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# Liquidity crisis detection: An application of log-periodic power law structures to default prediction

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## HIGHLIGHTS

- This study provides a quantitative description of the mechanism behind bank runs.
- We diagnosed the presence of log-periodic patterns in CDS spreads.
- We investigated univariate classification performances of log-periodic parameters.
- These parameters appear to characterize investor behavior.
- Further, they enable us to draw conclusions of banks' refinancing options.

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## ABSTRACT

We employ the log-periodic power law (LPPL) to analyze the late-2000 financial crisis from the perspective of critical phenomena. The main purpose of this study is to examine whether LPPL structures in the development of credit default swap (CDS) spreads can be used for default classification. Based on the different triggers of Bear Stearns' near bankruptcy during the late-2000 financial crisis and Ford's insolvency in 2009, this study provides a quantitative description of the mechanism behind bank runs. We apply the Johansen–Ledoit–Sornette (JLS) positive feedback model to explain the rise of financial institutions' CDS spreads during the global financial crisis 2007–2009. This investigation is based on CDS spreads of 40 major banks over the period from June 2007 to April 2009 which includes a significant CDS spread increase. The qualitative data analysis indicates that the CDS spread variations have followed LPPL patterns during the global financial crisis. Furthermore, the univariate classification performances of seven LPPL parameters as default indicators are measured by Mann–Whitney *U* tests. The present study supports the hypothesis that discrete scale-invariance governs the dynamics of financial markets and suggests the application of new and fast updateable default indicators to capture the buildup of long-range correlations between creditors.



## 1. Introduction

In economics the opinion prevails that complex financial systems are in general unpredictable [1]. Some econophysicists have nevertheless designed methods in order to predict financial market turmoil. The interactions between microscopic particles dealt with in physics are commonly of short range. But under certain conditions these short ranged interactions develop to long ranged interactions, culminating in cooperative behavior of the physical system. Financial markets also

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exhibit cooperative phenomena, for instance, in terms of crashes when investors decide in bulk to sell their shares. This apparent similarity between physical systems on the one hand and financial market dynamics on the other hand justifies the application of physical methods in order to extract the coarse-grained properties of these large ensembles of market participants [1–3]. In particular, the log-periodic power law (LPPL) has proven very fruitful in forecasting the bursting of speculative bubbles [1].

In a nutshell, the objective of the LPPL ansatz is to observe well defined patterns in price trajectories before critical points in time. In this context, financial markets are regarded as self-organized systems that can drive themselves toward critical points [4]. When financial markets approach their critical points, long-range correlations between traders build up and imitation becomes a leading motive of investment decision [4–6]. This positive feedback mechanism between investors results in a faster-than-exponential price increase decorated by log-periodic oscillations [7]. The faster-than-exponential price increase is defined by a growth rate which increases with time [8]. The log-periodic oscillations manifest themselves as peaks and valleys with progressively smaller amplitudes and greater frequencies that eventually reach the critical point in time $t_c$ at which the average state of the system becomes sensitive to external influences [6]. Any adequate disturbance may trigger a crash at this state. That is why the speculative bubble has the highest probability to burst at $t_c$. For the sake of illustration, we adopt the example originally given in Ref. [6]: "Consider a ruler put vertically on a table. Being in an unstable position, it will fall in some direction, and the specific air current or slight imperfection in the initial condition are of no real importance. What is important is the intrinsically unstable initial state of the ruler. We argue that a similar situation applies for crashes. They occur because the market has reached a state of global instability. Of course, there will always be specific events which may be identified as triggers of market motions but they will be the indicators rather than the deep sources of the instability" [6].

In order to provide an overview of the literature on log-periodicity, we first have to mention the pioneering works of Feigenbaum and Freund [9] and Sornette et al. [10] who independently of each other discovered ex post LPPL structures in the S&P500 index prior to the crash in October 1987. The hypothesis that the reasons for LPPL structures are rooted deeper in economic mechanisms than only in the dynamics of financial markets has met with skepticism and even triggered a heated discussion between two discoverers [11–14]. The academic community is also divided into two camps on this topic: Although, skeptics mainly acknowledge the presence of LPPL imprints in financial time series, they consider those structures as accidental patterns attributed to the stochastic processes of the financial market [12,15,16]. In contrast, the advocates of the Johansen–Ledoit–Sornette (JLS) model substantiate their point of view of LPPL patterns diagnosing speculative bubbles by offering a wide variety of investigations which can, for example, be partitioned into four groups as follows: First, there is rich literature on the ex post detection of LPPL patterns preceding financial crashes. LPPL structures were, for example, successfully identified in stock market bubbles [6,12,17–22], in real estate price bubbles [8,23], in the 2006–2008 oil bubble [24], and in the US FED Prime Rate [25].[1] Second, a vast body of empirical evidence has accumulated demonstrating that the herding behavior of investors not only results in speculative bubbles with accelerating market overvaluations, but also in anti-bubbles with decelerating market devaluations [27–29]. A third strand of literature went even one step further by claiming that financial crashes can be forecasted by extrapolating the LPPL [1]. The main idea of this research line is to integrate the LPPL structures into a pattern recognition approach in order to predict end times of bubbles and anti-bubbles [1,29–31]. Fourth, researchers have discovered that the presence of LPPL structures is predictive of crashes in real data, but they were unable to establish a link between LPPL patterns and crashes in the synthetic data [9,32,33].

Despite this large number of studies in favor of the LPPL hypothesis, "the statistical significance of these precursors and their predictive power remain controversial in part" [34]. However, an increasing number of case studies in a wide variety of financial time series reinforces one by one the LPPL hypothesis. The detection of LPPL structures in US corporate bond spreads [35], in the credit default swap (CDS) indices [36,37], and in the repurchase agreement market size bubble from 2007 to 2008 [38] can be considered as first applications of the LPPL to credit risk time series. The experiences of the global financial crisis 2007–2009 have shown plainly that high uncertainties about international banks' creditworthiness may induce serious consequences for the real economy [39–42]. Due to significant off-balance-sheet liabilities, it is difficult to estimate the default risk of financial institutions on the basis of conventional methods like balance sheet ratings or within the Black–Scholes–Merton framework [43]. Research on the causes of international banks' deterioration in creditworthiness is therefore of utmost importance for financial market stability. Our main hypothesis is that bankruptcies are not necessarily the consequences of bad business figures, but can also be the result of creditors' positive feedback interaction in analogy to critical phenomena in physics. Thus, it appears to be worthwhile to pursue the idea of LPPL structures as a harbinger of an impending liquidity crisis. We consequently apply the JLS model to explain the CDS spread movements of large banks during the financial crisis 2007–2009 [4,44]. This model is based on two central assumptions: First, CDSs provide an opportunity for creditors to transfer credit risks to counterparties. Hence, the individual creditor in our model has only two possible actions: Either he does hedge or he does not hedge against default by CDSs. Second, no creditor can precisely estimate the probability of default for any debtor. There is always an uncertainty about the obligor's credit standing. That is why each creditor steadily communicates with a limited number of other creditors about the obligor's solvency. The opinions of their networks are crucial for the creditors' future actions.

We perform both, a qualitative and a quantitative investigation on daily data of financial institutions' CDS spreads in order to answer the question whether there is a link between bankruptcies and phase transitions. At first, we calibrate the LPPL

[1] Sornette [26] provides further examples of cases in which LPPL patterns were diagnosed.