Economic Modelling xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Economic Modelling

journal homepage: www.elsevier.com/locate/econmod

Do bubbles have an explosive signature in markov switching models?

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ARTICLE INFO

JEL classification:
C52
E3

Keywords:
Explosive root regimes
Transient explosive roots
Bubbles
Bayesian model averaging

ABSTRACT

We investigate nine data series previously identified as containing bubbles using Bayesian Markov switching models. Nearly all series appear to display strong regime switching that could possibly be induced by 'bubble' processes, but in each case the type of model that best describes each price differs substantively. We pay particular attention to whether these series contain transient explosive roots, a feature which has been suggested to exist in several bubble formulations. Bayesian model averaging is employed which allows us to average across a range of submodels, so that our empirical findings are not based on only one well performing model. We show that explosive regimes may exist in many submodels, but only when the flexibility of the model is limited in other important respects. In particular, when Markov switching models allow for switching levels of error variance, explosive root regimes occur in only a minority of the series.

1. Introduction

There has been a long standing interest in the idea that asset prices may exhibit bubbles (e.g., Garber, 1990; Malkiel, 2012). This interest has been particularly apparent in the analysis of prices in markets that are subject to speculation with numerous papers supporting the existence of bubbles. For example, aggregate prices (Hall et al., 1999, henceforth referred to as HPS), oil prices (e.g., Shi and Arora, 2012; Zhang and Yao, 2016), stock market prices (e.g., Narayan et al., 2013; Chen et al., 2016; Shi and Song, 2016) and house prices (e.g., Phillips and Yu, 2011) have all been found to contain bubbles. There is also extensive behavioural experimental evidence supporting the existence of bubbles (e.g., Shiller, 2003). Yet, while there is widespread support[1] for the idea that some economic series exhibit bubbles, there are several ways of defining bubbles. Bubbles are an evocative yet imprecise metaphor when applied to prices, perhaps inviting people to think that prices must 'float' somewhat unpredictably upward then 'pop' in the sense that they suddenly collapse. To others the term bubble might signify that a market or price is somehow cut off (albeit temporarily) from the fundamental forces shaping the wider economy. Different types of bubbles are commonly differentiated in terms of being fundamental (intrinsic) or speculative (extrinsic), rational or irrational (Gurkaynak, 2008). This complicates the empirical identification of bubbles, since the term can describe a range of phenomena. Commonly, however, the word 'explosive' has been employed to describe bubbles and a strand of the literature has gone further by proposing that the Transient Explosive Root (TER) property of a series is a 'bubble signature' (e.g., Hall et al., 1999; Phillips and Yu, 2011; Phillips et al., 2015; Shi and Song, 2016).[2]

In this paper, we first inquire as to whether alternative bubble formulations necessarily imply that we should see explosive regimes in Markov switching models. We observe that while the wider literature often refers to the 'explosive' nature of bubbles, it does not generally infer that TERs are a necessary condition for the existence of bubbles. For example, in the rational intrinsic bubble model of Froot and Obstfeld (1991), a large and increasing divergence of a price from its fundamental value is labelled 'explosive', even though there may be no sudden change upwards or downwards, and the series need not display TER behaviour. Likewise, the bubble of Blanchard and Watson (1982) is regime switching, but not of an explosive root regime (ERR) variety and Evans (1991) provides a formulation, which has often been considered as explosive, which need not strictly be explosive in the TER/ERR sense.

The significance of identifying a TER within the bubble literature is

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[1] The awarding of the 2013 Nobel prize to economists holding a different perspective about the existence of bubbles has reinvigorated interest in this topic. It was awarded to Robert Shiller, Eugene Fama and Lars Peter Hansen, with a number of commentators highlighting the recipients differences in opinion regarding bubbles e.g., A very Rational Award, The Economist, Oct 19th 2013.

[2] We use the term TER to refer any case where the series displays an explosive root which is not permanent. We also use the term ERR as a specific form of TER, that it is specific to regime switching models.

http://dx.doi.org/10.1016/j.econmod.2017.06.001
Received 24 November 2016; Received in revised form 23 May 2017; Accepted 1 June 2017
0264-9993/

mostly due to Phillips and Yu (2011). Subsequently, Phillips (and various co-authors) developed the econometric theory enabling the testing for 'right valued alternatives' to the unit root hypothesis (see Phillips et al., 2011, 2015). They interpret the rejection of the unit root in favour of the right valued alternative as the rejection of the 'no bubble' hypothesis. In related research, a Bayesian Markov switching approach has been used by Shi (2013) and Shi and Song (2016), searching for ERRs as a bubble signature following Hall et al. (1999) who showed that Evans (1991) bubbles can be identified using ERRs in an autoregressive Markov switching model.[3]

The posited connection between explosivity and certain types of bubbles serves as an additional motivation for searching for TERs. But, we do not only focus on TERs. In the empirical part of our paper, we examine nine data series that have previously been identified as containing bubbles. These include the WuLiang Put Warrant data (Xiong and Yu, 2011) and Bitcoin prices. Both are strong candidates for containing bubbles. The former because, as demonstrated by Xiong and Yu (2011), there is a convincing case that the prices observed could not possibly be justified from their fundamentals, and the latter because the fundamental price should be close to zero, yet Bitcoins continue to hold substantial value. We examine whether these series contain common features that may constitute a 'bubble signature'.

Identifying a signature is difficult because the same data can be often be explained well by very different models. Existing work has established that for many series thought to contain bubbles, an autoregressive representation with a constant error variance does a poor job of modelling their behaviour. In contrast, permitting parameters to switch back and forward between regimes improves model performance. But, allowing all parameters to switch is less than ideal if only a few need to. Our empirical work shows that if one part of the model is held constant (e.g., not being regime specific or a parameter is set to zero) what remains flexible will do the 'explanatory work'. In this sense there is 'exchangeability' between models. There is nothing particularly new about this. For example, an ARMA model has both an AR and MA representation, and if one part is suppressed, the other will become more important. Unlike the ARMA example, we do not believe there is an exact exchangeability[4], between our submodels. However, models may be nearly exchangeable in the sense that several models may perform almost equally well. The classical statistical approach is to select models based on some testing down procedure, or because they are the better of two (or more) models no matter how small the difference in performance criteria. By contrast the Bayesian model averaging (BMA) approach, we employ, recognises that many models have merits and averages across the results/estimates in a way that gives better performing models more weight. We use the marginal likelihood (a Bayesian measure of the adequacy of a model) to discriminate among many models and to construct the model weights, employing the approach introduced by Frühwirth-Schnatter (2001), Frühwirth-Schnatter (2004). The marginal likelihoods allow us to see whether price behaviour can sometimes be explained by quite different models. But, unlike standard model selection procedures, BMA does not require us to select a specific model. Nor does it require us to adopt arbitrary sequential reduction sequences that determine parsimonious model selection. Thus, we see the BMA approach as being critical to addressing whether TERs are a feature of the dominant submodels of which there may be many.

Our research also differs to the existing Bayesian research by Shi and Song (2016). We allow for averaging over lag lengths and a number of other restrictions, the selection of which can be pivotal, whereas Shi and Song (2016) allow for endogenous selection of multiple regimes with fixed lag lengths. Importantly, we offer a more definitive approach than previous Bayesian papers for testing for ERRs, by calculating the marginal likelihood with and without the unit root imposed, since the imposition of a unit root throughout the sample period excludes the possibility of an ERR. In addition, our model specification also extends the existing literature by simultaneously allowing for shifts in error variance as well as t-distributed errors where degrees of freedom for the t–distribution are estimated endogenously. The importance of allowing for shifts in the error variance within a Markov switching specification has been noted by Shi (2013), who found that there may be bias in favour of finding bubbles unless provision is made for error variance shifts. Our results support Shi (2013) such that when using a Markov switching approach, clear ERRs will more commonly manifest when a constant variance is imposed. Thus, for many of the series considered in this paper the imposition of a constant variance is often pivotal.

The paper proceeds by first examining whether all bubbles should contain TERs from a theoretical perspective in Section 2. In Section 3, we introduce the regime switching model that we employ in the empirical section. In this section we also detail the restrictions that identify the special cases of interest. Given the use of Bayesian methods in this paper, we also describe and explain our choice of priors. Next we discuss estimation with details being relegated to appendices. The following sections present the empirical results with discussion and the last section concludes.

2. Models specifications and statistical tests for bubbles

We begin by considering various bubble model specifications, what this implies for data and what are the implications for econometric testing. We restrict our attention here to some formalised structures that exist in the literature, rather than the wider literature that considers the nature of bubbles. Thus, we focus on several rational extrinsic and intrinsic bubble models that have played an important role in the literature.

2.1. Rational intrinsic and extrinsic bubbles

These models posit the existence of a 'fundamental price', which is the sum of the discounted future dividends of an asset. Extrinsic models posit that the actual price of an asset is equal to this fundamental price plus a bubble component which is not a function of dividends (e.g., Blanchard and Watson, 1982; Evans, 1991; Brooks and Katsaris, 2005). Intrinsic models either specify the bubble component and make it a function of dividends (e.g., Froot and Obstfeld, 1991) or posit that the bubble is itself within the fundamental price (e.g., Phillips and Yu, 2011).

Bubble models are rational providing they observe the sub-martingale property, such that for a normal and constant rate of return r, the bubble at time t (B_t) obeys

$$E_t B_{t+1} = (1 + r)B_t \tag{1}$$

where E_t is the expectations operator at time t. As already noted, Phillips and Yu (2011) posit a time varying rate of return that can unambiguously generate bubbles of an explosive nature. However, not all bubbles necessarily have this property.

2.1.1. Non-explosive rational bubbles

The model of Blanchard and Watson (1982) posits that the bubble component at time t (B_t) is of a regime switching type with one component having a significantly faster upward trajectory than the other. They observe that the sub-martingale property can easily be satisfied in a regime switching context. The model in Froot and Obstfeld (1991) also satisfies this condition, however, they show that the bubble can be made to depend on dividends in the instance where the dividends are a random walk. Likewise the model of Brooks and Katsaris (2005) has the sub-martingale property. Importantly, how-

[3] As shown in Homm and Breitung (2012), tests based on right valued alternatives to the unit root also identify Evans (and other) bubbles in Monte Carlo studies.

[4] We cannot prove this conjecture, but we are not aware of any work that would suggest that this is the case.