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Negative bubbles and shocks in cryptocurrency markets

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ABSTRACT

In this paper we draw upon the close relationship between statistical physics and mathematical finance to develop a suite of models for financial bubbles and crashes. The derived models allow for a probabilistic and statistical formulation of econophysics models closely linked to mainstream financial models. Applications include monitoring the stability of financial systems and the subsequent policy implications. We emphasise the timeliness of our contribution with an application to the two largest cryptocurrency markets: Bitcoin and Ripple. Results shed new light on emerging debates over the nature of cryptocurrency markets and competition between rival digital currencies.

1. Introduction

Econophysics is an interdisciplinary subject that applies tools and techniques from theoretical and statistical physics to model financial and economic systems (Chen & Li, 2012; Mantegna & Stanley, 1999). For an introduction to econophysics and a comparison between finance and physics see Sornette (2014). As the econophysics movement has gained momentum our paper thus contributes to wider debates such as probabilistic and statistical approaches to econophysics (Bree & Joseph, 2013; Lin, Ren, & Sornette, 2014), the development of links between econophysics and mainstream financial models (Johansen, Ledoit, & Sornette, 2000) and the creation of tools to monitor the stability of financial systems and the subsequent policy implications that work in econophysics holds (Fry, 2015; Sornette, 2003).

Econophysics has been used to tackle a wide range of practical problems in finance and economics. This includes applications to options pricing and risk management (Bouchaud & Potters, 2003), the statistical characterisation of heavy-tailed asset returns distributions (Cont, 2001), empirical power-laws (Gabaix, Gopikrishnan, Plerou, & Stanley, 2003; Plerou, Stanley, & Gabaix, 2004), agent-based modelling (see e.g. Hommes, 2006; Le Baron, 2006), income-tax evasion (Pickhardt & Seibold, 2014), speculative bubbles (Johansen et al., 2000; Sornette, 2003) and the impact of high-frequency trading upon the stability of global financial markets (Filimonov & Sornette, 2012). One practical problem that econophysics has recently begun to address is the issue of Bitcoin and cryptocurrency markets.

Amid huge media and public interest Bitcoin and cryptocurrency markets present enormous legal (Grinberg, 2012; Plasaras, 2013), regulatory (Ali, Barrdear, Clews, & Southgate, 2014; European Central Bank, 2012; Gandal & Hałaburda, 2014) and ethical (Angel & McCabe, 2015) challenges. Cryptocurrency markets have also been extremely volatile with the market share and market capitalisations of several cryptocurrencies fluctuating wildly (White, 2014). Though initially dominated by other disciplines the financial and economic literature on Bitcoin and cryptocurrencies has recently started to emerge (see e.g. Dowd, 2014; Dwyer, 2015; Weber, 2014a). Cryptocurrencies have also been the focus of several recent econophysics papers (see e.g. Cheah & Fry, 2015; Garcia, Tessone, Mavrodiev, & Perony, 2014; Kristoufek, 2013). Their dependence on self-fulfilling expectations and the lack of a centralised governance body mean that, without wishing to exaggerate the importance of econophysics, cryptocurrency markets may prove especially amenable to econophysics approaches.

The objective of this paper is to showcase the use of tools and techniques from econophysics via a novel application to the two largest cryptocurrency markets. The importance of our contribution is fivefold. Firstly, we develop an econophysics model for bubbles and crashes that can be fitted to empirical financial data using standard statistical techniques such as maximum likelihood estimation. Whilst applicable to general financial markets our model may thus have specific relevance to cryptocurrency markets. Secondly, we contribute to a fledgling academic literature on Bitcoin and cryptocurrency markets. Thirdly, we find empirical evidence of negative bubbles in cryptocurrency markets – complementing earlier documented evidence of speculative bubbles in the literature. Fourthly, we address the issue of competition between rival cryptocurrencies. This is significant as the issue of contagion and co-dependence is particularly pertinent for cryptocurrency markets.

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One notable example of this is that the market share of the two largest cryptocurrencies Bitcoin and Ripple has fluctuated quite dramatically in recent months. Here, we find evidence of a spillover from Ripple to Bitcoin. Fifthly, we develop a model to independently verify the impact of putative market shocks (identified by academics and practitioners alike) upon Bitcoin. Results suggest that cryptocurrency markets are inherently complex and are often misunderstood by academics and practitioners alike.

The layout of this paper is as follows. Section 2 gives a brief overview of econophysics and reviews the academic literature on Bitcoin and cryptocurrencies. Section 3 develops the basic bubble/antibubble model and its extension to higher dimensions. Section 4 discusses a model for unpredictable market shocks. The model is later used to track the effect of events such as the closure of the illegal Silk Road website and the collapse of the Tokyo-based Bitcoin exchange Mt. Gox upon Bitcoin prices. Empirical applications are discussed in Section 5. Section 6 concludes.

2. Literature Review

2.1. Econophysics and the analysis of financial crashes

Econophysics is perhaps best defined as the use of paradigms and tools from theoretical and statistical physics to model financial and economic systems (Mantegna & Stanley, 1999). The movement has a long history. For a historical overview see e.g. Jovanovic and Schinckus (2013) and Chen and Li (2012). The term econophysics was first coined in Stanley et al. (1996) and the modern arm of the movement can trace its origins to several key developments that occurred in the 1990s. These include technical developments in the mathematics of Lévy processes and the development of increased computer processing power together with the ready availability of large electronic financial databases. Allied to the above as time has progressed several economics and finance journals have also become more receptive to ideas from econophysics (Jovanovic & Schinckus, 2013).

Speculation and financial crises have been endemic throughout human history (Reinhart & Rogoff, 2009). Bubbles typically occur when the price of an asset grows rapidly and does so in a manner far removed from realistic assessments of the asset's intrinsic value (Phillips & Yu, 2011). The implication is that such a dramatic price rise sets up asset prices for a subsequent fall. Kindelberger and Aliber (2005) describe bubbles as a sharp rise in asset prices – with the initial rise generating expectations of further rises and attracting new buyers via a process commonly labelled irrational exuberance (Shiller, 2005). However, beyond these definitions, and real economic suffering, both the theoretical existence of bubbles, and issues related to their empirical detection, remain hotly debated (Gurkaynak, 2008; Vogel & Werner, 2015).

From a statistical physics perspective stock market crashes represent a rupture event in a complex system (Feigenbaum, 2003). This analogy with exactly soluble models in statistical mechanics led to the development of phenomenological log-periodic power-law models for bubbles where the price exhibits unsustainably high super-exponential growth (Feigenbaum & Freund, 1996; Sornette, Johansen, & Bouchaud, 1996). A rational expectations version of the original model was then formulated in Johansen et al. (2000) thereby forming a potential bridge with the mainstream economics and finance literature. Despite some initial controversy (see e.g. Feigenbaum, 2001a, 2001b) econophysics modelling of financial bubbles has continued to grow from strength to strength – in part as a response to the increasingly volatile nature of global financial markets.

Even before the 2008 crisis one dramatic unintended consequence of the increased computerisation of financial markets described above was increased speculation and volatility (Barber & Odean, 2001). This in turn has lent weight to the empirically oriented approach favoured by econophysics as financial markets evolved. Statistical physics, and its reincarnation into econophysics, is chiefly concerned with providing the best possible explanation of empirically observable phenomena. This contrasts sharply with the rigid theoretical frameworks often associated with both financial economics and mathematical finance (Jovanovic & Schinckus, 2013).The modelling of financial bubbles and crashes has thus emerged as a key part of the wider econophysics movement (Feigenbaum, 2003). This has gained added impetus since the 2008 crisis with several econophysics papers modelling bubbles and crashes appearing in well-respected finance and economics journals in recent years (see e.g. Bree & Joseph, 2013; Geraskin & Fantazzini, 2013; Kurz-Kim, 2012; Lin & Sornette, 2013; Lin et al., 2014).

A range of empirical findings reported in the literature suggest that econophysics can indeed generate useful insights into real markets. For example, econophysics can be used to shed new light into the monetary roots of bubbles and crashes (Corsi & Sornette, 2014). In line with this practically-minded approach the functioning of Bitcoin and other cryptocurrency markets represents an interesting problem in its own right and one that also presents new challenges to mainstream economics and finance (see Section 2.2).

2.2. The cryptocurrency market

The use of cryptocurrencies has gained traction in response to the perceived failures of government and central banks during the 2008 crash (Weber, 2014a). Bitcoin and other cryptocurrencies may also offer cheaper alternatives to existing debit and credit card systems (Angel & McCabe, 2015), in part reflecting recent technological innovations in regular monetary systems (Böhme, Christin, Edelman, & Moore, 2015; European Central Bank, 2012). Amid huge media and public interest the academic literature on Bitcoin is only recently starting to emerge (see e.g. Frisby, 2014; Vigna & Casey, 2015). Initially the debate surrounding the use of cryptocurrencies appeared to be dominated both by Bitcoin and by other disciplines such as computer science (see e.g. Böhme, Brenner, Moore, & Smith, 2014; Sadeghi, 2013) and law (see e.g. Grinberg, 2012; Plasaras, 2013). However, as discussed in this subsection, a fledgling economics and finance literature is starting to emerge. In particular, previous literature on Bitcoin raises several interesting questions such as the exact nature of Bitcoin, the long-term sustainability of Bitcoin, competition in the market for digital currencies and an on-going ethical debate surrounding Bitcoin and cryptocurrencies. Our paper also contributes to these discussions and adds to a burgeoning econophysics literature on Bitcoin and cryptocurrencies.

The cryptocurrency market warrants close scrutiny given its increasingly high profile. The sums of money involved are substantial. The total cryptocurrency market capitalisation is estimated to be $7.1 billion (www.coinmarketcap.com, January 2016). Amongst over 600 traded cryptocurrencies Bitcoin and Ripple are the two most popular cryptocurrencies with around 91% and 2.8% of the entire cryptocurrency market capitalization respectively though as recently as May 2015 the market share of Ripple was as high as 6%. Ripple and Bitcoin share important characteristics such as their ultimate dependence upon the trust of their users and a unique network currency (Bitcoin for Bitcoin and XRP in Ripple respectively). However, there are also important differences. Ripple is primarily designed to serve as a medium of exchange and as a distributed payment system as opposed to an alternative currency per se. Ripple is thus arguably more like a new improved form of PayPal or Mastercard than a “digital dollar”. This ready convertibility means the Ripple network itself actually accepts Bitcoin and, inter alia, allows users to trade precious metals like gold and silver, cryptocurrencies, conventional currencies like the US Dollar and the GB Pound and even assets like air miles with lower transaction costs using its own native digital currency – the XRP. This added flexibility makes Ripple a strong potential rival to Bitcoin. Despite its obvious relevance and importance research into Ripple appears to be almost non-existent due to its lack of widespread usage prior to 2013.