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Clarifications to questions and criticisms on the Johansen–Ledoit–Sornette financial bubble model

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HIGHLIGHTS

- The JLS bubble model describes the dynamics of financial bubbles and crashes.
- Several serious misconceptions of the JLS model are presented.
- We summarize and comment on these common questions and criticisms.
- We synthesize the current state of the art and existing best practice of the JLS model.

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ABSTRACT

The Johansen–Ledoit–Sornette (JLS) model of rational expectation bubbles with finite-time singular crash hazard rates has been developed to describe the dynamics of financial bubbles and crashes. It has been applied successfully to a large variety of financial bubbles in many different markets. Having been developed over a decade ago, the JLS model has been studied, analyzed, used and criticized by several researchers. Much of this discussion is helpful for advancing the research. However, several serious misconceptions seem to be present within this literature both on theoretical and empirical aspects. Several of these problems stem from the fast evolution of the literature on the JLS model and related works. In the hope of removing possible misunderstanding and of catalyzing useful future developments, we summarize these common questions and criticisms concerning the JLS model and synthesize the current state of the art and existing best practice.

1. Introduction

The Johansen–Ledoit–Sornette (JLS) model [1–4] has been developed to describe the dynamics of financial bubbles and crashes. The model states that bubbles are not characterized by an exponential increase of price but rather by a faster-than-exponential growth of price. This phenomenon is generated by behaviors of investors and traders that create positive feedback in the valuation of assets leading to unsustainable growth ending with a finite-time singularity at some future time t_c.

One can identify two broad classes of positive feedback mechanisms. The first technical class includes (i) option hedging [5], (ii) insurance portfolio strategies (see paragraph 1 on p. 380 of Ref. [6] stating that "Positive feedback trading

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is also exhibited by buyers of portfolio insurance…") and Refs. [7,8], (iii) market makers bid–ask spread in response to past volatility [9,10], (iv) learning of business networks and human capital build-up [11,12], (v) procyclical financing of firms by banks (boom vs. contracting times) [13], (vi) trend following investment strategies, (vii) asymmetric information on hedging strategies [14] (viii) the interplay of mark-to-market accounting and regulatory capital requirements [15,16]. The second class of positive feedback mechanisms is behavioral and emphasizes that positive feedbacks emerge as a result of the propensity of humans to imitate, of their social gregariousness and the resulting herding. This critical time t_c of the model is interpreted as the end of the bubble, which is often but not necessarily the time when a crash occurs in the actual system. During this growth phase, the tension and competition between the value investors and the noise traders create deviations around the hyperbolic power law growth in the form of oscillations that are periodic in the logarithm of the time to t_c. Combining these two effects, this model succinctly describes the price during a bubble phase as a log-periodic (hyperbolic) power law (LPPL).

Since its introduction, the JLS model has been used widely to detect bubbles and crashes ex-ante (i.e., with advanced documented notice in real time) in various kinds of markets such as the 2006–2008 oil bubble [17], the Chinese index bubble in 2009 [18], the real estate market in Las Vegas [19], the UK and US real estate bubbles [20–24], the Nikkei index anti-bubble in 1990–1998 [25] and the S&P 500 index anti-bubble in 2000–2003 [26]. Other recent studies performed in an ex-post mode include the Dow Jones Industrial Average historical bubbles [27], the corporate bond spreads [28], a Polish stock market bubble [29], some Western stock market bubbles [30], UK stock market bubbles [31], the Brazilian real (R$)—US dollar (USD) exchange rate [32], 2000–2010 world major stock indices [33], South African stock market bubbles [34], the US repurchase agreements market [35] and emerging markets [36,37]. Moreover, new experiments in ex-ante bubble detection and forecasts have been launched since November 2009 in the Financial Crisis Observatory at ETH Zurich [38–40]. In many cases, market risk is contagious [41] and market corrections and crashes occur successively in a short period [42] including the latest financial crisis, which is partially due to globalization and assets diversification such that the US stock market and world financial stock market exhibit long-range cross-correlations [43,44].

Having been developed over a decade ago, the JLS model has been studied, used and criticized by many researchers including Feigenbaum [45], Chang and Feigenbaum [46,47], van Bothmer and Meister [48], Fry [22], and Fantazzini and Geraskin [49]. The most recent papers addressing the pros and cons of past works on the JLS model are written by Bree and his collaborators [50,51]. Many ideas in these last two papers are correct, pointing out some of the inconsistencies in earlier works. However, there are some serious misunderstandings concerning both the theoretical and empirical parts of the model. Therefore, it is necessary to address and clarify the misconceptions that some researchers seem to hold concerning the JLS model and to provide an updated, concise reference on the JLS model.

The structure of this paper is as follows. Section 2 discusses the questions about the theory and derivation of the JLS model. The questions on fitting methods of the model are commented on in Section 3. Issues on probabilistic forecast will be addressed in Section 4. We conclude in Section 5.

2. Presentation and remarks on the theoretical foundation of the JLS model

We will give the derivation of the JLS model first in this section. Then we discuss three issues related to the derivation and the proper parameter ranges.

2.1. Derivation of the JLS model

The JLS model starts from the rational expectation settings of Ref. [52], where the observed price p_o of a stock can be written as

$$p_o = p^* + p, \quad (1)$$

where p^* and p represent respectively the fundamental value and the bubble component. Eq. (1) shows that the price is a linear combination of the fundamental value and the bubble component. The JLS model specifies the dynamics of the bubble component *independently* of the dynamics of the fundamental price. The later can be specified according to standard valuation models, for instance leading to the usual geometrical random walk benchmark. The JLS model adds to this featureless fundamental price the so-called log-periodic power law structure, which is used to diagnose the presence of bubbles. Lin et al. [53] have considered a self-consistent mean-reverting process for p^* that makes consistent the calibration of the observed price p_o by the JLS model.

The JLS model starts from the assumption that the dynamics of the bubble component of the price satisfies a simple stochastic differential equation with drift and jump:

$$\frac{\mathrm{d}p}{p} = \mu(t)\mathrm{d}t + \sigma \mathrm{d}W - \kappa \mathrm{d}j, \quad (2)$$

where p is the stock market bubble price, $\mu(t)$ is the drift (or trend) and $\mathrm{d}W$ is the increment of a Wiener process (with zero mean and unit variance). The term $\mathrm{d}j$ represents a discontinuous jump such that $j = 0$ before the crash and $j = 1$ after the crash occurs. The loss amplitude associated with the occurrence of a crash is determined by the parameter κ. Each

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