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Testing Bubbles: Exuberance and Collapse in the Shanghai A-share Stock Market?

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Abstract

In this paper, we use the sup ADF test (SADF) and the generalized sup ADF test (GSADF) to identify periodically collapsing bubbles in the Shanghai A-share stock market. To our understanding, this is the first time in the literature that the SADF test and the GSADF test have been applied to this stock market. The empirical results show that the GSADF test performs well in identifying two important periods of exuberance and collapse of Shanghai A-share. The first begins in November 2006 and runs until January 2009. The second begins in May 2014 and ends in July 2015. The evolution process of the two periodically collapsing bubbles are further analysed in depth.

Keywords: Shanghai A-share stock market, Periodically collapsing bubbles, Generalized sup ADF test, sup ADF test

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1. Introduction

When a stock market bubble bursts, financial crises that spread to the real economy can be triggered, which implies the potential danger of bubbles. New and selectively very complicated time series methods are emerging that allow for better understanding of bubbles retrospectively. In this paper, we use the sup ADF test (SADF) developed by Phillips, Wu and Yu (2011) and the generalized sup ADF test (GSADF) developed by Phillips, Shi and Yu (2013) to identify bubbles in the Shanghai A-share stock market, and which also can track the bubble's origination and termination date. To our understanding, this is the first time in the literature that the SADF and the GSADF has been applied to this stock market.

The study of speculative bubbles is a long-standing topic of interest in the economics research. Many researchers have proposed various testing methods to analyse these dynamics from multiple perspectives. Lehkonen (2010) used the duration dependence test to examine weekly and monthly stock prices in China, and found that bubbles for Mainland China's stock markets are observable in weekly but not in monthly data. This result suggests

that duration dependent tests might not be appropriate for identifying bubbles in Mainland China. Yu, Pi and Zhou (2013) suggested combining the variance decomposition method with the dynamic autoregression method in order to obtain a measure of bubble risk. Unfortunately their test methodology process is so tedious that it is not generally supported by economists.

Phillips, Shi and Yu (2013) successfully developed a new test methodology for detecting multiple bubbles in continuous time and date-stamping bubble cycles, the generalized sup ADF test (GSADF), which is a generalized version of the sup ADF test (SADF). The GSADF improves the flexibility of the rolling window of the SADF test. This improvement makes the test relatively suitable for multiple bubble phenomena with both a nonlinear structure and a break mechanism. Their method succeeded in correctly identifying famous episodes of exuberance and collapse over the period of January 1871 to December 2010 using the S&P 500 stock market data.

Such results suggest that the SADF and GSADF tests offer a potentially stronger power to identify exuberance and collapse of multiple bubbles in Shanghai A-share stock market than other test methodologies, and hence we adopt these test methods in this paper. The organization of the rest of this paper is as follows. Section 2 reviews the literature of the other bubble test methodologies. Section 3 provides an overview on the theoretical model

background. Section 4 introduces the model specifications and data-stamping strategies behind the SADF test and the GSADF test. Section 5 discusses the testing data. The empirical testing results of the SADF test and the GSADF test are reported in Section 6. Section 7 analyses the evolution process of each periodically collapsing bubble in Shanghai A-share stock market. The paper closes with conclusion as Section 8.

2. Literature Review

The concept of a rational bubble was originally proposed by Blanchard (1979a) based on his work using an overlapping generations model. If the elasticity of the current price with respect to next period's expected price is smaller than one unity, there should exist a forward solution that takes the stationarity requirement into account, and so the rational expectation solution is conditional upon the relationship between the current price and expected future price (Blanchard, 1979a). Blanchard (1979b) consequently constructed models for detecting speculative bubbles that adopted rational expectations assumptions. Flood and Garber (1980) published the completed rational expectations model for testing the first-time existence of a price-level bubble. As required by the rational expectations model, bubbles appear when the

current price is mainly determined by the change in the expected market price. The rational expectation model here becomes the theoretical basis for measuring market bubbles. In this way, Blanchard and Watson (1982) explain rational bubbles as the deviation of asset prices from the fundamental value by use of a dynamic forecasting model which follows from the fact that speculative bubbles are not ruled by rational behaviour, even though rational behaviour has a real effect on market fundamentals and also modifies the behaviour of prices (Blanchard and Watson, 1982). But with the interference of irrationality variables, it is not easy to find a high power procedure to test rational stock market bubbles.

In general, most econometric methodologies that seek to detect bubbles rely upon rational expectations theories, and are differentiated by different testing techniques. These different testing techniques, however, produce diametrically opposite results. Two different variance bounds tests (Shiller, 1981 and West, 1987) reached the same conclusion of rejecting the null hypothesis of no bubbles. But Diba and Grossman (1988a) consider that mixed testing results produced by a co-integration test probably reflect the low power of the tests rather than the presence of explosive rational bubbles in stock prices. Diba and Grossman (1988a) and Flood and Hodrick (1990) concur that the rejection of no bubbles hypothesis cannot be used to confirm the existence of bubbles, because the composite null hypothesis in fact already has contained bubbles.

The reason why the composite null hypothesis includes bubbles is that bubbles are expected to emerge gradually, hence a variance bounds test does not well suit testing for bubbles. Another problem is that the test methods proposed by Shiller (1981), West (1987) and Diba and Grossman (1988a) also are restricted to linear testing. But through Monte Carlo simulation, Evans (1991) finds that popular linear testing strategies cannot detect periodically collapsing bubbles since highly non-linear periodically collapsing bubbles usually do not have integration and co-integration properties. Evans's (1991) findings served to inspire further work toward constructing non-linear testing models for successfully detecting periodically bubble collapse.

Taylor and David (1998) use a non-cointegration test and Monte Carlo analysis to demonstrate the presence of periodically collapsing bubbles. Ahmed et al (1999) use a VAR model to examine nonlinearities in stock market movement in ten Pacific-Rim countries and districts, although they do not offer certainty that the estimated fundamentals are absolutely correct. After learning from the existing experience of test failure, Wu (1997) projects that if a bubble can be treated as an unobserved state vector in the state-space model, then the Kalman filter technique should easily detect market bubbles. Using S&P 500 stock market data, Wu (1997) explains many of the stock price deviations of the bull and bear markets of the 20th century. Hall, Psaradakis and Sola (1999) suggests use of a generalized Dickey-Fuller test procedure that makes use of

a class of Markov regime-switching models to achieve a nonlinear testing methodology. This method works because when the ADF regression parameters are allowed to switch values among different regimes, the ADF formulation will match the dynamic changing process of periodically collapsing bubbles. Kang (2010) opts for the STAR (smooth threshold autoregressive) model to identify bubbles in China's stock market. The empirical results show that the nonlinear motion of bubbles tracked by the STAR model closely links with the real stock market volatility. Kang (2010) also acknowledges however, that the STAR model cannot perfectly cope with nonlinear and asymmetrical dynamics of bubbles in China stock market.

More recently, Phillips, Wu and Yu (2011) use a forward recursive right-sided unit root test to solve the issue proposed by Diba and Grossman (1988a). They conduct the Dickey-Fuller (DF) statistics sequentially for date-stamping the origination and termination date of bubbles. This new testing procedure of periodically collapsing bubbles is called the sup ADF (SADF) test. Using the SADF test, Phillips, Wu and Yu (2011) successfully document all explosive bubbles in the 1990s-Nasdaq stock market. In the Monte Carlo experiment, the SADF test exhibits powerful superiority in detecting periodically collapsing bubbles among all tests from the study of Homm and Breitung (2012). Phillips, Shi and Yu (2014) express confidence in the recursive right-tailed ADF test again, given its use in detecting mildly explosive or sub-martingale behavior in

the data as a form of market diagnostic alert.

The GSADF test was developed by Phillips, Shi and Yu (2013). The GSADF test has a similar econometric detection mechanism as the SADF test, since the GSADF test and the SADF test both rely upon a recursive right-tailed ADF unit root test to detect periodically collapsing bubbles. The difference is that the SADF test has a relatively fixed window width with an identified starting point and changeable ending point, while the GSADF test extends sample data coverage by a feasible rolling window size range so as to overcome the weakness of the SADF test. This modification is greatly important. The SADF test is only able to identify a single bubble because of the fixed starting point design. The GSADF test design expands the detection range so that the GSADF test is able to identify all exuberances and collapse of multiple bubbles. The GSADF test is at this stage in the literature likely to be the most advanced bubbles detection strategy, which we will use for the Shanghai A-share stock market. We further elaborate in Section 4.

3. Theoretical Model Background

This section presents the basic theoretical background to models of bubbles detection. Under the assumption of rational expectations and efficient markets, Lehkonen (2010) allows for deviations of stock prices from fundamental values,

and such deviations are actually caused by rational traders rather than irrational traders. Blanchard and Watson (1982), Diba and Grossman (1988a) and Flood and Hodrick (1990) agree that deviation between the stock price and the fundamental value is a product of rationality-driven bubbles, and hence the size of the deviation is equivalent to the size of the bubble.

Under the efficient market hypothesis, the market will realize a 'no-arbitrage equilibrium' at that time of which the expected return of risky assets will be equal to the yield demanded by investors. We assume that the stock price at time t is P_t , and the stock dividend at time t+1 is D_{t+1}. Then, R_{t+1} is the return of an asset at time t+1 and is influenced by the changes of stock price and dividend. We thus have:

$$R_{t+1} = \frac{P_{t+1} - P_t + D_{t+1}}{P_t} = \frac{P_{t+1} + D_{t+1}}{P_t} - 1 \qquad (1)$$

Under rational expectations:

$$E_t(R_{t+1}) = r_{t+1} \qquad (2)$$

Where E_t denotes expectations mathematically given the information set at time t, r_{t+1} is equal to the time-varying required rate of return.

$$P_t = \frac{E_t(P_{t+1} + D_{t+1})}{1 + r_{t+1}} \qquad (3)$$

Then, we reach equation (3), which implies that the current stock price is equal to the sum of expected future prices and dividends at time t+1 divided by the required return rate. Using the iterative solution method, we can then solve the fundamental value of the asset P_t^* under the equilibrium condition:

$$P_t^* = \sum_{i=1}^{\infty} \frac{E_t(D_{t+i})}{\prod_{j=1}^{i}(1+r_{t+j})} \qquad (4)$$

And from which we can derive a new formula containing a bubble variable:

$$P_t = P_t^* + B_t \qquad (5)$$

where B_t is the rational price bubble and $B_t = E_t(B_{t+1})/(1 + r_{t+1})$. Equation (5) demonstrates that bubble factor B_t drives the stock price P_t to deviate from the fundamentals P_t^*. On average, this bubble factor discounts at the required rate of return r_{t+1}. Flood and Hodrick (1990) re-write the bubble equation as:

$$B_{t+1} = B_t * (1 + r_{t+1}) + \tilde{B}_{t+1} \qquad (6)$$

where $\tilde{B}_{t+1} = B_{t+1} - E_t(B_{t+1})$. B_t is a stock price bubble, and $\tilde{B}_{t+1}$ reflects innovation in the bubble which has mean zero.

In the rational speculative bubble model, Blanchard and Watson (1982) describe the formulation and bursting process of bubbles as follows:

$$B_{t+1} = \begin{cases} \dfrac{(1 + r_{t+1})B_t}{\pi} + u_{t+1} \\ u_{t+1} \end{cases} \qquad \begin{pmatrix} prob = \pi \\ prob = 1 - \pi \end{pmatrix}$$

From the above mathematical expressions, we can observe that the bubble factor B_t grows at a fixed rate with probability π, and collapses with probability 1-π back to the initial value u_{t+1}, where u_{t+1} is a random variable with mean zero. If the bubble does not collapse, investors can receive a realized return of r_{t+1} which equates compensation and risk values. In other words, when investors want to be compensated for over-payment (over the fundamental price) by future appreciation of the bubble component, the bubble

component must be positive.

When rational bubbles occur in the stock market, this thus will induce market exuberance or financial crash. Phillips, Shi and Yu (2013) conclude that financial exuberance derives from pricing errors, or the deviation of stock price in response to fundamentals. In the literature, there are two conditions resulting in market exuberance. In the viewpoint of Phillips, Shi and Yu (2013), the first condition is that market exuberance arises from behavioural factors and the second condition relates to the fact that fundamentals themselves might be highly sensitive to changes in the discount rate. Thus its property of high sensitivity forces the increases in the price to mimic the inflation of a bubble.

Evans (1991) believes that the standard linear test methodology fails to identify periodically collapsing bubbles in empirical testing, and that only non-linear bubble detection models can avoid aforementioned mistakes. Since then, Evans (1991) suggests to describe periodically collapsing bubbles in the following way:

$$B_{t+1} = (1+r)B_t u_{t+1} \qquad if \ \ B_t \leq \alpha$$

$$B_{t+1} = [\delta + \pi^{-1}(1+r)\theta_{t+1} * (B_t - (1+r)^{-1}\delta)]u_{t+1} \qquad if \ \ B_t > \alpha$$

where δ and α are positive parameters with $0 < \delta < (1+r)\alpha$, u_{t+1} is an exogenous independently and identically distributed positive random variable

with $E_t u_{t+1} = 1$ and identically distributed Bernoulli process (independent of u) which takes the value 1 with probability π and 0 with probability $1 - \pi$, where $0 < \pi \leq 1$. If $B_t \leq \alpha$, the bubble will continually grow at mean rate $(1 + r)$. But if $B_t > \alpha$, the bubble will rapidly increase at an explosive rate $\pi^{-1}(1 + r)$, and it has a probability of $1 - \pi$ to collapse in each period. Once a bubble bursts, it drops back to the mean value δ, and the process restarts again. Hence, the evolution of bubbles is cyclical and recursive. Moreover and in brief, when π is close to 1, the unit root test can locate the existence of bubble. When π gradually becomes smaller, the unit root test loses its detection power. This owes to the fact that when π contracts, the explosiveness of bubble component B_t becomes less significant. At this moment, the unit root test no longer works.

In order to effectively detect the explosiveness of a bubble using a unit root test, Phillips, Wu and Yu (2011) adopt the recursive regression technique and the right-sided unit root test. These are more useful for detecting mild explosiveness or sub-martingale behaviour than the left-sided unit root test. The SADF test (Phillips, Wu and Yu, 2011) can directly test the stock price without calculating the fundamentals and rapidly capture the origin and terminal of multiple bubbles. In the light of the SADF test, Phillips, Shi and Yu (2013) re-modify the test model to improve the flexibility and accuracy of test methodology. This new test methodology is referred to as the generalized

sup-ADF (GSADF) test. In next section, the model specifications and date-stamping strategies of the SADF test and the GSADF test will be introduced in detail.

4. Model Specifications and Date-stamping Strategies of the SADF test and the GSADF test

4.1 Model Specifications

For the asset pricing equation for detecting financial bubbles, here we adopt the same equation as Phillips, Shi and Yu (2013):

$$P_t = \sum_{i=0}^{\infty} (\frac{1}{1+r_f})^i E_t(D_{t+i} + U_{t+i}) + B_t \qquad (7)$$

where P_t is the after-dividend price, D_t is the dividend, r_f is the risk-free interest rate, and B_t is the bubble factor. Equation (7) is equivalent to equation (4) and equation (5) plus a new variable U_t denoting the unobservable fundamentals. We know that B_t satisfies the sub-martingale property, as follow:

$$E_t(B_{t+1}) = (1 + r_f)B_t \qquad (8)$$

If there is no bubbles at time t, $B_t = 0$, thus $P_t = \sum_{i=0}^{\infty} (\frac{1}{1+r_f})^i E_t(D_{t+i} + U_{t+i})$.

The degree of non-stationarity of the asset price is decided by the D_t and U_t.

When U_t is at I (1) and D_t is stationary after differencing, empirical evidence of explosive behaviour in asset prices may be used to conclude the existence of bubbles (Phillips, Shi and Yu, 2013).

There is general agreement that bubble phenomenon can occur during periods of market exuberance and collapse. Disagreement however, centres on how to measure and predict the bubble. The SADF test and the GSADF test measure the bubble based on the price-dividend ratio. Their derivation processes are taken from the model specification of Campbell and Shiller (1988).

Here we first take the logarithm of equation (3)

$$p_t = \kappa + \rho p_{t+1} + (1 - \rho)d_{t+1} - r_{t+1} \qquad (9)$$

Here, $\kappa = -\log(\rho) - (1 - \rho)\log(1/\rho - 1)$. Note that $\rho = 1/[1 + e^{\overline{p-d}}]$ with $\overline{p-d}$ is the average price-dividend ratio. Variables p_t, d_t and r_t are natural logarithmic values of P_t, D_t and R_t. Solving equation (9) by forward iteration and taking expectations yields Equation (10), which includes the logarithm of the price-dividend ratio

$$p_t - d_t = \frac{\kappa}{1-\rho} + \sum_{i=0}^{\infty} \rho^i E_t(\Delta d_{t+1+i} - r_{t+1+i}) + \lim_{i \to \infty} \rho^i E_t(p_{t+i} - d_{t+i}) \qquad (10)$$

When we set $p_t^f = \frac{\kappa}{1-\rho} + \sum_{i=0}^{\infty} \rho^i E_t(\Delta d_{t+1+i} - r_{t+1+i})$ as the fundamental component, and $b_t = \lim_{i \to \infty} \rho^i E_t(p_{t+i} - d_{t+i})$ as the rational bubble component, we arrive at:

$$p_t - d_t = p_t^f + b_t \qquad (11)$$

Further, $E_t(b_{t+1}) = \frac{1}{\rho}b_t = [1 + \exp(\overline{p-d})]b_t, with\ g = [1 + \exp(\overline{p-d})] > 0$.

And the logarithm of the bubble component has the growth rate g.

In the absence of a bubble component condition $b_t = 0$, since $p_t = d_t + p_t^f$.

From the equation of p_t^f, we can obtain

$$d_t - p_t = -p_t^f = -\frac{\kappa - r}{1 - \rho} - \sum_{i=0}^{\infty} \rho^i E_t(\Delta d_{t+1+i}) \qquad (12)$$

When p_t^f is ruled out from stock price p_t, the residual component should be stationary. If the residual part is non-stationary, this indicates there is bubble in p_t.

When explosive bubbles are presented (i.e. $b_t \neq 0$), p_t is greatly determined by b_t, irrespective of whether d_t is an integrated process I (1) or a stationary process I (0) (Phillips, Wu and Yu, 2011). In other words, the stock price follows a non-stationary process. Thus, the dynamics of $p_t - d_t$ are determined by p_t^f and b_t. If the variables in p_t^f have stationary process I (0), there is only b_t remaining with a relationship with the explosiveness in $p_t - d_t$. That means a test for the explosive behaviour of $p_t - d_t$ is also a test for the bubble component b_t.

Although the SADF test and the GSADF test share a common testing variable, the price-dividend ratio, the difference between them is at the rolling window setting. The basic idea behind the GSADF test is in fact specifically to change the rolling window widths firstly by forward recursive progression, and then get the SADF test sequence, and at last to find the maximum value from its SADF test sequence and compare this with the corresponding SADF critical value to decide whether to reject the null hypothesis. Phillips, Shi and Yu (2013)

assumes that a random walk (or more generally a martingale) process with an asymptotically negligible drift. The form is written as follows:

$$y_t = cT^{-\lambda} + \theta y_{t-1} + u_t, \quad u_t \sim i.i.d. N(0, \sigma^2), \theta = 1 \qquad (13)$$

Where c is constant, $\lambda > 1/2$ serves as a localizing coefficient that controls the magnitude of the drift and T is the sample size with $T \to \infty$. Obviously, this equation is a unit root procedure without trend item, but with a gradually disappearing intercept.

If the initial sample proportion of the recursive approach is r_0, and the total sample is T, then the test sample size is expressed as $t = \lfloor Tr_0 \rfloor$, where $\lfloor \cdot \rfloor$ takes the integer part of the input variable. From the first observation, Phillips, Wu and Yu (2011) set the recursive right-sided unit root test with sample data to $t = \lfloor Tr \rfloor$. The SADF test mainly relies on recursive calculations of the ADF statistics with a fixed starting point and a changeable width window. Suppose that r_1 is the starting point of the test and r_2 is the ending point, then $r_w = r_2 - r_1$ is the window size of the regression. The empirical model is defined as:

$$\triangle y_t = \alpha_{r_1}^{r_2} + \beta_{r_1}^{r_2} y_{t-1} + \sum_{i=1}^{k} \psi_{r_1,i}^{r_2} \Delta y_{t-i} + \varepsilon_t \qquad (14)$$

where k is the lag order and $\varepsilon_t \sim i.i.d. \left(0, \sigma_{r_1,r_2}^2\right)$. $ADF_{r_1}^{r_2}$ denotes the ADF statistic value (t-value) of equation (14).

The SADF test requires a repeated ADF test on a forward expanding sample

sequence. The obtained test result is the sup value of the corresponding ADF statistics sequence (Phillips, Shi and Yu, 2013). Under this model specification, the starting point is fixed at r_0, in contrast the ending point r_2 can freely expand from r_0 to 1. The SADF statistic can be written as

$$SADF(r_0) = \sup_{r_2 \in [r_0, 1]} ADF_0^{r_2} \qquad (15)$$

The GSADF test is distinct from the SADF test in that it allows the starting point and the ending point to change simultaneously. Therefore, the starting point r_1 can vary within the range $[0, r_2 - r_0]$ and the size of window width r_w also flexibly shifts within the bounds of r_1 and r_2. Since this modification extends the range of sub-sample data, the GSADF test is more accurate for detecting multiple bubbles than the SADF test. The GSADF test is defined as follows

$$GSADF(r_0) = \sup_{\substack{r_2 \in [r_0, 1] \\ r_1 \in [0, r_2 - r_0]}} \{ADF_{r_1}^{r_2}\} \qquad (16)$$

The asymptotic GSADF distribution might be effected by the smallest window width r_0, according to the limit theory of the SADF test. As a result, the starting point r_0 is determined by T, which is the total number of sample observations. Phillips, Shi and Yu (2013) summaries the negative relationship between r_0 and T. If T is small, r_0 needs to be large enough to ensure there are enough observations for adequate initial estimation. If T is large, r_0 can be set to be a smaller number so that the test does not miss any opportunity to detect an early explosive episode.

4.2 Data-stamping strategies

We summarize the data-stamping strategies used by Phillips, Wu and Yu (2011) and Phillips, Shi and Yu (2013) for the SADF test and the GSADF test.

In order to detect bubbles, an information set is defined as $I_{[T_r]} = \{y_1, y_2, \ldots, y_{[T_r]}\}$. In the current information set $I_{[T_r]}$ this could include multiple bubbles, a single bubble, or no bubble. Phillips, Wu and Yu (2011) propose a backward sup ADF test on $I_{[T_r]}$ to enhance the accuracy of bubble detection and to avoid pseudo stationary behaviour. The backward sup ADF test has the same arithmetic logic as the GSADF test, except for having a different direction of the test. Specifically, the backward SADF test chooses a fixed ending point at r_2, which is opposite from the forward SADF test that sets a fixed starting point of r_0. To this end, the starting point of the backward SADF test becomes a changeable point varying from 0 to $r_2 - r_0$. The backward SADF statistic can accordingly be defined as follow

$$BSADF_{r_2}(r_0) = \sup_{r_1 \in [0, r_2 - r_0]} \{ADF_{r_1}^{r_2}\} \qquad (17)$$

If $BSADF_{r_2}(r_0)$ is bigger than the corresponding critical value of the standard ADF statistic at time Tr_2, then this time point, denoted by Tr_e, is identified as the starting date of a bubble. If after time $\lfloor T\hat{r}_e \rfloor + \log(T)$, $BSADF_{r_2}(r_0)$ is smaller than the critical value of the standard ADF statistic, then this is the termination date of the bubble denoted by $\lfloor T\hat{r}_f \rfloor$. Phillips, Wu and Yu (2011) impose a condition that the duration of a bubble should be longer than a slowly

varying quantity $L_T = \log(T)$. The condition nicely excludes short-term volatility in the fitted autoregressive coefficient and takes the data frequency into consideration (Phillips, Shi and Yu, 2013). From the above discussion, we can thus use the following formulations to represent the origination and termination time of a bubble.

$$\hat{r}_e = \inf_{r_2 \in [r_0, 1]} \left\{ r_2 : ADF_{r_2} > cv_{r_2}^{\beta_T} \right\} \qquad (18)$$

$$\hat{r}_f = \inf_{r_2 \in [\hat{r}_e + \log(T)/T, 1]} \left\{ r_2 : ADF_{r_2} < cv_{r_2}^{\beta_T} \right\} \qquad (19)$$

Where $cv_{r_2}^{\beta_T}$ is the 100*(1-β_T)% critical value of the ADF statistic based on $\lfloor Tr_2 \rfloor$ observations.

Similarly, when the equation (17) relaxes the limitation of supremum value r_2, in this way, r_2 has a feasible range from r_0 to 1. We obtain the date-stamping strategy of the GSADF test.

$$GSADF(r_0) = \sup_{r_2 \in [r_0, 1]} \left\{ BSADF_{r_2}(r_0) \right\} \qquad (20)$$

The explosiveness observation of bubbles for the GSADF test is based on the backward SADF statistic $BSADF_{r_2}(r_0)$. Phillips, Shi and Yu (2013) assume that that the interval time between the origination date and the termination date is $\lfloor T\hat{r}_e \rfloor + \delta \log(T)$, where δ is a frequency dependent parameter. The estimated equations of the bubble period under the GSADF test are

$$\hat{r}_e = \inf_{r_2 \in [r_0, 1]} \left\{ r_2 : BSADF_{r_2}(r_0) > scv_{r_2}^{\beta_T} \right\} \qquad (21)$$

$$\hat{r}_f = \inf_{r_2 \in [\hat{r}_e + \delta \log(T)/T, 1]} \left\{ r_2 : BSADF_{r_2}(r_0) < scv_{r_2}^{\beta_T} \right\} \qquad (22)$$

Formally, $scv_{r_2}^{\beta_T}$ is the 100 $(1\text{-}\beta_T)$% critical value of the SADF statistic on the basis of $\lfloor Tr_2 \rfloor$ observations. The significance level β_T has an opposite approach with the sample size T. If T goes to zero, the significant level β_T moves to infinity. If the sample size T approaches infinity, β_T goes to the zero.

5. The Data

The empirical data employed are the price index of the Shanghai A-share stock market and the dividend yield of the 1,061 listed companies in the Shanghai A-share stock market. The frequency of our data is monthly. Before 2000, most listed companies in Shanghai A-share stock market did not pay out dividends, so this part of dividend data is unavailable. Hence, the sample period starts from January 2000 to July 2015. Specifically, the monthly dividend yield time series of the Shanghai A-share stock market is calculated by summing the dividend yields of 1,061 listed companies. Then, the price-dividend ratio time series is calculated to reflect the relationship between the asset price and market fundamentals. All data are downloaded from *Datastream.*
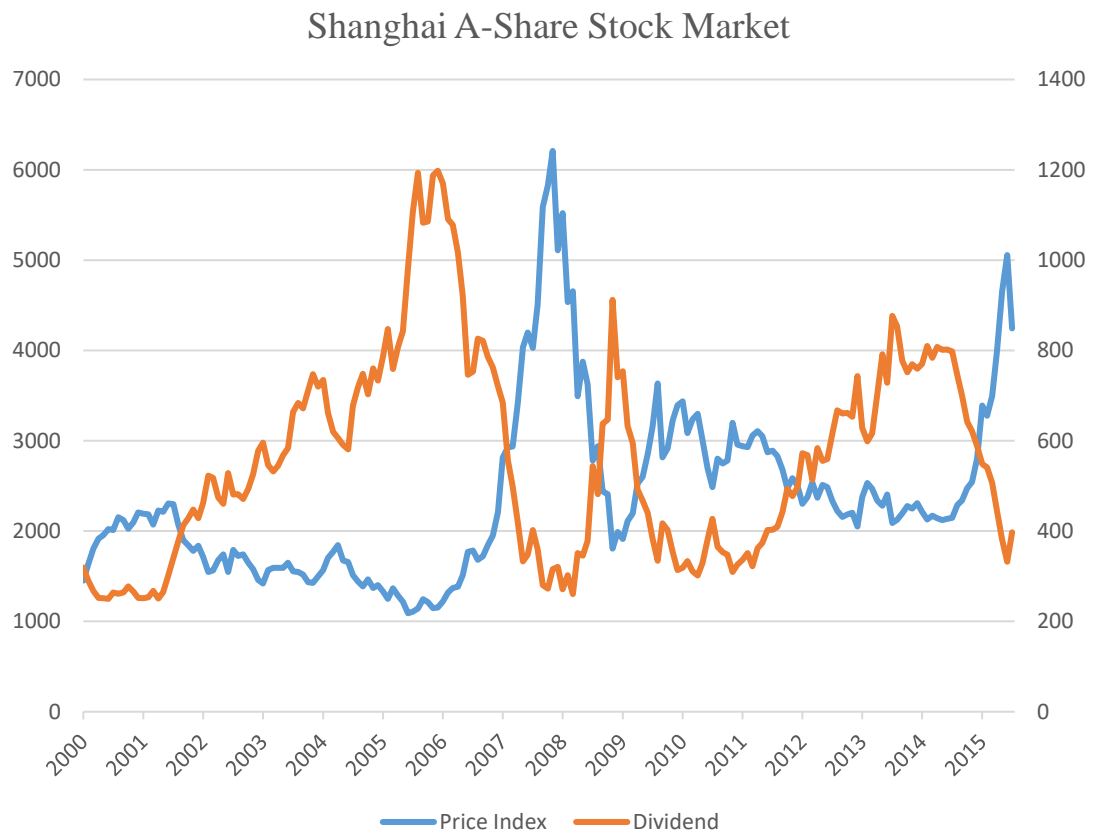
Figure 1: Time series of price index (left axis), and dividend yield (right axis) of Shanghai A-share stock market

In Figure 1, there are two series. The blue line denotes the evolution of the price index. Primarily, shanghai A-share stock price index was stable from January 2000 to January 2006, and suddenly soared up to 6395.75 points on 16th October 2007, then it rapidly dropped down around 2000 points on September 2008. After experiencing this violent volatility period, A-share had maintained a period of relatively stable fluctuation for six years, and restarted to enter another new rapid increasing period on October 2014. The red line represents the dividend yield. It shows an generally opposite pattern with the

blue line. When the stock price increases, the dividend yield decreases, and vice versa.

Price-Dividend Ratio (Shanghai A-Share)

Figure 2: Price-Dividend Ratio of Shanghai A-share Market.

Figure 2 displays our testing data, price-dividend ratio of Shanghai A-share market, ranging from January 2000 to July 2015. Generally, the Shanghai A-share price-dividend ratio was fluctuating dramatically in our sample period. Before 2006, it gradually decreased and abruptly jumped more than 20 in 2007. After the financial crisis in 2008, the price-dividend ratio shrinked sharply to around 3. During 2009 to 2012, it fluctuates within the range of 4 and 11. Until 2014, it started to climb up again.

6. Empirical Testing of the SADF test and the GSADF test

6.1 The SADF Test

Using Eviews 8.0 software, we apply the SADF test to price-dividend ratio time series. The result is as follow:

		Statistics	P-value
SADF		2.815	0.035
Test Critical Values	*99% Level*	7.373	
	95% Level	2.232	
	90% Level	1.672	

Table 1: Critical values of SADF test are calculated from Monte Carlo simulation with 2,000 replications (sample size 187). The initial window size is 4.
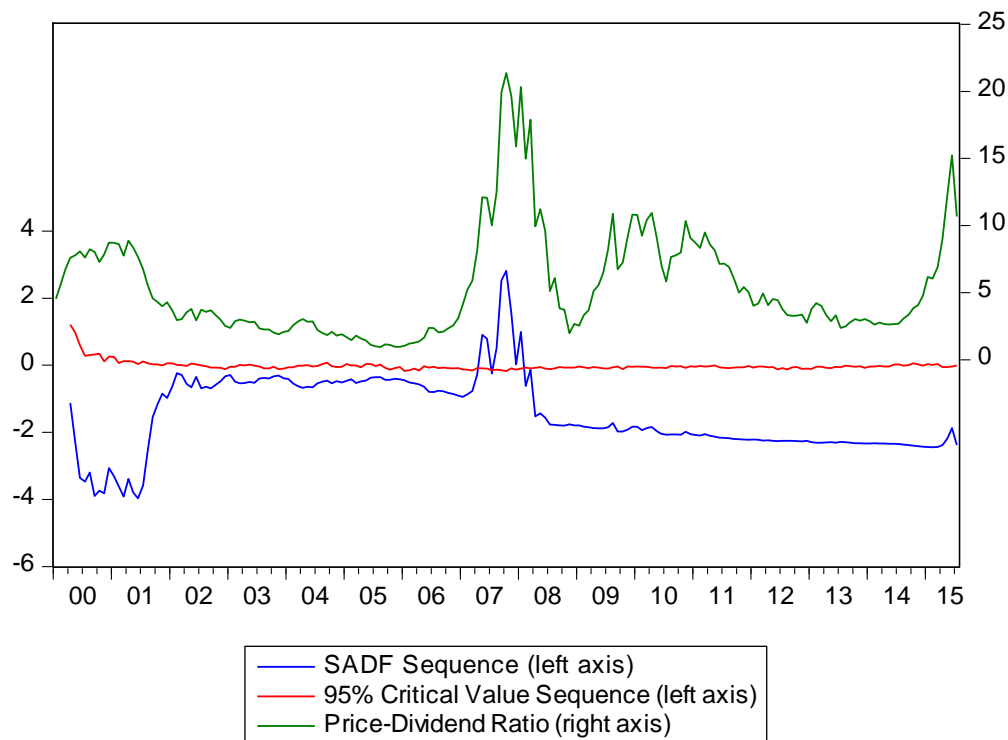

Figure 3: Date-stamping bubble periods in the Shanghai A-share modified price-dividend ratio: the SADF test.

Table 1 shows that the SADF statistic value, of 2.815 is greater than the critical values at the 95% and 90% confidence levels. This indicates that we cannot reject the null hypothesis below a 95% confidence level, and in other words, that the Shanghai A-share stock market is characterised by periodic bubbles. From Figure 3, it is evident that the blue line exceeds the red line, which indicates one periodic collapsing bubble occurred from March 2007 to February 2008.

6.2 The GSADF Test

We applied the GSADF test to price-dividend ratio. The result is shown below.

		Statistics	P-value
GSADF		35.735	0.011
Test Critical Values	*99% Level*	36.403	
	95% Level	14.180	
	90% Level	10.080	

Table 2: Critical values of GSADF test are calculated from Monte Carlo simulation with 2,000 replications (sample size 187). The initial window size is 4.
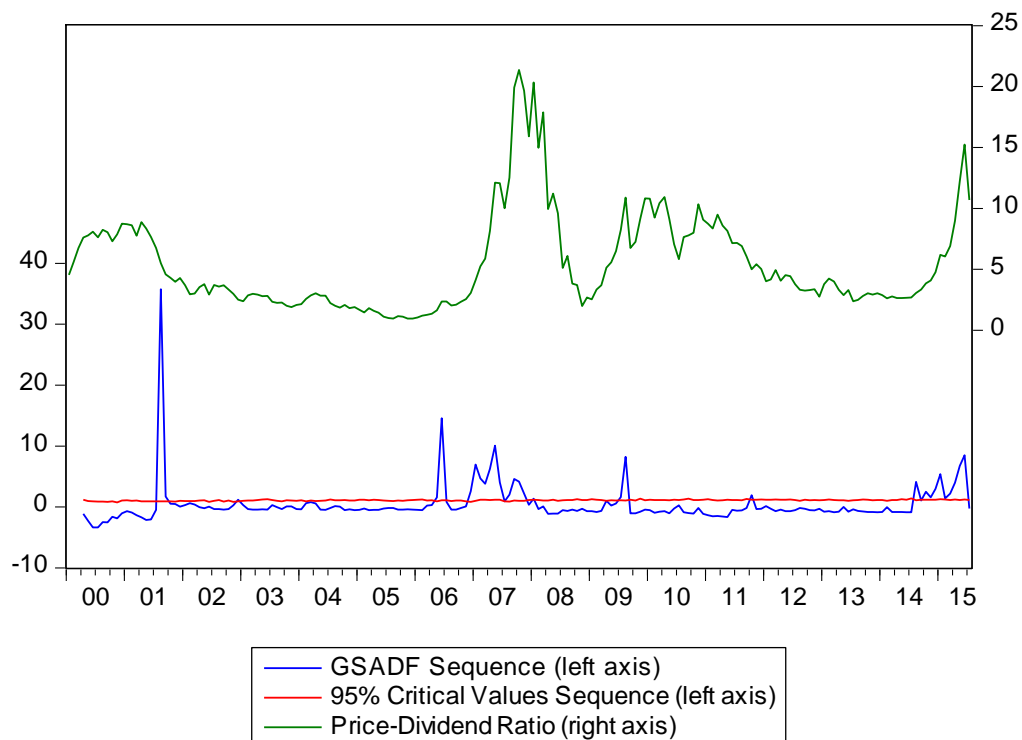
Figure 4: Date-stamping bubble periods in the Shanghai A-share modified price-dividend ratio: the GSADF test.

From Table 2, we see that the GSADF statistic obtained from sample data is 35.74, and this is bigger than the two critical values at the 5% and the 10% significant levels. Thus, we can reject the null hypothesis of no bubbles. And in fact Figure 4 clearly shows there are a total of three periodically collapsing bubbles between January 2000 and July 2015.

The bubble, between June and September of 2001, had a shorter duration. The short length of the exuberance and collapse was possibly the result of media, government intervention, or some other factor. Particularly, this increase of bubble comes from a positive news published by CSRC (China securities regulatory commission), that is the B-share stock market officially

open to domestic investors from February 2001. With the encouragement of this policy, Shanghai and Shenzhen stock indexes rose together. The later collapse was also provoked by a news, but a bad news. China securities regulatory commission announced the issuance of listed company management approach and performed state-owned shares reduction plan. For above reasons, this exuberance and collapse cycle is completely manipulated by China securities regulatory commission, embodying the characteristic of "policy market". Considering that it did not produce uncontrolled serious consequence, it is possible for the CSRC to guide this volatility deliberately. In next section, to make analysis more meaningful, we neglect the small short-period bubble and focus on two significant periodically collapsing bubbles, namely the subprime mortgage crisis bubble period (October 2006-January 2009) and the new bubble period (May 2014 to July 2015).

7. Analysis for exuberance and collapse of multiple bubbles

7.1 The subprime mortgage crisis bubble period (October 2006 - January 2009)

Under impetus around RMB appreciation expectations and the share-split reform policy, the Shanghai A-share stock market began a slow upward trend in the first half of 2006. By June 2006, the stock price had already risen up to the critical 1,700 points level. As the stock market had just bailed out a bear

market at that time, the A-share index has maintained around 1,700 points for three months. Starting from October 2006, easing monetary policy and looser credit policy created a large amount of liquid and ideal funds, which helped to instigate a flood in investing in the stock market. The Shanghai A-share stock market provided an appealing investment channel for domestic individual investors. Consequently, the Shanghai A-share index kept increasing strongly, and finally broke through 6,000 points on November 2007. In fact, in 2006 and 2007, the Shanghai A-share stock price grew by as much as 80% every year. For comparison, in same period, the S&P 500 stock price only increased about 20%.

Table 3 compares the monthly growth rate of the Shanghai A-share price index and S&P 500. The Shanghai A-share price index is much more volatile than S&P 500, and generally has much higher monthly growth rate during this bubble period. It shows that the Shanghai A-share price index kept an average monthly growth rate pf 8.5%, and the highest growth rate was reached 27.4%, in January 2007. The highest stock price, in November 2007 was 4.1 times the lowest point, which was in May 2006. The PE ratios of many stocks were over 100%. Such a high PE ratio requires a stronger earning growth rate and a higher ROE (return on equity). Typically a ROE sits at around 10%, but the average ROE of Shanghai A-share listed companies is only 6.9%. From the

perspective of PE ratio and ROE, the stock price has thus greatly deviated from the listed companies' fundamental value.

Period (First Day of Month)	Shanghai A-share Price Index	Monthly Growth Rate (%)	S&P 500	Monthly Growth Rate (%)
May-06	1,511.7	-	1,305.2	-
Jun-06	1,769.6	17.1	1,285.7	-1.5
Jul-06	1,784.5	0.8	1,280.2	-0.4
Aug-06	1,682.5	-5.7	1,270.9	-0.7
Sep-06	1,720.5	2.3	1,311.0	3.2
Oct-06	1,840.3	7.0	1,331.3	1.5
Nov-06	1,949.8	6.0	1,367.8	2.7
Dec-06	2,208.9	13.3	1,396.7	2.1
Jan-07	2,815.1	27.4	1,418.3	1.5
Feb-07	2,926.8	4.0	1,445.9	1.9
Mar-07	2,937.8	0.4	1,403.2	-3.0
Apr-07	3,418.7	16.4	1,424.6	1.5
May-07	4,035.1	18.0	1,486.3	4.3
Jun-07	4,197.1	4.0	1,536.3	3.4
Jul-07	4,027.1	-4.1	1,519.4	-1.1
Aug-07	4,510.8	12.0	1,465.8	-3.5
Sep-07	5,587.3	23.9	1,474.0	0.6
Oct-07	5,827.7	4.3	1,547.0	5.0
Nov-07	6,209.4	6.6	1,508.4	-2.5

Table3: Shanghai A-share price index and S&P 500 and their monthly growth rates

To reduce the risk of a stock market crash, Chinese regulatory authorities imposed some policies that sought to reduce the explosiveness of bubbles in the stock market. For example, the People's Bank of China has raised the RMB deposit reserve rate ten times since the beginning of 2007. That year, the statutory deposit reserve ratio increased from 9% to 13%. However, rising of deposit reserve ratio did not decrease excessive liquidity in the stock market. A large volume of hot money continued to flow into the Shanghai A-share stock market, driving the stock price continuously up. Besides currency appreciation

supporting the value of the RMB-denominated A-share stock market, the price increases were largely driven by the appreciation expectation of the RMB. Compared to other investor markets, the stock market has provided a relatively quick and easy way to make money, especially due to the low barriers to entrance and exit.

At the end of 2007, turbulence in global financial markets caused major international stock markets to fall sharply. From November 2007 to January 2009, the Shanghai A-share stock price fell 224.8%, or from 6,209 points to 1,911 points – and so set an international milestone as the largest-ever such share price decline in history. That is, the periodically collapsing bubble burst without precedent. With limitations on short selling, the stock price can mainly reveal good news, such as the split-share reform or the RMB appreciation expectation. When the hidden bad news was comparatively suddenly released, the stock followed its pattern of not just dropping, but dropping heavily (Chen and Zhang, 2009).

7.2 The new bubble period (May 2014 - July 2015)

The GSADF test helped us to identify that there have been a second periodically collapsing bubble already formulating in early 2014. On the last trading day of 2013, the Shanghai A-share price index closed at 2,116 points.

2013 was in fact the fourth consecutive year that the Shanghai A-share stock market ended lower than it had started. From May 2014 the Shanghai A-share stock market has begun to rise again. From mid-2014 to June 2015, the A-share stock price grew from 2,121 points to 5,056 points, or 138.3%.

This recent rally has several sources. Firstly, after the sub-prime crisis, China retained a steady economic growth rate, where the growth rate of many economies, especially high-income economies, fell significantly during the crisis and have not since recovered. This higher growth macroeconomic climate has provided favourable conditions for the rising of A-share index. Meanwhile, the People's Bank of China as China's central bank has imposed easing monetary policy and encouraged loose credit policy since the subprime crisis (Song, 2015). Such policies increased market liquidity and this helped the rebound of A-share stock market. Additionally, China Securities Regulatory Commission also carried out some new policies in 2014, included the securities issuance system reform, approving the issuance of preferred stock and opening Shanghai-Hong Kong stock connect. These also helped to boost confidence in the stock market.

The Shanghai A-share stock price had climbed to the 5,166 points by mid-June 2015. Many individual investors hoped that the A-share market would return to 6,000 points like in 2007. But by 19th June, the Shanghai A-share market had

fallen below 4,500 points to close at 4,478 points. The weekly decline was as high as 13.32%, making this the biggest weekly decline since 2008. Until the 3rd July, the Shanghai A-share market had fallen further, closing at 3,686 points.

These trends are similar to the last periodically collapsing bubble burst, though there are some new characteristics. The problem of over-high PE ratio is particularly prominent. The PE ratio of the Shanghai A-share stock market was up 22 times by June. In general, a high PE ratio represents a high valuation. If there is not a proper ROE matching with the PE ratio, the Shanghai A-share stock market should would with a high probability fall. Again, the newly opened stock accounts in the first half of 2015 were close to that of 2007. Under China's high-leverage stimulus, herding behaviour also drives many institutional investors to sell out their shares. When the stock index falls, the leveraged funds might be required to liquidate.

The two periodically collapsing bubbles identified by GSADF test have many similarities in their formulation, development and bursting phases. Bubbles often appear when a stock market has sufficient liquidity. Initially, the existence of a bubble promotes the stock market value. Thereafter, a high PE ratio, turnover rate and some irrational behaviours induce the bubble to gradually inflate to the out of control level. Ultimately, only bad news or a sudden market

crisis will rapidly puncture the stock market bubble and destroy the false prosperity of the stock market.

8. Conclusion

Our study, using the GSADF test, confirms the two prominent episodes of exuberance and collapse in the Shanghai A-share stock market, which SADF test only does find a single bubble. The empirical test results, in other words, suggests that the GSADF test is, in practical terms, better than the SADF test in the case of multiple bubbles detection.

The evolution process of the periodically collapsing bubbles are further analysed in depth. The first bubble revolves around the subprime mortgage crisis bubble period, falling between October 2006 and January 2009. The other one is a more recent bubble period, extending from May 2014 to July 2015. These have many common characteristics in terms of the process of bubble formulation, development and the bursting phase, like high PE ratio, high turnover, and some irrational behaviours.

In sum, this paper confirms two bubbles in the Shanghai A-share stock market in retrospect, using the GSADF test. The use of these results for understanding past bubbles in the Shanghai A-share stock market is

significant and meaningful. However, this method can only be employed to identify existed bubbles. Further research may wish to explore methods to predict bubbles in the future.

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