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Detection and prevention of speculative bubbles in the stock market.

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Introduction

The stock market serves as a critical driver of investment, capital allocation, and economic growth in modern economies. However, throughout history, speculative bubbles have emerged in the stock market, presenting substantial risks to financial stability and investor confidence. Speculative bubbles, characterized by rapid and unsustainable asset price increases fueled by investor optimism and market psychology, can lead to severe market volatility, asset price crashes, and economic downturns. As a result, understanding how to effectively manage and prevent speculative bubbles has become a vital concern for policymakers, regulators, and market participants.

Historically, several notable speculative bubbles have left a lasting impact on stock markets. One of the earliest recorded bubbles was the tulip mania in seventeenth-century Holland. This phenomenon originated in the market for tulip bulbs, which quickly attracted speculators. The skyrocketing prices led individuals to trade valuable assets, including land, livestock, and life savings, for a single tulip bulb. However, when the market eventually crashed, the consequences were devastating, causing significant financial turmoil for an extended period.

Another significant bubble unfolded in eighteenth-century Britain, known as the South Sea Bubble. In an attempt to finance war debt, the British government granted the South Sea Company exclusive trading rights in the South Sea, sparking a surge in its stock price. This success motivated numerous other joint-stock companies to enter the market. To protect its own shares, the South Sea Company lobbied for the passing of the Bubble Act, which prohibited unauthorized joint stock ventures. Nevertheless, once officers and directors realized the unsustainable nature of the market, they sold their holdings, resulting in the collapse of the bubble and a subsequent ban on share issuance.

The late 1920s witnessed the emergence of another major speculative bubble in the United States, culminating in the devastating stock market crash of 1929, known as "Black Thursday." During this period, share prices experienced a sharp rise, attracting increased investor participation and further inflating the bubble. However, the subsequent crash had far-reaching consequences, triggering the Great Depression and leaving a profound impact on the global economy.

More recent examples include the stock market crash of 1987, commonly referred to as Black Monday, and the Internet bubble of the late 1990s. In 1987, the stock market experienced a massive crash following a period of significant growth, fueled by factors such as hostile takeovers, leveraged buyouts, and merger mania. Similarly, the Internet bubble was characterized by the rapid growth of internet-based companies, with stock prices skyrocketing despite many being unprofitable. However, in both cases, the bubbles eventually burst, resulting in substantial losses in market value and significant economic repercussions.

Given the recurrence of speculative bubbles throughout stock market history and their profound impact on financial markets, effectively managing and preventing these bubbles has become a vital concern for policymakers, regulators, and market participants.

This research aims to contribute to the field of managing and preventing speculative bubbles in the stock market by investigating their formation, identifying effective prevention strategies, and evaluating their impact on public policy and corporate management. To achieve these objectives, a comprehensive review of the literature will be conducted, delving into the definitions, characteristics, causes, and underlying theories of speculative bubbles in the stock market. Furthermore, this review will explore the economic and financial implications of these bubbles, providing important contextual background for the significance of this research.

A key aspect of the literature review will involve examining various predictive models proposed to identify speculative bubbles, as well as the strategies and approaches employed to prevent and correct them. By evaluating the strengths and limitations of existing methodologies, this research seeks to develop a comprehensive understanding of speculative bubbles and refine the tools available for their detection and management.

The methodology employed in this study will entail gathering relevant stock market data from Yahoo Finance, namely historical values of the American Index S&P 500. The econometric test BSADF will be utilized to identify speculative bubbles in the US stock market and the date of their appearance. This empirical study will be useful in the assessment of the characteristics, the duration, and the impact of identified speculative bubbles, further contributing to the body of knowledge on this subject.

The results and discussions section will present the findings from the empirical study, including the identification and analysis of speculative bubbles in the American stock market. Furthermore, this section will discuss the implications of these findings for public policy and corporate management, highlighting potential measures and strategies that can be implemented to manage and prevent speculative bubbles effectively.

In conclusion, this research aims to provide valuable insights into the management and prevention of speculative bubbles in the stock market. By examining the characteristics of these bubbles, evaluating prediction models, and assessing prevention strategies, this study aims to contribute to the development of more effective policies and approaches to mitigate the risks associated with speculative bubbles. It is essential to acknowledge the limitations of this research, as it serves as a basis for further exploration in this field, offering valuable perspectives for future research and practical applications.

Overall, this research seeks to advance the understanding of speculative bubbles in the stock market and provide practical guidance for policymakers, regulators, and market participants. By exploring the formation of speculative bubbles, evaluating prediction models, and assessing prevention strategies, this study aims to contribute to the management and prevention of speculative bubbles, ultimately promoting financial stability and sustainable market growth.

Literature Review

1- Definitions and characteristics of speculative bubbles

A speculative bubble (sometimes referred to as a “market bubble”, “price bubble”, “financial bubble”, or “speculative mania”) is “an upward price movement over an extended range that then implodes.”(Kindle Berger 1978). It is a market phenomenon where the price of specific goods (e.g. foods or natural resources) or assets (stocks, real estate, foreign currencies, etc.), rises significantly higher than its fundamental value, fueled by speculation and hype. This phenomenon is characterized by a collective belief among investors that the asset's value will continue to rise indefinitely, leading to an increase in demand and driving up prices even further.

The stock market bubbles formed in the financial markets are a term that applies to a self-propagating rise or increase in the share prices of stocks in a particular industry or sector. A bubble happens when speculators notice a swift rise in value of stocks and then decide to buy more of the same stocks as a way of anticipating further rises rather than because the shares have been undervalued. This buying spree results in many companies’ shares becoming grossly overvalued creating a widening discrepancy between the share price and the actual value of the stocks (Lei et al. 2001).

These bubbles are usually followed by rapid sales and prices when starting to decline. Generally, a bubble grows slowly, moving gradually to the climax over a period of several years. After the bubble peaked prices began to fall and panicked selling investors created massive pressures leading to an accelerated fall of market prices. Regarding stock markets financial analysts believe that stock is in a bubble when the stock rates affect the economy more than exchange rates affect the economy. This can be considered a common feature of all bubbles in history. Bubbles are a type of investment phenomenon that demonstrates the fragility of investor psychology. Investors put their hopes so high that they exceed the stock courses any rational reflection of the real value of those securities. Early that bubbles have no substance at some point they "bust" and the money invested in these shares is dissipated in the wind.

For a stock, this fundamental value corresponds to the sum of the income that the stock can bring in the future, i.e. the expected sum of future dividend flows discounted at an interest rate including a risk premium. Thus, the assets most likely to experience a bubble are those whose fundamental value appears most uncertain. According to Kindle Berger and Aliber (Kielburger and Aliber 2005), a speculative bubble is "a significant increase in the price of an asset or security or commodity that cannot be explained by fundamental values". Similarly, Barlevy (Barlevy 2007) has pointed out that most economists define a bubble as 'a situation where the price of an asset exceeds the fundamental value of the asset'. In (Tan and David 2012) it is stated that "A financial bubble is a temporary situation where prices become high beyond any realistic fundamental valuation". The fundamental value or fair price of an asset is, by definition, the discounted sum of the future dividends that the asset will pay to its owner. For a fundamentalist investor, who is looking for a long-term investment, this is a key factor in his decisions. However, for an investor who is looking for short-term profitability, and who is called a speculator, the dividends of the asset do not play an important role in the decision making. Suppose an investor buys a stock for a price Pt at time t. In t, the price becomes Pt. At t+1, the price becomes Pt+1, this security will entitle him to a dividend dt. His gain Gt will therefore be Gt = Pt+1 - Pt+ dt. The difference in price between t and t+1 is therefore decisive in this equation for the profitability of the security in the short term. The rational approach for a speculator wishing to make a short-term investment will therefore no longer be to calculate as accurately as possible the sum of future dividends he will receive (the fundamental value), but the variation in price (Derveeuw 2008). Many theorists consider that the generalization of speculative behavior is the cause of bubbles and crashes (Gravereau 2001, Orléan 2001).

2- The causes of speculative bubbles

Speculative bubbles can eventually burst, resulting in a sudden and severe drop in the asset's price, often leading to significant financial losses for investors. The causes of speculative bubbles are complex and can be influenced by a range of factors, such as low-interest rates in a particular asset class, a spike in demand of a product, or shortage of a particular commodity in the market. However, speculative bubble forms due to sheer speculation, and financial fundamentals of the asset class do not support asset inflation. There are also rational and irrational bubbles in the stock market. A rational bubble involves investors buying stocks with the knowledge that the asset is overvalued and investors purchasing stocks at inflated prices after evaluating the market fundamentals and determining the chances of procuring profits (Dwyer and Hafer,2013). However, an irrational bubble can be generated by irrationality of the investors. According to J. Galbraith(1929), the rise in the stock market depended on “the vested interest in euphoria that leads men and women, individuals and institutions to believe that all will be better, that they are meant to be richer and to dismiss as intellectually deficient what is in conflict with that conviction.” This eagerness to buy stocks was then fueled by an expansion of credit in the form of brokers’ loans that encouraged investors to become dangerously leveraged. In this respect, Shiller(1987) argues that the stock price increase was driven by irrational euphoria among individual investors, fed by an emphatic media, which maximized

TV ratings and catered to investor demand for pseudo-news. An irrational bubble involves investors' purchasing stocks at inflated prices without considering important market fundamentals. Namely, in an irrational bubble, investors engage in a price bidding war to procure stocks. The two market bubbles differ in that rational bubbles are supported by fundamental market factors while irrational bubbles involve investors making rash decisions without regard for the market fundamentals (Salge, 2012). Investors usually employ the Capital Asset Pricing Model to determine the rationality of the market bubble.

3- The phases of Speculative bubble phases

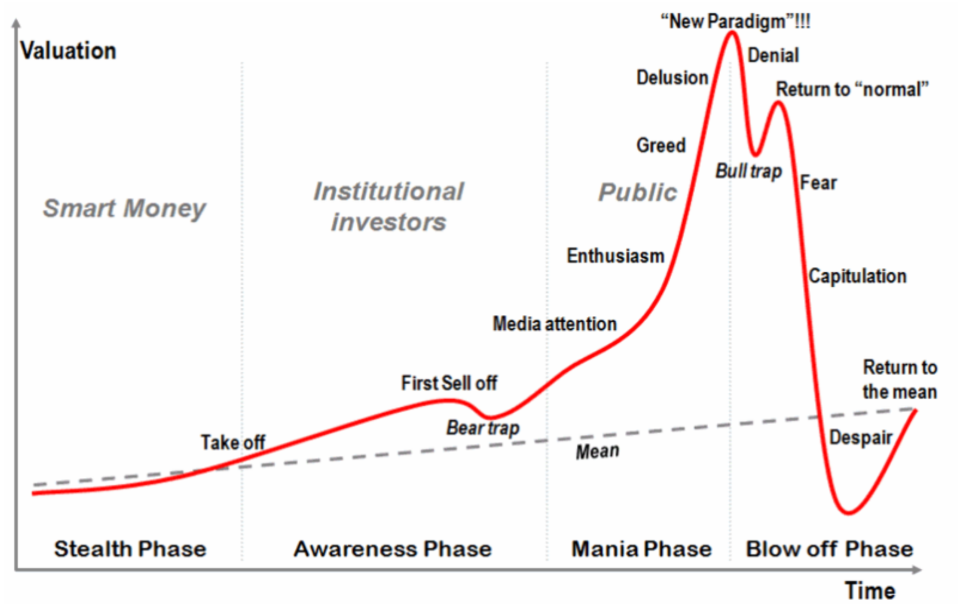


FIGURE 1: PHASES OF A BUBBLE

Source: https://en.wikipedia.org/wiki/Jean-Paul_Rodrigue

- **Stealth**. Those who understand the new fundamentals realize an emerging opportunity for substantial future appreciation, but at a high risk since their assumptions are so far unproven. Therefore, the "smart money" gets invested in the asset class, often quietly and cautiously. This category of investors tends to have better access to information and a higher capacity to understand the wider economic context that would trigger asset inflation. They can also rely on speculative and unproven assumptions. Prices gradually increase but often go completely unnoticed by the general population. Larger and larger positions are established as the smart money starts to understand better that the fundamentals are well-grounded and that this asset class is likely to experience significant future valuations.
- **Awareness**. Many investors start to notice the momentum, bringing additional money in and pushing prices higher. There can be a short-lived sell-off phase taking place as a few

investors cash in their first profits (there could also be several sell-off phases, each beginning at a higher level than the previous one). The smart money takes this opportunity to reinforce its existing positions. This phase may experience a drop in price due to profit-taking by some investors who were present in the first phase. As their expectations have come true, they have no reason to stay longer. In the later stages of this phase, the media starts to notice positive reports about how this new boom benefits the economy by "creating" wealth; those getting in become increasingly "unsophisticated".

- **Mania**: This is the most interesting but also the most complicated phase. During this phase, the bubble is self-sustaining and grows due to indebtedness. The price development in the third phase is based on the growth of the second phase. Everyone is noticing that prices are going up, and the public jumps in for this "investment opportunity of a lifetime". The expectations about future appreciation become a "no brainer," and a linear inference mentality sets in; future prices are an extrapolation of past price appreciation, which of course, goes against any conventional wisdom. However, this phase is not about logic but a lot about psychology. Floods of money come in, creating even greater expectations and pushing prices to stratospheric levels. The higher the price, the more investments pour in. Fairly unnoticed by the general public caught in this new frenzy, the smart money, as well as many institutional investors, are quietly pulling out and selling their assets. Unbiased opinion about the fundamentals becomes increasingly difficult to find as many players are heavily invested and have every interest to keep asset inflation going. The market gradually becomes more exuberant as "paper fortunes" are made from regular "investors," and greed sets in. Everyone tries to jump in, and new entrants have absolutely no understanding of the market, its dynamic, and fundamentals.
- **Blow-off**: At this level, stock market indices end their upward trend following certain events (bad statistics, bankruptcy...). At the highest point of the bubble, an event reverses the sentiment of the investors. This may be the realization that their expectations are unrealistic. The price drop may in some cases fall below the average price of the asset. The more sophisticated investors will see this as a buying opportunity, while the public will have no confidence in the investment. At this point, they consider this sector as "the worst possible investment one can make". This is the time when the smart money starts acquiring assets at low prices. This phase ends with stock market crashes, which are considered the starting point for the bursting of the speculative bubble.

4- Theories of speculative bubble formation in the stock market

The literature on speculative bubbles spans across various disciplines, including economics, finance, psychology, and sociology. Scholars have analyzed the causes and consequences of speculative bubbles, as well as their historical and contemporary examples. Many studies have focused on the role of investor sentiment and herd behavior in driving these events, as well as the impact of government policies and market regulations. Speculative bubbles are intuitively recognized to represent situations where market prices significantly exceed the level dictated by fundamentals.Yet broad agreement as to the properties of speculative bubbles has remained elusive virtually ever since the concept of speculation has been invoked.

The relation between literature and speculative bubble research started from the 1980s when the financial theory of the efficient market hypothesis (EMH) was challenged by studies of the excess volatility of stock prices. Literature about speculative bubbles (Al-Anaswah & Wilfling, 2011; Anderson & Brooks, 2014; Madrid & Hierro, 2015) has mostly used the present value of dividends as a representative variable for the intrinsic value of stocks. For Smith, Suchanek, and Williams (1988), the actual value of a specific stock converges with a value equivalent to the flow of expected dividends for that stock, as adjusted by a risk factor related to the business and brought to the present value. However, since the present value of the expected dividends depends upon the relative risk factor adjusting the stock, it can suffer from deviations according to investors' expectations. Expressing a conflicting perspective, Aglietta (2004) argues that dividends are not the best variable for determining the returns expected by investors.

Shiller (1981) proposed and verified that stock prices are too volatile to be justified by changes of dividends. While some researchers attributed the failure of explanation to the irrational behaviors, rational bubbles were viewed as a more theoretically reasonable and parsimonious alternative. From then on, economists have paid widespread professional attention to bubble issues. However, this research is stuck in the hypothesis test which suffers from many unreasonable assumptions and statistical biases. Therefore, with the aid of psychology, the effort goes further to model individual behaviors, which are the major source forming prices.

Blanchard and Watson (1983) provide a rational bubble model that is fully consistent with rational expectations and constant expected returns. They use a discrete-time setting with homogenous rational investors and infinite periods, and specify the price of an asset with two components--a fundamental value component and a rational bubble component. The fundamental component is determined by the asset's discounted cash flow. The rational bubble component is independent of the asset's fundamentals and fluctuates over time on its own. As long as it grows on average at the same rate as the discount rate, it is consistent with rational expectations. Blanchard and Watson allow the bubble component to burst with a constant probability in any period. If it does not burst, it grows at a rate higher than the discount rate. Rational bubbles have attracted considerable attention in the academic literature. However, there are both theoretical and empirical arguments that can be used to rule out the existence of such a rational bubble component in asset prices.

McQueen & Thorley (1994) adapted the traditional duration dependence test and derived a new testable implication from the rational bubble model. In their test, the real monthly data of returns for both equally and value-weighted portfolios of all New York Stock Exchange stocks were employed instead of stock price data, and the rejection of the no-bubble hypothesis was particularly robust. Afterwards, Chan et al. (1998) extended this test method for six Asian stock markets (Hong Kong, Japan, Korea, Malaysia, Thailand and Taiwan) and found that none of these markets were likely to be consistent with the presence of rational bubbles when the duration dependence was applied.

Other researchers have focused upon the broader social dimensions of bubbles, with their tendency to engulf members of society who typically have little interest in financial matters (Mackay, 1841; Keynes, 1936; Kindleberger, 1978; Chancellor, 2000; Shiller, 2000a; Bonner and Rajiva, 2007; Reinhart and Rogoff, 2009; and Akerlof and Shiller, 2009). Yet definitional ambiguity and inference problems have long plagued formal studies of speculative bubbles. Distinguishing irrational investor exuberance from the rational response to lower perceived risk is made difficult in real time by numerous issues, not least that it can only be known with absolute certainty ex-post whether the optimistic ex-ante projections embedded in asset prices were in fact justified.

Phillips and Yu (2011) show that in certain dynamic structures a time-varying discount rate can induce temporary explosive behavior in asset prices. Similar considerations may apply in more general stochastic discount factor asset pricing equations. Whatever its origins, explosive or mildly explosive (Phillips and Magdalinos, 2007) behavior in asset prices is a primary indicator of market exuberance during the ináationary phase of a bubble and it is this time series manifestation that may be subjected to econometric testing using recursive testing procedures like the right sided unit root tests in PWY. As discussed above, recursive right sided unit root tests seem to be particularly effective as real time detection mechanisms for mildly explosive behavior and market exuberance. The PWY, also known as the Phillips, Wu, and Yu test is a reduced form approach to bubble detection. In such tests as distinct from left sided unit root tests), the focus is usually on the alternative hypothesis (rather than the martingale or unit root hypothesis) because of interest in possible departures from fundamentals and the presence of market excesses or mispricing. Right sided unit root tests, as discussed in PWY, are informative about mildly explosive or submartingale behavior in the data and are therefore useful as a form of market diagnostic or warning alert.

Deev et al. (2014), attempting to determine the occurrence of speculative rational bubbles in three central European stock markets (Czech Republic, Hungary, and Poland), and the likelihood that historical inefficiencies in the stock market and recent stock market boom-busts contributed to the stock market bubbles. The study identifies specific characteristics of the stock markets studied and evaluates the prices of individual blue-chip stocks. The study was crucial in determining the onset of the country's asset bubble from 2004 to 2007, and has implications for tracing the bubble's origins. Comparing countries, they find speculative bubbles in the Polish chemical and energy company stock market and the Hungarian renewable energy technology stock market during the study period.

5. Predictive models and indicators for identifying speculative bubbles

Many methods were used to determine and analyze speculative bubbles in financial markets.

One of them is the Variance Bound Test that is used to evaluate the presence of speculative bubbles in the prices of assets. It assumes that speculative bubbles are excessively volatile, given the increasing uncertainty of investors about the real value of the stock, which stimulates their speculative trading behavior. The aim of this test is to compare the actual volatility of a stock price with its expected volatility that is predicted by the fundamental value and can be named the maximum volatility. If the actual volatility of the asset outweighs the expected volatility, then it is proven that speculative bubbles exist in the market. The Variance Bound Test is implemented with a regression model where the squared returns of the stock is the dependent variable, while the independent ones are the fundamental value and other economic and financial indicators such as interest rates. Once the maximum volatility is predicted in the model, we use it as a benchmark to which the observed volatility is compared through a statistical test. Among the studies that used this empirical method, there are Schiller (1991), LeRoy and Porter (1981) and Gürkaynak (2005). Nevertheless, this method is no longer used in recent studies due to high criticisms.

Schiller (1991) examined the factors and characteristics of volatility in the stock market. His analysis included investigating the role of speculative bubbles in driving market volatility. To assess whether stock prices are influenced by rational expectations or bubbles, Schiller introduced a variance bounds test. LeRoy and Porter (1981) introduced a test based on implied variance bounds to assess the validity of the present value model for asset prices. By utilizing the variance bounds test, they aimed to evaluate whether the observed stock prices align with the predictions of the present value model or not. Gürkaynak (2005) conducted an extensive review of econometric tests used for detecting asset price bubbles. The focus of the review was on the variance bounds test. Gürkaynak examined the theoretical foundations of the variance bounds test and provided an overview of its empirical implementation in existing literature. Furthermore, he discussed both the advantages and limitations associated with this test.

Another method to study West's s two-step test that was introduced by Kenneth D. West in 1987 with the aim of detecting speculative bubbles in stock markets. It is implemented through two steps. The first one involves regressing the stock's price on a specific set of variables that are thought to define the fundamental value of the stock. This regression model allows us in the end to determine the residuals that stand for the part of the stock's price that cannot be explained by the set of variables. The second step includes the use of the determined residuals to detect the presence of speculative bubbles, by running a second regression model of the squared residuals on their lagged values and the lagged values of the stock's price. If the values of the lagged values of the squared residuals are positive and significant, they are serially correlated. Hence, deviations from the fundamental value are persisting over time, and the volatility of the stock will continue to increase, which proves the existence of speculative bubbles.

Some authors also used the Cointegration and the Unit-root process like Cheung and Ng, 1996; Phillips et al., 2011; Jirasakuldech and Mitra, 2013; Sharma et al., 2018. These two tests are commonly used in statistical analysis in finance, like the identification of speculative bubbles in stock markets. Cointegration and unit-roots allow us to detect the time at which the price of the stock started to move too far away from its fundamental value, which is a sign of the existence of speculative bubbles.

Cheung and Ng (1996) introduced a causality-in-variance (CIV) test to examine the causal relationship between stock prices and dividends, and, on the other hand, between exchange rates and interest rates in the US, Canada, and Japan. In their study, they used unit roots and cointegration tests to test for the long-run relationship between the aforementioned variables. However, their analysis can provide useful information for the context of speculative bubbles. If the study suggests that stock prices and dividends are driven by short-term fluctuations rather than long-term fundamentals, this could suggest the presence of a speculative bubble. Consequently, although their study does not aim directly at detecting speculative bubbles, it can still be helpful in analyzing the factors that contribute to these bubbles. Also, Phillips, Wu, and Yu (2011) detected the presence of speculative bubbles in the NASDAQ stock market in the 1990s, using a unit root test and an explosive root test. The findings suggest that the bubble appeared in the late 1990s and exploded in early 2000, which was in line with the dot-com crash. Moreover, Jirasakuldech and Mitra (2013) investigated the presence of speculative bubbles in the Thai stock market, using a cointegration test and an error correction model. Their study proved the presence of a bubble in the late 1990s, that was consistent with the Asian financial crisis. Additionally, Sharma, Kumar, and Kumar (2018) used both unit root and Johansen cointegration tests along with a vector error correction model (VECM) to examine the existence of speculative bubbles in the Indian stock market. The authors confirmed the existence of a bubble in the late 2000s, due to the global financial crisis.

Also, other authors used the run test to analyze the presence of speculative bubbles in financial markets.

The Run test, also known as the Geary test, has been widely utilized in the literature to examine the presence of speculative bubbles in stock markets. Blanchard and Watson (1982) introduced the Run test as a non-parametric method for identifying consecutive upward or downward movements, referred to as runs, in financial time series data. Their study aimed to detect and understand deviations from random or independent movements, specifically focusing on identifying speculative bubbles in financial markets. Santoni (1987) expanded the application of the Run test to analyze stock market data and investigate the impact of speculative bubbles on investor behavior. The study emphasized the importance of using the Run test to identify and analyze runs in stock prices, providing insights into the behavioral aspects associated with speculative bubbles. Furthermore, Bozoklu and Zeren (2013) proposed a modified version of the Run test that incorporated the detection of structural breaks in time series data. Their study aimed to identify shifts in the distributional properties of data, including those related to speculative bubbles in stock markets. By employing the Run test, these authors contributed to a better understanding of the dynamics of speculative bubbles and their influence on market behavior.

Adding to that, several authors have made significant contributions to the study of speculative bubbles in stock markets by employing the Duration Dependence test. The Duration Dependence test is an empirical method used to analyze speculative bubbles in stock markets by examining time-dependent patterns in stock prices to identify the presence and duration of these bubbles. McQueen and Thorley (1994) introduced the Duration Dependence test as a means to study the duration and persistence of speculative bubbles in stock markets. Their research focused on identifying the presence of time-dependent patterns in stock market prices, shedding light on the dynamics and duration of speculative bubbles. Building upon this work, Chan et al. (1998) further developed the Duration Dependence test by incorporating additional variables to enhance its explanatory power. Their study expanded the understanding of speculative bubbles by exploring the impact of market-specific factors on the duration of bubble periods. Yu and Hassan (2010) extended the Duration Dependence test to investigate the role of investor sentiment and market liquidity in the formation and duration of speculative bubbles. Their research emphasized the importance of psychological factors and market conditions in understanding the persistence of speculative bubbles. Finally, Yanık and Aytürk (2011) applied the Duration Dependence test to the Turkish stock market, examining the impact of market fundamentals on the duration of speculative bubbles. Their study provided insights into the specific context of the Turkish market and contributed to the understanding of speculative bubbles within an emerging market setting.

There is also the Weibull Hazard model. It is an empirical method used in the context of speculative bubbles in stock markets. Mudholkar, Srivastava, and Kollia (1996) introduced this model as a survival analysis technique to examine the hazard or risk of an event occurring over time. In the study of speculative bubbles, the Weibull Hazard model is applied to investigate the duration and intensity of these bubbles. It enables researchers to analyze the probability of a bubble bursting or ending at different time points, providing insights into the dynamics and vulnerability of speculative market behavior. The contribution of Mudholkar, Srivastava, and Kollia lies in their development and application of the Weibull Hazard model, offering a valuable tool for understanding the temporal aspects and risk factors associated with speculative bubbles in stock markets.

Finally, there is the Sup-Augmented Dickey Fuller (SADF), the generalized Sup-Augmented Dickey-Fuller (GSADF) and the Backward Sup Augmented Dickey-Fuller (BSADF). The tests are widely used methods for investigating speculative bubbles in various financial markets. They aim to detect explosive behavior or non-stationarity in time series data, which are indicative of speculative bubbles.

The SADF test, introduced by Phillips et al. (2011), builds upon the traditional Augmented Dickey-Fuller (ADF) test by incorporating additional information from the supremum of ADF statistics over different lag lengths. This approach allows for improved power in detecting explosive behavior, making it a valuable tool for identifying speculative bubbles in financial markets. The BSADF test, introduced by Phillips, Wu, and Yu (2011) and advanced by Phillips, Shi, and Yu (2015), is a statistical method designed to detect speculative bubbles in financial markets. It's an extension of the standard Augmented Dickey-Fuller (ADF) test, with the key difference being that it allows for time-varying means in the data, making it better suited to detecting financial bubbles. The BSADF applies the ADF test recursively across sub-samples of the data, hence it's capable of detecting multiple bubbles within the same sample period. Furthermore, unlike some other tests, it does not require the specification of a bubble's collapse date.

Korkmaz et al. (2016) extended the SADF test by proposing the GSADF test, which utilizes a generalized version of the ADF statistic. The GSADF test accounts for possible structural breaks and allows for a more robust detection of explosive behavior in financial time series.

Çağlı and Mandacı (2017) further contributed to the literature by applying the SADF and GSADF tests to examine speculative bubbles in the Turkish stock market. Their study provided insights into the existence and timing of bubbles, shedding light on the dynamics of the market and the potential risks associated with speculative behavior.

Koy (2018) conducted a similar analysis using the SADF and GSADF tests to investigate speculative bubbles in the cryptocurrency market. By applying these methods, the study contributed to the understanding of the presence and duration of bubbles in this emerging asset class.

7. Strategies and Approaches to Prevent and Correct Speculative Bubbles in Stock

Speculative bubbles in stock markets pose significant risks to the stability and efficiency of financial systems. Preventing and correcting such bubbles requires the implementation of effective strategies and approaches that address the underlying causes and mitigate the associated risks. This paragraph aims to provide an overview of some key strategies and approaches that have been proposed and implemented by academics and policymakers.

a. Regulatory Measures:

One approach to prevent and correct speculative bubbles involves the implementation of regulatory measures aimed at enhancing market transparency, reducing excessive speculation, and curbing market manipulation. Regulatory authorities can enforce stricter disclosure requirements, surveillance mechanisms, and restrictions on short-selling activities to enhance market integrity and prevent the emergence of speculative bubbles (Griffith-Jones & Segoviano, 2012).

b. Macroprudential Policies:

Macroprudential policies are another set of tools that can be employed to address speculative bubbles. These policies aim to monitor and control systemic risks by adjusting capital requirements, implementing countercyclical measures, and tightening lending standards during periods of excessive asset price growth (Borio, 2014). By mitigating the build-up of excessive leverage and promoting financial stability, macroprudential policies can help prevent and correct speculative bubbles in stock markets.

c. Investor Education and Awareness:

Promoting investor education and awareness is crucial in preventing and correcting speculative bubbles. Educated and informed investors are less prone to irrational exuberance and are more likely to make sound investment decisions based on fundamental analysis rather than following the herd (Hong & Stein, 2007). By fostering financial literacy and promoting a better understanding of market dynamics, regulators and market participants can help reduce the occurrence and impact of speculative bubbles.

d. Market Surveillance and Early Warning Systems:

The development and implementation of robust market surveillance systems and early warning mechanisms are essential for detecting and responding to potential speculative bubbles. Utilizing advanced data analytics, machine learning, and artificial intelligence, regulators can identify abnormal market patterns, excessive price movements, and potential bubble formations in real-time (Wong, 2013). Timely intervention and corrective measures can then be implemented to mitigate the risks associated with speculative bubbles.

Preventing and correcting speculative bubbles in stock markets necessitates a multi-faceted approach encompassing regulatory measures, macroprudential policies, investor education, and market surveillance. By implementing these strategies and approaches, policymakers and market participants can work towards reducing the occurrence and impact of speculative bubbles, fostering more stable and efficient financial markets.

Methodology

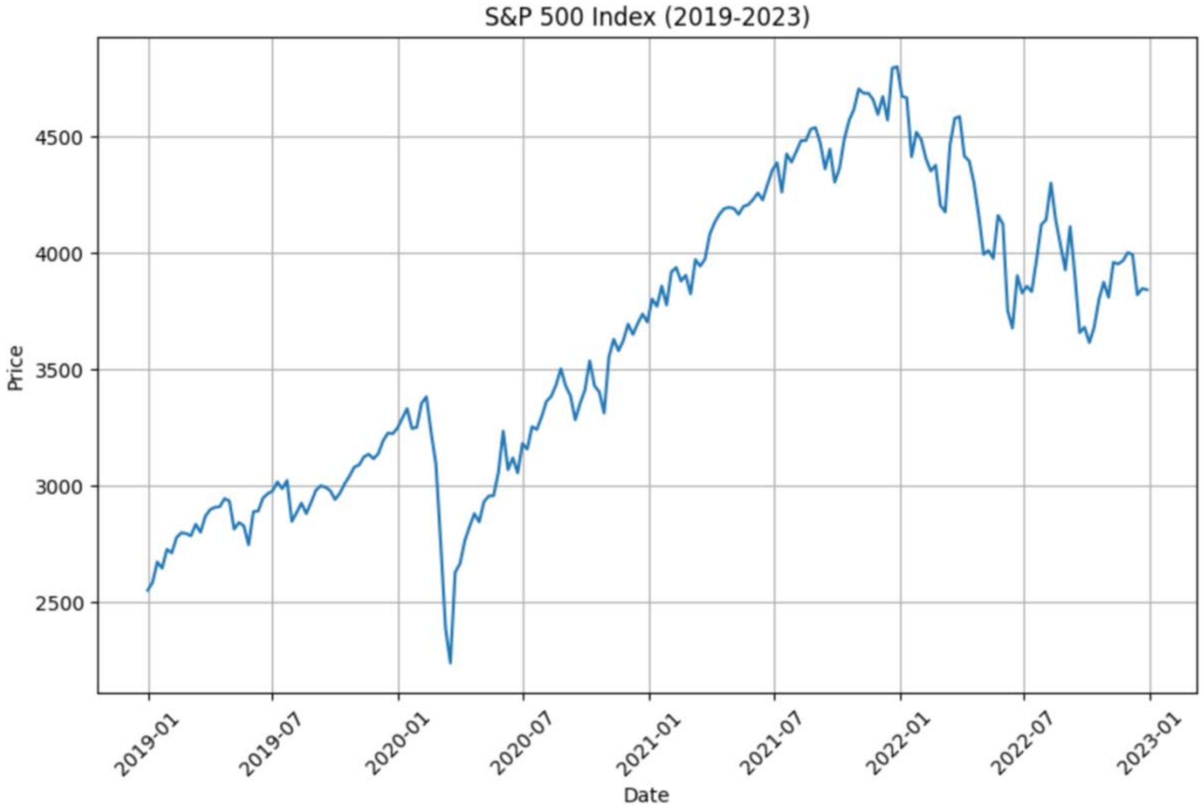
This research investigates the occurrence of speculative bubbles in the S&P 500 index & CAC 40 index. We applied the supremum Augmented Dickey-Fuller (BSADF) test to historical price data for the S&P 500 and CAC40.

1- Data Source and Collection

Raw price data was downloaded from Yahoo Finance, a comprehensive source of historical financial data. The yfinance library in Python was used to fetch the daily closing price of the S&P 500 index and CAC 40 index over the study period, spanning from January 1, 2019 to January 1, 2023.

2- Descriptive and Statistical Analysis of the Data

S&P 500 Descriptive Analysis:



Mean Price: The mean price of the S&P 500 index during the specified period is 3626.30. This indicates that, on average, the index had a value of approximately 3626.30 points. The mean price is a measure of central tendency and provides insight into the overall level of the index.

Standard Deviation: The standard deviation of 634.32 indicates the average amount of variation or dispersion in the S&P 500 index prices during the period. It represents the typical distance between each data point and the mean. A higher standard deviation suggests higher volatility in the index prices, indicating potential market fluctuations.

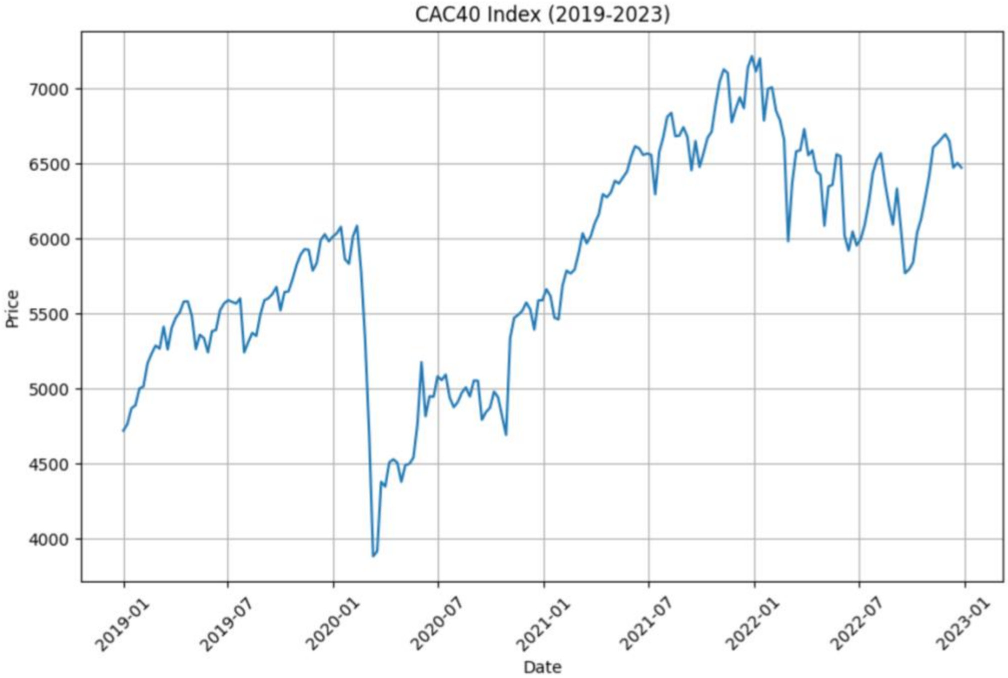
Minimum Price: The minimum price of 2237.40 represents the lowest recorded value of the S&P 500 index during the specified period. This indicates the lowest point the index reached and provides information about the potential downside risk in the market.

Maximum Price: The maximum price of 4796.56 represents the highest recorded value of the S&P 500 index during the specified period. This indicates the highest point the index reached and provides insights into potential market highs and the level of optimism or bullish sentiment.

Median Price: The median price of 3677.95 represents the middle value in the sorted list of S&P 500 index prices during the specified period. It is a measure of central tendency that is less sensitive to extreme values. The median provides an alternative reference point to the mean and can indicate the general level around which the index prices tend to cluster.

In conclusion, the S&P 500 index between 2019 and 2023 exhibited an average value of 3626.30 points with a standard deviation of 634.32, indicating moderate volatility. The index reached a minimum of 2237.40 and a maximum of 4796.56, suggesting a range of market conditions and potential opportunities or risks. The median price of 3677.95 provides additional insight into the central tendency of the index prices. These descriptive statistics offer a summary of the S&P 500 index performance during the specified period and can be used to understand its characteristics and trends for further analysis.

CAC 40 Descriptive Analysis:



Mean Price: The mean price of the CAC40 index during the specified period is 5844.26. This indicates that, on average, the index had a value of approximately 5844.26 points. The mean price is a measure of central tendency and provides insight into the overall level of the index.

Standard Deviation: The standard deviation of 729.62 indicates the average amount of variation or dispersion in the CAC40 index prices during the period. It represents the typical distance between each data point and the mean. A higher standard deviation suggests higher volatility in the index prices, indicating potential market fluctuations.

Minimum Price: The minimum price of 3881.46 represents the lowest recorded value of the CAC40 index during the specified period. This indicates the lowest point the index reached and provides information about the potential downside risk in the market.

Maximum Price: The maximum price of 7217.22 represents the highest recorded value of the CAC40 index during the specified period. This indicates the highest point the index reached and provides insights into potential market highs and the level of optimism or bullish sentiment.

Median Price: The median price of 5863.02 represents the middle value in the sorted list of CAC40 index prices during the specified period. It is a measure of central tendency that is less sensitive to extreme values. The median provides an alternative reference point to the mean and can indicate the general level around which the index prices tend to cluster.

In conclusion, the CAC40 index between 2019 and 2023 exhibited an average value of 5844.26 points with a standard deviation of 729.62, indicating moderate volatility. The index reached a minimum of 3881.46 and a maximum of 7217.22, suggesting a range of market conditions and potential opportunities or risks. The median price of 5863.02 provides additional insight into the central tendency of the index prices. These descriptive statistics offer a summary of the CAC40 index performance during the specified period and can be used to understand its characteristics and trends for further analysis.

3- Method of Analysis

The BSADF test, developed by Phillips et al. (2015) and based on the Augmented Dickey-Fuller test, was utilized for detecting potential bubbles in the financial data. The test identifies explosive behaviors indicative of a speculative bubble.

The Augmented Dickey-Fuller (ADF) test equation would be:

$$\Delta P_t=\alpha+\beta t+\gamma P_{t-1}+\delta_1\Delta P_{t-1}+\delta_2\Delta P_{t-2}+\ldots+\delta_p\Delta P_{t-p}+\epsilon_t$$

Where:

- P_t is the index price at time t
- ΔP_t is the first difference of the index price series
- t is the trend
- α, β, γ, $1\delta_1$, $2\delta_2$, ..., δ_p are parameters to be estimated
- ϵ_t is the error term

The null hypothesis of the ADF test is that $\gamma=0$, i.e., the index price series has a unit root and follows a random walk. The alternative hypothesis is $\gamma<0$, i.e., the index price series does not have a unit root and is stationary.

The BSADF test is then applied to all possible subsamples of the index price series, starting from an initial sample that ends at time t and expands backward until it includes all available data. The BSADF statistic at time t is the maximum ADF statistic over all these subsamples. The mathematical representation of the BSADF test is:

$$BSADF_t=\max\{ADF(\tau):\tau\leq t\}$$

Where:

- $ADF(\tau)$ is the ADF statistic for the subsample of the index price series ending at time τ
- $BSADFt$ is the BSADF statistic at time t

The null hypothesis of the BSADF test is that there is no speculative bubble in the index, i.e., the price follows a random walk. The alternative hypothesis is that there is a speculative bubble in the index, i.e., the price deviates from a random walk.

The implementation of the BSADF test began with setting an initial window of 10% of the total sample size for recursive testing. The number of lags for the Augmented Dickey-Fuller (ADF) test was specified as 3. Following Phillips et al. (2015), a critical value of 1.49 was used for the right-tailed ADF test at the 95% confidence level.

The closing prices were transformed into log prices, from which the sequence of price changes (delta_log_prices) was calculated. The ADF statistics were then computed recursively, with the maximum of these providing the BSADF statistic for each sub-sample.

4- Software Used

Python was utilized as the main programming language for this analysis, with the inclusion of several scientific computing and data analysis libraries. The yfinance library was used to download historical data from Yahoo Finance. NumPy was used for numerical computations including the computation of log prices and price changes, while pandas facilitated data manipulation and indexing. The statsmodels library was utilized for conducting the Augmented Dickey-Fuller test and computing the regression results. Matplotlib, a data visualization library, was used to visualize the BSADF statistics over the study period.

To enhance reproducibility, the dates when the BSADF statistics exceeded the critical value (indicative of a speculative bubble) were printed and visualized using Matplotlib.

- **ADF test**: The ADF test equation we used is :

$$\Delta Pt=\alpha+\beta t+\gamma Pt-1+\delta 1\Delta Pt-1+\delta 2\Delta Pt-2+\delta 3\Delta Pt-3+\epsilon t$$

It is implemented in the nested for loop where the script calculates the ADF statistic for all possible subsamples of the data. The ADF statistic is calculated as the coefficient on the lagged price divided by its standard error. This is done using the **statsmodels** package, which provides a method for fitting a linear regression model and calculating the standard errors of the coefficients.

In the script, **X0** corresponds to $Pt-1$, **X[j]** corresponds to $\Delta Pt-j$ for $j=1,2,3$, **Y** corresponds to ΔPt, and **res.params[1]** and **res.bse[1]** correspond to the estimated coefficient γ and its standard error, respectively.

- **BSADF test**: The BSADF test equation we used is :

$$BSADFt=\max\{ADF(\tau):\tau\leq t\}$$

It is implemented in the outer for loop where the script calculates the maximum ADF statistic over all subsamples of the data ending at time **t**. The BSADF test equation is: In the script, **ADFS** is an array that stores the ADF statistics for all subsamples ending at time **t**, and **BSADF** is an array that stores the maximum ADF statistic over all subsamples up to time **t**, i.e., the BSADF statistic at time **t**.

The parameter **r0** is set to 10% of the length of the price series, which determines the minimum size of the subsamples used in the BSADF test. The parameter **adf_lags** is set to 3, which determines the number of lagged differences included in the ADF test. The critical value for the ADF test is set to 1.49, which is the 95% critical value from Phillips et al. (2015). This is used to determine when the BSADF statistic indicates the presence of a speculative bubble.

5- Procedure of the analysis

The analysis involves the following steps:

a. **Data Preprocessing:** The closing prices of the index are downloaded and transformed into logarithmic prices. The logarithmic price differences are then calculated to capture the changes in prices over time.
b. **BSDAF Algorithm:** The BSDAF algorithm is applied to identify potential speculative bubble episodes. It involves iterating through different subsets of the data, conducting the ADF test on each subset, and storing the maximum ADF statistic obtained. The ADF test is performed by regressing the changes in log prices on lagged changes in log prices.
c. **Visualization:** The BSDAF statistics are visualized over time using a line plot. Additionally, a horizontal line is plotted to represent the critical value (95% confidence level) obtained from Phillips et al. (2015). This critical value serves as a threshold for determining when the BSDAF statistic exceeds a significant level.
d. **Bubble Detection:** Dates when bubbles are detected are printed based on the BSDAF statistic surpassing the critical value. These dates indicate potential periods of speculative bubble activity in the index.

Results and Discussion

In the following Results and Discussion section, we present the empirical findings of our research. We applied the BSADF test, a method pioneered by Phillips and Yu (2011) and Phillips et al. (2015), to detect the presence of speculative bubbles in both the S&P 500 and CAC 40 indices. This comparative analysis allowed us to assess the presence and temporal occurrences of speculative bubbles in two distinct markets. Our objective was not only to validate the effectiveness of the BSADF test but also to examine the nature and dynamics of detected bubbles across different markets. This provided us with a broader perspective and a more comprehensive understanding of speculative bubbles' behavior in stock markets. The discussion accompanying the results attempts to interpret and contextualize these findings within the broader literature on speculative bubbles, market dynamics, and investor behavior.

1- **S&P 500 :**

First period: 01-01-2019 to 01-01-2020

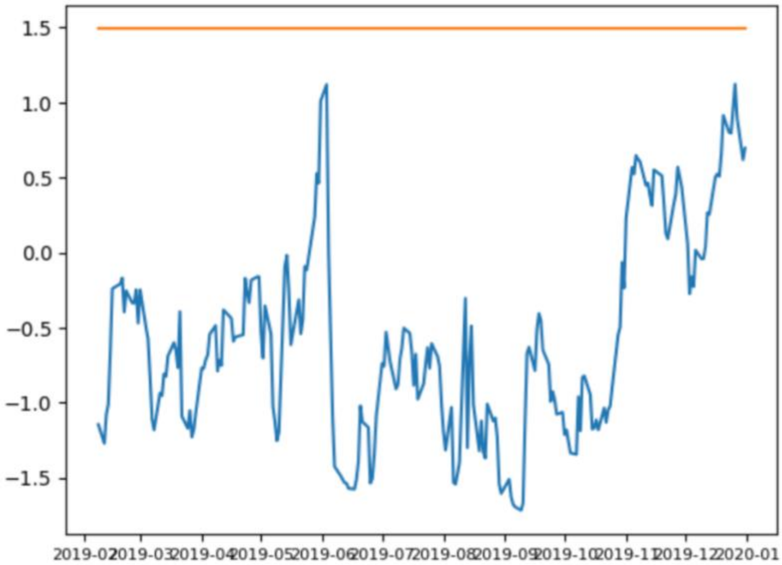


FIGURE 2: BSADF TEST STATISTIC FOR S&P 500 WITH BUBBLE DETECTION THRESHOLD (2019-2020)

Between 2019 and 2020, the BSADF test did not identify any speculative bubbles in the S&P 500. This suggests that during this period, the price movements in the S&P 500 were largely reflective of underlying market fundamentals and did not exhibit signs of excessive speculation or irrational market behavior. However, our results must be understood within the specific economic context of the time, which was marked by relatively stable economic conditions and sustained market growth.

Second period: 01-01-2020 to 01-01-2021

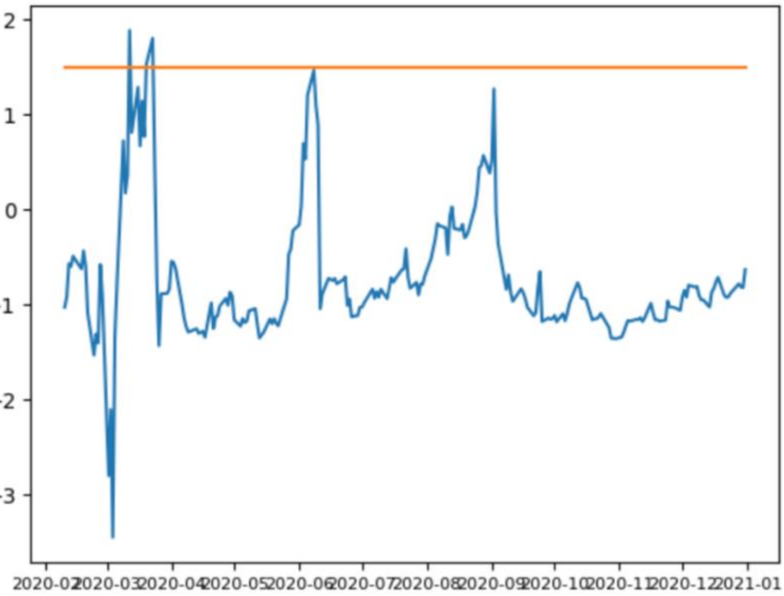


FIGURE 3: BSADF TEST STATISTIC FOR S&P 500 WITH BUBBLE DETECTION THRESHOLD (2020-2021)

The onset of the COVID-19 pandemic in 2020 radically altered this landscape. The ensuing economic turbulence was associated with three identified speculative bubbles on March 12, March 20, and March 23, 2020. This period, characterized by dramatic market swings and extreme investor uncertainty, may have led to irrational trading behaviors and market overreactions that culminated in bubble formations. The presence of such bubbles amidst a global crisis underscores the complex relationship between macroeconomic events, market sentiment, and asset pricing dynamics.

Third period: 01-01-2021 to 01-01-2022

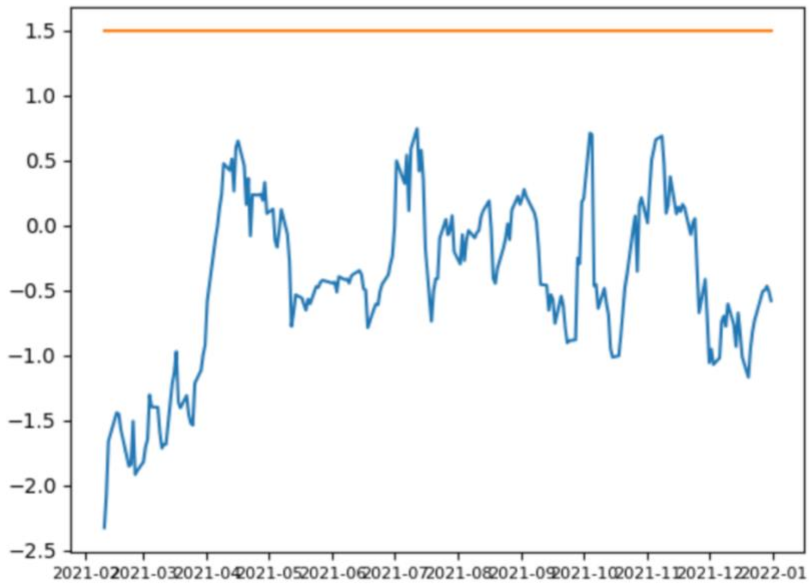


FIGURE 4: BSADF TEST STATISTIC FOR S&P 500 WITH BUBBLE DETECTION THRESHOLD (2021-2022)

Fourth period: 01-01-2022 to 01-01-2023

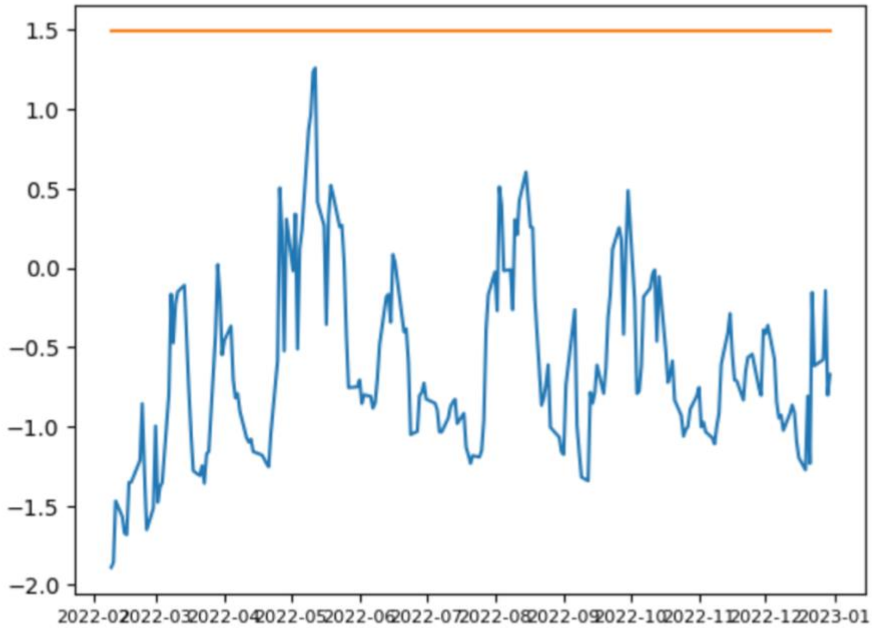


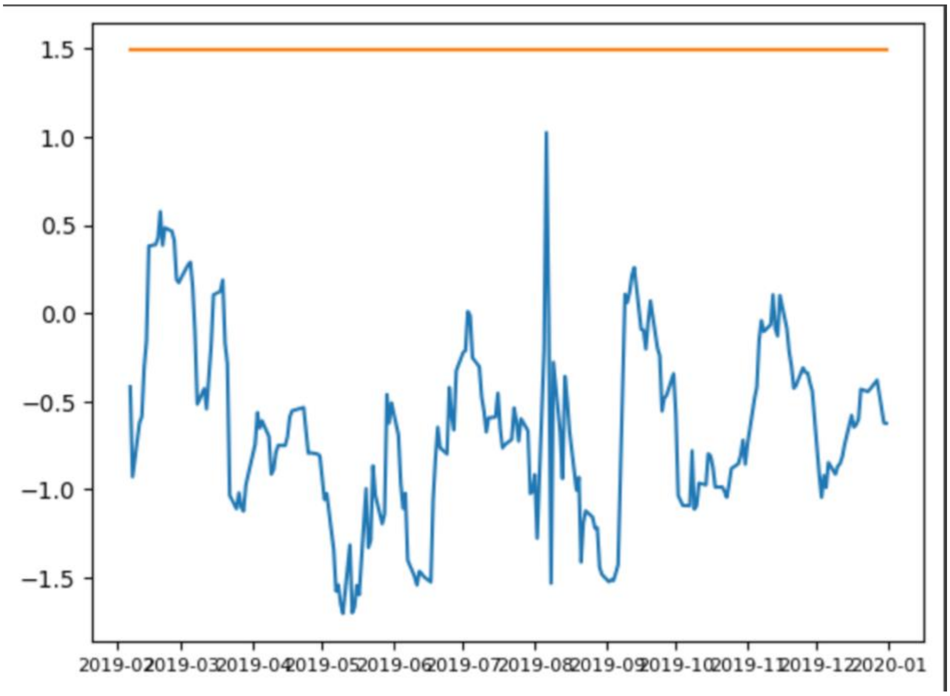
FIGURE 5: BSADF TEST STATISTIC FOR S&P 500 WITH BUBBLE DETECTION THRESHOLD (2022-2023)

Interestingly, following this volatile period, the years from 2021 through 2023 saw no evidence of speculative bubbles in the S&P 500 according to the BSADF test. This might suggest that market participants adjusted their expectations, trading behaviors became more rational, and price movements once again aligned more closely with fundamental valuations. Alternatively, this could be attributed to the impact of government and central bank interventions, which helped stabilize markets and restore investor confidence.

These findings underscore the value of the BSADF test as an effective tool in identifying episodes of potential market irrationality and speculative bubbles. However, they also highlight the test's limitations in distinguishing between price movements triggered by speculation and those induced by significant changes in the economic environment. Thus, our results reinforce the need for a multi-faceted approach to bubble detection, one that takes into account a broader array of economic indicators, market sentiment measures, and behavioral finance insights. In this regard, our study contributes to a deeper understanding of the intricate dynamics that govern financial markets and the complex nature of speculative bubbles.

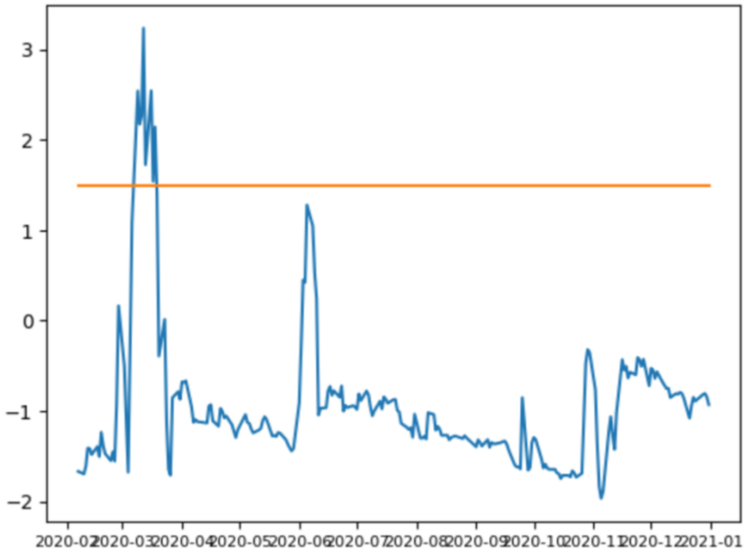
2- CAC 40 :

First period: 01-01-2019 to 01-01-2020



Between 2019 and 2020, that the BSADF test did not detect any speculative bubbles in the CAC 40 index for the specified period. This implies that during this time, the CAC 40 index did not exhibit characteristics associated with speculative bubble behavior, such as rapidly increasing prices followed by a sharp drop. This might suggest that the French market, represented by the CAC 40, was relatively stable and did not experience severe overvaluation episodes during the period under investigation.

Second period: 01-01-2020 to 01-01-2021

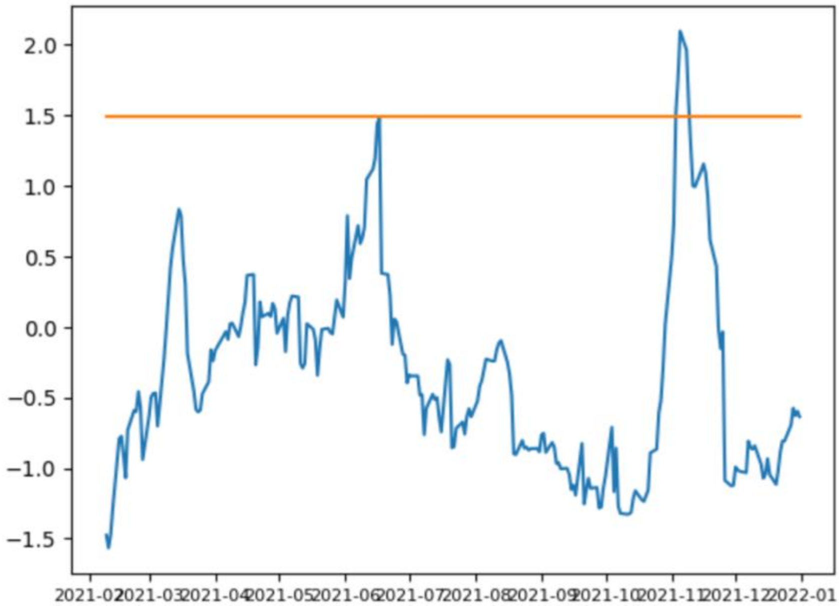


The presence of detected speculative bubbles during this period is noteworthy. Notably, these dates correlate to a period of significant volatility in global financial markets due to the unfolding of the COVID-19 pandemic. As governments worldwide started implementing lockdown measures to contain the virus, investors faced significant uncertainty, leading to erratic trading behaviors and extreme market fluctuations.

For instance, on March 9, 2020, the CAC 40 experienced a significant drop due to the combination of the escalating pandemic and the oil price war between Russia and Saudi Arabia. This trend continued through mid-March as France entered a nationwide lockdown on March 17, causing further instability.

These results indicate that the BSADF test successfully captured periods of intense market volatility and rapid price changes, aligning with real-world events. The findings suggest that during periods of global crises and market instability, the probability of speculative bubble formation increases, which underscores the need for careful monitoring and swift policy responses.

Third period: 01-01-2021 to 01-01-2022



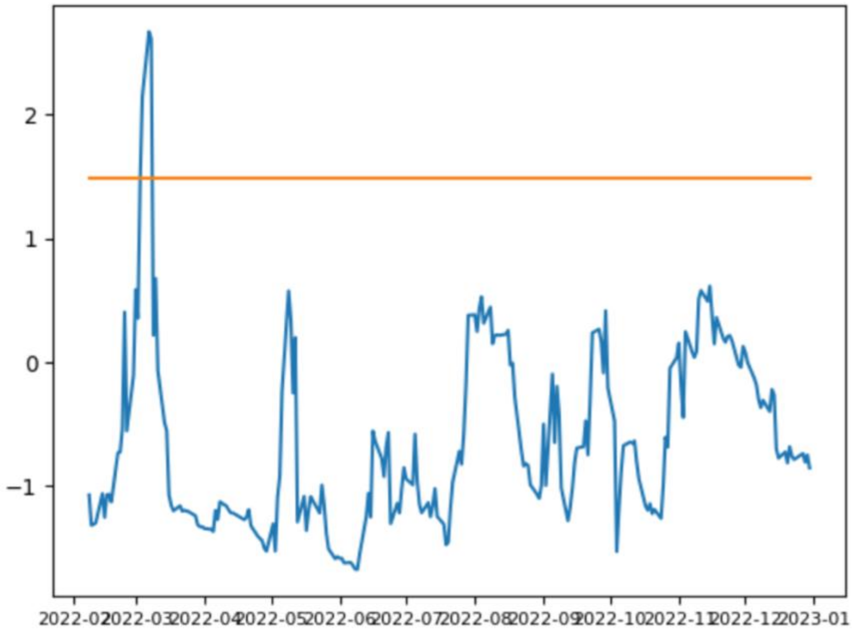
During this time, there were no global crisis events comparable to the impact of the COVID-19 pandemic in early 2020. However, it's worth noting that this period marked a strong performance for the CAC 40 index. The markets during this period were characterized by a strong recovery from the pandemic lows and an optimistic economic outlook.

This could indicate that the detected speculative bubbles may have been a result of an overenthusiastic market response to positive economic indicators and expectations for continued recovery. The apparent disparity between the market's optimistic outlook and the

BSADF's bubble detection underlines the complexity of identifying speculative bubbles and differentiating them from legitimate market rallies.

These findings underscore the importance of vigilance and the need for sophisticated tools like the BSADF test in monitoring market dynamics and assessing the potential for bubble formation. The presence of detected speculative bubbles during periods of relative economic stability reminds us that bubbles are not solely a feature of crisis periods; they can form in any market environment.

Fourth period: 01-01-2022 to 01-01-2023



While this period is not linked to a global crisis event like the onset of the COVID-19 pandemic, it may still be characterized by significant market activities or economic developments that could have influenced investor behavior and the overall market sentiment.

The identification of speculative bubbles during this period could suggest that the market was experiencing a period of overvaluation due to various factors. These factors might include positive financial news, encouraging economic indicators, or strong company performances within the CAC 40 index that led to an overzealous market response.

This once again underlines the complexity of identifying speculative bubbles, and the importance of using advanced tools like the BSADF test to track and potentially predict bubble formation. As shown through these findings, speculative bubbles can form during any market phase, not just during times of economic crises or significant upheaval.

Conclusion

In this research, we embarked on a comprehensive exploration into the complex domain of speculative bubbles in the stock market, scrutinizing their defining characteristics, causes, life cycles, and the theoretical underpinnings of their formation. We emphasized that speculative bubbles are not random or inexplicable phenomena; rather, they result from complex interactions among market factors, investor behaviors, and broader economic circumstances.

Employing the BSADF test - a sophisticated statistical technique - on the S&P 500 and CAC 40 index data enabled us to detect potential speculative bubble periods. The empirical application of this model illuminated both the potential and the challenges associated with bubble detection. Speculative bubbles were flagged during certain periods of significant market turmoil, such as the onset of the COVID-19 pandemic, but also during other periods unique to each market. This reinforced the challenge of distinguishing between price movements that are driven by speculative bubbles and those influenced by fundamental shifts in the market.

Our study has profound implications for public policy and corporate management in both the US and France. Policymakers must carefully consider these findings, which underscore the critical importance of robust financial regulation and proactive oversight. Early detection and intervention measures, such as the application of statistical models like the BSADF test, could help mitigate the potentially devastating impact of speculative bubbles on economies. Implementing comprehensive investor education programs could also be beneficial in promoting prudent investment behaviors, reducing the likelihood of bubble formation, and enhancing market stability.

Corporate management can also draw significant insights from our research. Understanding the risks associated with speculative bubbles and developing strategies to manage these risks are essential in periods of potential overvaluation. This involves effective communication with shareholders about the potential risks and maintaining a level-headed approach in strategic decision-making, avoiding decisions based on inflated stock prices which could lead to overexpansion.

Despite the promising capabilities of the BSADF test, it's crucial to recognize its limitations. Even with the use of such advanced models, distinguishing between price movements driven by market fundamentals and those driven by speculative bubbles isn't always clear-cut. Moreover, while the test can signal the existence of a bubble, it does not provide information on when the bubble might burst. Therefore, while the BSADF test provides a valuable tool for bubble detection, it should be integrated with a broader set of techniques and data types to truly understand and anticipate market behavior.

Our research contributes meaningfully to the understanding of speculative bubbles, their detection, and potential prevention strategies. However, it merely represents one step in the ongoing quest for more stable and efficient financial markets. Future research might delve deeper into sector-specific or geography-specific bubbles, providing richer insights into the mechanisms driving bubble formation and burst. Also, the role of novel factors, such as the growing influence of social media and artificial intelligence on market dynamics, warrants further exploration.

Integrating insights from behavioral finance into existing predictive models could further enrich our understanding of bubbles. By deciphering the psychological biases and heuristics that guide investor decision-making, we can potentially predict and respond more effectively to the formation of speculative bubbles.

In conclusion, our exploration into the world of speculative bubbles is far from over. Our research emphasizes the complexity of speculative bubbles and underscores the importance of continuous academic and practical engagement with this critical aspect of financial markets. As we continue to refine our understanding and improve our methodologies, we move closer to our goal of creating more resilient and efficient financial markets. This research serves as a stepping stone towards this end, shedding light on the multifaceted nature of speculative bubbles and the urgent need for ongoing engagement with this crucial topic.

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Appendix

Bubble detection algorithm based on the work of Phillips and Yu (2011) and Phillips et al. (2015:

https://colab.research.google.com/drive/1HsymvG0rGrcqd3XTUC46JwapaKk13CCH?usp=sharing

Descriptive analysis of CAC40 and S&P 500 between 2019 and 2023 using python :

https://colab.research.google.com/drive/1XYgMbJd6iQvfBJtrqvpTDcRFRedZBNAs#scrollTo=B0DyZ8zo7zMH