LPPLS Bubble Status), the End-of-Bubble signal (DS LPPLS End-of-Bubble), and the confidence (DS LPPLS Confidence), which are also used in this study.

The aim of the present study is to identify positive and negative bubbles in the S&P500 since the first month of 1814, based on an initial estimation from August 1791 to December 2013, i.e., a rolling-window of 269 months. Sornette et al. [1], Sornette [2], and Sornette and Johansen [5,6] define a positive (negative) bubble as an accelerating ascending (descending) log-price ending at some future critical time. That is, positive (negative) bubbles are not characterized by an exponential increase (decrease) of price but rather by a faster than exponential growth (decay) of price [20,21]. For this purpose, we use the log-periodic power law singularity (LPPLS) methodology, developed by Sornette et al. [1], Sornette [2], and Sornette and Johansen [5,6]. The main motivation for using this methodology is to diagnose the bubbles ex-ante. We show that the LPPL methodology is able to identify bubbles quite early, but the signals often do not stop immediately after the real bubbles fade. We undertake our analysis in two phases. In the first phase, the timeline of "DS LPPLS Bubble Status indicators" of the S&P500 monthly data from January 1814 to August 2014 are derived. In the second phase, we derive the timeline of "DS LPPLS End-of-Bubble" signals and "DS LPPLS Confidence" indicators of the S&P500 monthly data from January 1814 to August 2014. There are two times, 1842–1843 and 2002–2003, for which the End-of-Bubble signals of negative bubbles

1 See Balance Sheet of Households and Nonprofit Organizations (B.100) in Financial Accounts of the United States.

2 See Refs. [2,29] demonstrating the analogies between the quantification of risks in finance and insurance and the optimization of portfolios on one hand and statistical physics concepts and methods on the other.

3 Extended and condensed reviews of the literature can be found in Refs. [3,4], respectively.

4 The simple LPPLS model [9], the second-order Weierstrass model [10] and the second-order Landau model Sornette (1997), [11–13].

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