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Analysing Rational Bubbles in African Stock Markets: Evidence from Econophysics Frequency Domain Estimates and DCC MGARCH Model

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Abstract: The stock market operates on informed decisions based on information gathered from heterogeneous sources, encompassing diverse beliefs, strategies, and knowledge. This study examines the validity of rational bubbles in stock market prices, focusing on eight African stock markets: South Africa, Nigeria, Kenya, Egypt, Morocco, Mauritius, Ghana, and Botswana. Utilizing newly developed econophysics-based unit root tests and the Dynamic Conditional Correlation Multivariate Generalized Autoregressive Conditional Heteroskedasticity (DCC MGARCH) models, the authors analyzed daily data from 1996 to 2022. Our findings indicate that these markets experienced bubbles at various points, often followed by bursts. These bubbles coincided with significant economic changes, suggesting a strong link between stock market behavior and economic growth. For instance, financial crises, political instability, and global economic downturns significantly influenced bubble formation and bursts in these markets. The study reveals that market-specific events, such as regulatory changes and shifts in investor sentiment, also contributed to the occurrence of bubbles. Three key policy options are proposed to address bubbles in the studied markets including, enhancing regulatory frameworks to monitor and mitigate bubble formation, improving financial literacy among investors to promote informed decision-making, and strengthening economic policies to stabilize macroeconomic conditions and reduce vulnerability to external shocks. By implementing these measures, policymakers can enhance market stability and foster sustainable economic growth in African stock markets.

Keywords: bubbles; Africa; stock market; econophysics

JEL Classification: F1; F310; F32; G12; G15

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1. Introduction

Literature has established that shocks to the stock market have significant implications for the economy, and their effects can be global as evidenced in the aftermath of the 2008 global financial crisis (Lawal et al. 2018b). Several studies have attempted to examine the behaviour of the stock market using different methodologies to analyze several stock market data around the globe with different results. Some of these studies examined the efficient nature of the markets, mostly within the context of the Efficient Market Hypothesis (EMH), Random Walk Hypothesis (RWH), Mean Reversion, the Adaptive Market hypothesis among others (Lee et al. 2010; Stoian and Iorgulescu 2020; Durusu-Ciftci et al. 2019; Al-Khazali and Mirzaei 2017; Lawal et al. 2018b). Over the last two decades, there has also been an intensive and unconcluded debate on the validity of rational bubbles in stock markets (Balcilar et al. 2016; Virtanen et al. 2018; Escobari et al. 2017; Tran 2017). Evidence of the existence of rational bubbles implies there is no long-run relationship between stock prices and dividends. When a bubble and burst occur in the market, it could have overarching effect on the economy, as its impact is transmitted and spread through the mechanism of the enterprise/family balance effect, which could induce a spike in corporate liquidity risks, and banking and currency crises, with ultimate impact on financial security.

A bubble is a product of innovation that has created uncertainty about fundamental valuations. As noted by (Kruse et al. 2018), a bubble occurs when the market price of an asset exceeds its price determined by fundamental factors by a significant amount for a prolonged period. Umar et al. (2021) noted that detecting a bubble event will assist in predicting asset prices and their potential fluctuations. Having a better understanding of the bubble is key as evidence abounds that when the bubble bursts, it exerts turmoil on the financial market and the economy. When a bubble bursts, it exacerbates volatility, increases risks, leads to massive losses, destabilizes the market and increases the fragility of the overall financial system (Aharon et al. 2010; Chen et al. 2016; Lawal et al. 2022, 2019b).

According to (Phillips 2016; Tran 2017) speculative bubbles can be examined from five (interwoven) approaches: Excess volatility; Bubble premiums; Bubble specifications; Duration dependencies bubble; and rational bubbles. Other classifications according to (Balcilar et al. 2016) are Credit fuel bubbles and Irrational behaviour bubbles. Our focus in this study is to expand the frontier of knowledge on rational bubbles.

Understanding the dynamics of stock markets vis-a-vis the presence or otherwise of rational bubbles is important to various economic agents, especially investors (both institutional and private) as well as policymakers. Policymakers are often confronted with knowing what causes asset bubbles. What is the welfare effect of an asset bubble? Is the assets bubble profitable for the economy? If yes? What policies can be used to prevent a bubble from bursting? As noted by Miao et al. (2015) rational bubbles generate excessive investment (which could be inefficient) and reduce welfare. For policymakers, financial stability responsibility goes beyond characterizing a bubble or its collapse but entails real-time determination of whether or not a bubble is evolving.

To know what policy options are available to policymakers in handling a crisis resulting from a bubble burst, hence mitigating its impact on the financial market in particular, and the wider economy in general, it is important that policymakers have a good understanding of bubble build-up (Bell et al. 2022; Liu and Conlon 2018; Ayub et al. 2020; Okere et al. 2019). Over the years, concerted efforts have been deployed to understand the causes and consequences of the asset price bubble. For instance, Zhang and Zheng (2017), Kruse et al. (2018) and Lawal et al. (2019a) identified the role of the inflation rate, interest rate as well as other monetary policy tools in shaping the behaviour of asset prices bubble. They argued that if the natural rate is high in a period characterized by a low inflation rate, monetary policy intervention that targets a low interest rate will trigger a bubble in asset prices. Other factors are changes in the macroeconomic environment that drive up the GDP (Lawal et al. 2016; Acharya and Naqvi 2018); excess liquidity in the economy resulting from banking sector overaggressive lending cum with underpricing risk (Pérez-lechuga 2017); leverage effect (Balcilar et al. 2016; Versmissen and Zietz 2017). Knowing that bubbles may hurt the macro economy, the question is, what are the available policy responses to bubbles? Several policy options have been put forward. For instance, Dudley (2010) recommends the Bully Pulpit (announcement effect) approach that emphasises awakening the caution of the various economic agents to the dangers of the incipient bubble; Bernanke and Gertler (1999) suggest (the Jackson Hole consensus monetary policy easing) which recommends little or no restrictive monetary policy measure during the bubble formation and growth periods; Borio (2003) suggest the use of macro-prudential measures aimed at protecting against the effect of a bubble burst especially on financial instability.

The financial liberation exercise embraced by emerging economies led to foreign capital inflows with implications on the capital market development and economic growth. Evidence suggests that an unprecedented increase in capital inflows to developing economies may induce asset bubbles. Although the returns on investment in emerging economies are higher than those of developed economies, emerging markets are less studied.

Furthermore, large number of the studies on emerging economies focused on Asian and Latin American economies with little on African economies. This motivates our interest in African stock markets with a focus on the eight (8) largest markets on the continent.

As argued by (Virtanen et al. 2018; Chang et al. 2016; Hirano et al. 2015; Bejan and Bidian 2014), timely and precise detection of volatilities, bubbles and bursts facilitate competent macro-prudential actions against financial instabilities.

Most literature which investigates whether stock prices exhibit rational bubbles employed cointegration techniques like the Johnsen cointegration test, Johansen and Juselius (Claver et al. 2019; Guidi and Ugur 2014). These tests are linear and have lower power for any form of asymmetric adjustments thus yielding poor results when employed to measure equilibrium relationship. They also have lower power in the presence of misspecified dynamics (Enders and Lee 2012; Becker et al. 2004; Harvey et al. 2017). Ye et al. (2011) noted that linear models are inappropriate if prices are sticky in the downward direction without a corresponding upward movement. Recent methodologies adopted to examine the existence of rational bubbles in the stock market include the time domain (Phillips et al. 2015a, 2015b) that assumes the existence of a stochastic trend in data (SADF and GSADF); Markov–Switching model. Though these techniques offer better results than the existing linear models they are equally faced with the disadvantages of economic models resulting from the utilization of individualistic and equilibrium methodologies believed to be inadequate in the study of complex dynamics and social interactions (Bai et al. 2019; Kassouri 2022; Herzog 2007; Lawal et al. 2019a, 2018a). More so, it has been convincingly argued in the literature that econophysics frequency domain models offer a better analysis of data manipulation as they capture both the time and frequency domain property of the data generating set (see Aloui and Hkiri 2014).

Identifying and pinpointing the location of previous bubbles are essential for formulating macroprudential policies regulations and interventions that will mitigate future bubbles and bursts, hence preventing potential economic recession. To address the challenges associated with traditional models, the current study employed the econophysics frequency domain estimates developed by Herzog (2015). The model is preferable because it calibrates the impacting complex dynamics and social interaction of financial bubbles when examining complex financial dynamics. The model is efficient in identifying the structural break dates.

The motivation and justification for this study focus on the need to enhance the knowledge of bubble and their impact on asset prices, as they affect the financial system in particular, and the aggregate economy as a whole (Lawal et al. 2022). This is important for various economic agents especially investors (both institutional and private), policy makers and the academic community. This study, therefore, employed a novel econophysics frequency domain particle financial model to examine the existence of rational bubbles in the eight largest African Stock Markets. Having established the existence of bubbles in these markets, we further employed the dynamic conditional correlation multivariate generalized autoregressive conditional heteroskedasticity (DCC MGARCH) to examine the existence of interlink of bubbles in the studied economies. This study made five important contributions to the knowledge of rational bubbles in the asset price market: (i) we examine a large sample of stock price data, including the most recent and turbulent period of the COVID-19 global pandemic. This is essential in understanding the time-varying behaviour of asset prices; besides, the sample is made up of eight (8) Africa's largest markets (BRVM (Bourse Régionale des Valeurs Mobilières) and Dar es Salaam Stock Exchange were dropped because of too many missing values for some years)). (ii) The methodology employed helps to identify structural breaks in the stock market price which is key to identifying or detecting bubble build-up in financial variables. (iii) We employed a DCC-MGARCH model to examine the existence of correlation of bubbles among the markets. This is important in knowing whether the bubbles in these markets are interdependent and, hence, possess a common source. (iv) advanced the frontier of knowledge on asset price bubbles within the context of the frequency domain model. (v) We offer some policy implications to various economic agents.

The rest of the paper is structured as follows: Section 2 provides the literature review; Section 3 deals with methodology; Section 4 presents the results and Section 5 concludes the study.

Literature Review

Recently, a new school of thought emerged with a focus on knowing whether significant deviation and decoupling exist between the fundamental values of assets and their actual market prices. These studies examine whether a long-run relationship exists between stock prices and dividends. They postulated that when no long-run relationship is established between the two, then rational bubbles exist. Some of these studies are briefly reviewed in this section.

For China, Lehkonen (2010) investigates the notion of rational bubbles in the Chinese stock markets and China-related share indices in Hong Kong by employing a duration dependence test to analyse both monthly and weekly abnormal market returns of the Shanghai, Shenzhen A-and-B-markets, the Hong Kong China enterprise and the China Affiliated Corporations indices. Findings from these studies reveal mixed results, for instance, results from the weekly data show that for all the mainland Chinese stock markets, evidence exists to establish the existence of rational bubbles whereas bubbles cannot be established when the analysis was conducted using monthly series. When the Hong Kong market was examined, evidence reveals that no traces of a bubble could be established. The study also noted market segmentation in mainland China has no effect on the existence or otherwise of bubbles. The study stressed the impact of the duration dependence test when examining bubbles and their effects on a given economy.

Ye et al. (2011) investigate the existence of rational bubbles in the G7 stock markets based on monthly data between January 2000 and June 2009 by employing a newly developed Fourier unit root test and a nonparametric rank test for cointegration. The study observed that the null of unit root test I(1) in stock prices can be rejected for stock markets of Canada, France, Italy and the UK, though the results as suggested by the rank test techniques show that stock market prices of all the studied economies lack evidence to support the existence or validity of rational bubbles.

Anderson and Brooks (2014) calibrated the impact of the microstructure components on the debate of a bubble's existence. The study developed and tested an empirical asset pricing model that allows for speculative bubbles to affect stock returns by showing that stock that incorporates a larger bubble yields higher returns. The study further reveals that bubble deviation at the stock level rather than the industry or aggregate level is a priced source of risk separated from the standard market risk, size and value factors. The study noted that much of the common variation in stock returns that demonstrate a substantial relationship with market risk is largely influenced by the co-movement of bubbles rather than market fundamentals.

Herzog (2015) developed a mathematical model of financial bubbles based on an econophysics frequency domain model that identifies bubbles in asset price dynamics with news and without stochastic and martingale theory. The study utilized a new theoretical model to detect ex-ante financial bubbles. The study noted that agents identify bubbles only with a time delay and that the detention of bubbles are different from either the individual or the collective point of view. The author concludes that the properties and developments of financial bubbles are largely important in studying the existence of the behaviour of rational bubbles in asset prices.

Cho and McCallum (2015) developed a forward convergence model with a linear rational expectation refinement scheme and an associated no–bubble selection criterion to examine the existence or otherwise of rational bubbles in a typical stock market with a determinacy and indeterminacy framework. The study observed that a determinate solution is economically cogent for most of the cases investigated. The study also noted that models that are not forward-convergent lack economic solutions suggesting the absence of evidence of a bubble.

Chang et al. (2016) investigated the existence or otherwise of rational bubbles in the South African stock market by employing SADF and GSADF estimation techniques to analyze data on the Johannesburg stock exchange. The study observed that two bubbles existed from 2005 to 2006. This was traced to the influx of money from investors that led to the bidding up of prices of stocks above their justified fundamentals. This is the usual occurrence when there is a massive influx of cash into the stock market characterized by few investment options.

In a related development (Balcilar et al. 2016) examined the existence of bubbles in the South African stock market by employing three stylized or alternative models to analyse monthly data sourced from January 1954 to April 2015. These models control for nonlinearities inherent in asset price return by allowing for the existence of multiple regimes. The author reported that the bubble model is better off and fits the model than competing models. Furthermore, the study establish the existence of rational bubbles in the studied stock market. The authors concluded that rational bubbles established in the South African stock market are largely traced to either leveraged positions or irrational behaviour of investors in the South African market. However, though the models identify the bubbles based on probabilistic estimates, they could not specify what behaviour (credit-induced or herding behaviour) motivated the existence of a rational bubble in the South African stock market.

Chen et al. (2016) employed the momentum threshold unit root test (MTAR) and the logistic smooth transition momentum threshold (LNU–MTAR) unit root test that accounts for the nonlinearity properties of the data generating process to analyse data sourced from four international stock markets comprised of the US, Belgium, Denmark and Finland. The study examines the validity of rational bubbles' existence in the selected stock markets, by testing for the presence of periodically collapsing bubbles. The study observed that the hypothesis of rational bubbles cannot be rejected and that evidence show that the hypothesis of periodic collapse of bubbles cannot be established when we allow for non-linear adjustment and structural breaks.

Liang et al. (2017) examined the validity of a rational bubbles hypothesis in a three-period market where investors are risk-averse, privately informed and heterogeneous expectations order, trade on private signals, and make decisions based on sentiment and sparsely based bounded rationality. The study observed that bounded rationality leads to mispricing and reduces over time, investor sentiment generates a higher significant impact than private signals, and optimistic investor sentiment stimulates hedging demand, thereby reducing price soaring. The result further stimulates the demanding effect of higher order expectations on price volatility and the heterogeneity expectation implies inconsistent investor behaviour in financial markets. The study concluded that investors' expectation about the future price is distorted by their sentiment and bounded rationality, thus investors obtain a biased mean from the signal extraction.

For the Asian and Latin American stock markets, Tran (2017) employed the newly developed non-cointegration residual-augmented least squares (RALS) estimation techniques to analyse monthly data of price indexes and dividends to test for the existence of periodical collapsing stock price bubbles in the studied stock markets. The study observed that the hypothesis of the formation of bubbles cannot be rejected for the studied market. This development was traced to the impact of market openness in the studied economies.

For Bitcoin and other cryptocurrencies, Fry (2018) established robust evidence of the existence of rational bubbles in Bitcoin & Ethereum by developing a bespoke rational bubble technique that calibrates both heavy tail and the probability of a total collapse in asset prices into a model. The study emphasized the place of timely response to changes in asset characteristics as a haven for investors against the consequence of a bubble burst.

Farjam and Kirchkamp (2018) calibrated the impact of the interaction between human agents and machines in the study of rational bubbles. The authors examined the impact of algorithmic traders on human trading activities by separating the direct effects of algorithmic traders from the indirect effect of algorithmic traders by measuring the observed deviations from the fundamental value, speed of trading, volatility of prices and bid-ask period. The authors observed that the magnitude of the bubbles is smaller, and prices are relatively closer to the fundamental value when both the two sets of traders participate than when only human traders participate in the market.

Caspi and Graham (2018) extended the (Anderson and Brooks 2014) work by calibrating the use of book-to-market ratio into the study of a rational bubble with a focus on market microstructure that emphasized individual stock market behaviour rather than aggregate estimates when the validity of the rational bubble is considered. The study empirically investigates the validity of the rational bubble hypothesis for the Israeli stock market based on monthly data from July 1996 to August 2014 and observed that no evidence abounds to support the existence of a bubble.

Khan et al. (2022) employed the SADF and the GSADF models to examine the explosiveness of different energy prices based on data from January 2000 to September 2021, to know if bubbles exist. The study noted that bubbles are most explosive in the liquefied natural gas, with crude oil prices coming next, while coal prices lag during the period studied. The study noted that speculation, economics and political events are the major drivers of bubbles, with 2007–2008 and 2014–2015 global economic crises coinciding with bubbles. The results are agreeing with that of Umar et al. (2021) who documented the existence of multiple bubbles in crude oil prices, driven by global economic events.

Adewuyi et al. (2020) noted that detecting bubbles in metal prices is key to effective and efficient policy-making by various economic agents. The study employed a battery of unit root tests to analyse data from 1960 to 2017 and noted that the linearity and nonlinearity components of the data generation set is key to detecting bubbles. The study showed that while bubbles are noted for some precious metals, some do not exhibit existence of bubble. Ozgur et al. (2021) further advanced the study of bubbles in metal prices by calibrating the impact of potential financial, real, and speculative factors on metal price bubbles. The study noted that the financial factors are more critical in predicting bubbles in the precious metal prices, followed by monetary policy rate, but ruled out speculative activity as a driver of bubble in the studied markets.

For the bitcoin industry, Yao and Li (2021) examined the existence of bubble by employing the Log-Periodic Power Law Singularity (LPPLS) to analyse the existence of bubble. The study began with the deployment of the Generalized Supremum Augmented Dickey-Fuller (GSADF) model, and noted that bubbles existed twice in the bitcoin industry between 2017 and 2019. To accurately identify the time of bubble burst, the study employed its main model, the LPPLS, and noted that bubble burst occurred on 25 November 2017 and 29 June 2019. The study concluded that the oscillating frequency of bubble in 2019 was low and unstable.

For the carbon markets, Xu and Salem (2021) noted that the immature market mechanism is the key driver of explosive bubbles in the Chinese carbon market. The study employed the GSADF, and noted that bubbles occur at five (5) different times.

Ma and Xiong (2021) employed the GSADF and the BSADF models to detect bubble existence in the future prices of six dominant nonferrous metals for the period 2014 to 2018. The study refutes the view that market fundamentals can exclusively drive future prices, questioning the validity of bubbles in the housing markets in the European Union based on data sourced between 1980Q1 and 2018Q4. The study noted that interest rate manipulation is key to controlling bubble behaviour in the housing market.

Wahab and Adewuyi (2021) noted that bubbles cannot be established in the prices of precious metals based on daily and weekly data from 1990 to 2021. The study employed a battery of unit root tests (with or without structural breaks). The study concluded that bubbles is slightly noted for platinum and silver.

Pedersen and Schütte (2020) noted that weaker evidence of bubbles exists in the housing sector, when compared with existing evidence among the OECD economies (see Caravello et al. 2023).

Khan and Köseoğlu (2020) noted that bubbles were discovered at four times between 1994 and 2020 in palladium price deviated from its fundamental value in the period 1997 to 1998, 1999 to 2001, 2011 and 2019 to 2020. These bubbles were motivated by geopolitical tension, supply deficit, low production and tight environmental regulations.

For the S&P 500, Nguyen and Waters (2022) documented the existence of multiple bubbles with two prominently associated with the Spanish Flu in 1917, and the 2008 housing crisis. This was in line with earlier findings of Shengquan, Wang and Chen (2019), who employed the panel logit model to analyse data set from 22 economies sourced from 2000Q1 to 2018Q3, and noted that bubbles exist in the studied economies, and the bubbles are driven by trading volume, price volatility, and credit (Dong et al. 2024).

Tarlie et al. (2022) varied the mean reversion speed in time based on an AR (1) process, enhancing the deployment of standard state space methods to detect multiple bubbles in the US stock market. The study identified five (5) periods of explosive dynamics based on data from 1881 to 2017. The study warned against folding of hands in tackling bubbles.

Bellón and Figuerola-Ferretti (2022) noted that a speculative bubble does not exist for the Ethereum blockchain, rather the explosive behaviour noticed in prices is a reflection of the abrupt rally demand for Ethereum Virtual Machine, given its usefulness in the development of the decentralized application (dApp) ecosystem.

From the reviews, it is evidence that: (i) the debate on the existence of rational bubbles in the stock market is inconclusive; (ii) examining the existence of rational bubbles is key to understanding market behaviour vis-a-vis aggregate economy; (iii) African stock market is less studied when it comes to discussions on stock market bubbles. These reasons, among others, motivate the current study.

2. Methodology

2.1. Data

Data for the current study were sourced from DataStream, a historical data archive. The frequency of the data is daily and covers from 4 January1996 to 31 December 2022 for the eight largest African markets[1]. The data considered numerous past and recent economic events including the most recent COVID-19 pandemic, hence accounting for the factors that trigger bubbles over the years. We denominated the stock market indices of the studied markets in US dollars to be able to facilitate effective comparisons of results, among the series and; second, allow international investors to appreciate the evolution of the first and second moment dynamics of the studied economies; third, to mitigate the impact of different inflation rates experienced individually by each of the economies. A critical review of African stock markets shows that except for South Africa, all stock markets in Africa are comparatively small, exhibit high volatility, low market capitalization, poor regulating system, weak investor base, and are characterized by some levels of illiquidity when compared with other stock markets in the world (Boamah et al. 2017a, 2017b; Gourène et al. 2019; Boako and Alagidede 2016). We adjust for thin trading to address the issues of biases induced by illiquidity and non-trading days of African stock markets.

As earlier stated, the current study followed (Herzog 2015; Bai et al. 2019; Kassouri 2022) to employ econophysics based financial bubbles techniques that calibrate the impact of complex dynamics and social interactions, to financial bubbles literature to analyze the complex financial dynamics.

The model was built on particle physics that relies on the interaction of single elements/agents that induce collective outcomes. The model stresses that the financial bubble represented by massive price increases/decreases is largely caused by many buying/selling players in a herd. It stresses that bubbles often occur without any significant changes in the fundamental values.

Unlike existing economic models that employed stochastic and martingale theory; which are often characterized by the use of individualistic and equilibrium methodology with a severe downside in understanding complex dynamics and social interactions, our econophysics frequency domain model provides brighter perspectives and high analytic power to analyze complex dynamic and social interactions. Our model stresses that a bubble can be characterized as a social interaction problem and not just induced by individual rationality or irrationality as claimed by stochastic techniques.

Drawing from social system theory, our model separates the behaviour of individual economic agents from that of the group, stressing that more buyers imply a higher trading density and higher risk for an exuberance under a group model, the reverse is the case from the individual perspective. It further implies that a high density connotes a small price movement with correspondingly lower risk and higher willingness to buy/sell assets. Financial bubbles are often induced by intermediation and imbalances in herding behaviour.

By factoring in time, (Herzog 2007; Kassouri 2022; Su et al. 2017) noted that more often financial bubbles are characterized by a negative benefit to loss (BLF), this suggests that good news induces a jump with a diminishing change of asses prices which indicates a lower probability of a bubble burst. The implication is that the market reaction time is shortened, with chances that a bubble could burst when small prices jump occurs. Under this condition, the nature of the market efficiency matters, for instance, efficient markets characterized by much news may witness small financial bubbles while inefficient markets characterized by asymmetric information may experience large financial bubbles.

The majority of the debate in literature is of the view that African stock markets are inefficient (see for instance (Lawal et al. 2018b; Gourène et al. 2019; Boamah et al. 2017a)). It is therefore important to account for the sources, types and signals of rational bubbles in these markets. This study attempts to fill this gap as we focus on economic events that signal the bubble build-up in the selected African stock markets. The study set out among others to challenge orthodox thinking on bubbles.

2.2. The Model

We begin our analysis by following (Herzog 2015; Lawal et al. 2019b; Wan 2024; Wang et al. 2020) to employ recently developed econophysics techniques to examine the existence or otherwise of a bubble in the studied African stock markets. Apart from examining the existence of a bubble in the market, it is important to know whether there is a correlation in the market. This is important, as it will show whether the sources of the bubble in the market are common or not. When the correlation among the market is less than the unconditional correlations, then these markets are said to operate independently of the other, hence, shocks that affect these markets are not the same. To account for this, we employed the DCC-MGARCH model following Fromentin (2022); Fromentin et al. (2024); Canh et al. (2019).

Econophysics Frequency Domain Estimation Techniques

In presenting our econophysics frequency domain model, we assume that $p_i(f,t)$ denote financial asset price dynamics, given that i is a function of assets that depends on two variables: the fundamental price vector f and time t. Here, the benefit-loss-rate (BLR) for each asset is defied by $v_i = \partial p_i(f,t)/\partial t$.

Given the fact that a functional relationship exists between BLF and each trading density and trading volume we have

$$q(p,t) = \rho(p,t) * u(p,t) \quad (1)$$

where $q(p,t)$ is the BLF, $\rho(p,t)$ is trading volume while $u(p,t)$ represents trading density.

Calibrating the impact of news into the model in Equation (2), we followed Herzog (2015) by utilizing the idea of jump-discontinuity[2] such that

$$N(t) = \int_{p_a}^{p_b} \rho(p,t) d_p \tag{2}$$

Relying on Equation (1), we manipulate Equation (2) to derive the d_t yields such that

$$\frac{d}{dt} = \int_{p_{(a)}}^{p_{(b)}} \rho(p,t)dp = \left[q(p_a,t) - \rho(p_b,t)\frac{dp_a}{dt} \right] - \left[q(p_a,t) - \rho(p_b,t)\frac{dp_b}{dt} \right] \tag{3}$$

Given the assumption that the trading density changes on both sides of the interval at equal measure such that $\frac{dp_a}{dt} = \frac{dp_b}{dt} = \frac{dp_s}{dt}$, let Equation (3) = 0, such that $\frac{dp_s}{dt}[\rho(p_a,t) - \rho(p_b,t)] = q(p_b,t) - q(p_b,t)$ and transform the results, such that we obtain

$$\frac{dp_s}{dt} = \frac{[q(p_a,t) - q(p_b,t)]}{[\rho(p_a,t) - \rho(p_b,t)]} = \frac{[q]}{[\rho]} \tag{4}$$

where $[q] := q(p_s^-,t) - q(p_s^+,t)$ and $[[\rho] := \rho(p_s^-,t) - \rho(p_s^+,t)$. When we substitute Equation (4) back into Equations (3) and (2), it yields

$$\frac{dp_s}{dt} = \frac{[q(p_a,t) - q(p_b,t)]}{\rho(p_a,t) - \rho(p_b,t)} = \frac{\rho_{max} * u_{max} - \rho_0 * U(\rho_0)}{\rho_{max} - \rho_0} \tag{5}$$

This implies that a financial bubble is characterized by a negative BLF when accounting for time, such that

$$\rho(0,t) = \rho_0 + \epsilon f(0) \tag{6}$$

Since $f(0) = \rho_1(0,t)$. To compute the first derivative, we calibrate the properties of the function

$$\frac{d}{dt}\int_{p_{(a)}}^{p_{(b)}} \rho(p,t)dp = \left[q(p_a,t)\frac{dp_a}{dt} \right] - \left[q(p_b,t)\frac{dp_b}{dt} \right] \tag{7}$$

alongside Equation (5) such that the evolution of asset price with news and yields is as follows

$$p_s = -\frac{\rho_0 * \mu(\rho_0)}{\rho_{max} - \rho_0} * t \tag{8}$$

In other to examine the existence of interlink between bubble periods across the markets, we followed (Engle and Sheppard 2001; Engle 2002, 2009; Vrontos et al. 2003; Escobari et al. 2017; Akkoc and Civcir 2019) to adopt a DCC MGARCH by taking the logarithmic of the closing prices of each of the stock prices. The prices of the series are adjusted for seasonal effects characterized by fluctuations in the prices arising from noise and suspicious trading, by subtracting the price (in log form) of each series on day t of the previous year prior to other estimations.

The choice of the DCC-GARCH model was informed by its superiority over alternative models like GARCH, EGARCH et al. For instance, the model allows for correlation matrix to depend on the time, and have clear computational strength such that the number of parameters to estimate in the correlation process does not depend on the number of series to be correlated. Unlike in the CCC model, where the conditional correlation matrix of the residuals from the conditional mean model is constant over time, the DCC is time-varying in an autoregressive way.

DCC model accounts for the correlation between asset returns as a function of their past volatility and correlation among them. The ability of the DCC estimation techniques to model the interrelationship among the markets has significant policy implications. For instance, it has significant impact on globalization or convergence of the African economies, especially during the period of international instability. The movement can serve as the platform or transmission channel for negative impulses that distort the real sector, with severe consequences for economic management as a policy tool. It is therefore important to timely identify the interdependencies among stock markets, with a proper analysis of their strength, to effectively manage the risk associated with financialization of the economy. To achieve this objective, the study employed the DCC-GARCH model to estimate the time-varying conditional correlation in the markets. The existence of interrelationships among the markets suggests that events in any of the markets are shaped and are being shaped by events in other markets.

The DCC-MGARCH model possesses the ability to capture the volatility correlation between two series in two ways: directly, through its conditional variance; and indirectly, through its conditional covariances. Besides, the techniques can examine volatility spillover from one series to another. When the conditional correlation in a series increases over time, the series becomes more integrated.

Following Sajid et al. (2022); Fromentin (2022); Fromentin et al. (2024), we expressed the DCC MGARCH model is as follows:

$$r_t = \mu + \alpha r_{i-1} + \varepsilon_t \quad (9)$$

where $\varepsilon_t = H_t^{1/2} z_t$ is employed to estimate the residuals in Equation (9), given that H_t is the conditional covariance matrix for r_t and z_t, where H_t is a $n \times 1$ vector of i, i, d random errors.

The conditional covariance matrix $(n \times n)$ is defined as:

$$H_t = D_t R_t D_t \quad (10)$$

where D_t is the diagonal matrix with at time-varying conditional standard deviation. The matrix D_t is such that

$$D_t = \text{diag}(h_{1,t}^{\frac{1}{2}}, \ldots h_{n,t}^{\frac{1}{2}}) \quad (11)$$

R_t is the time varying conditionl correlation matrix of the returns on an asset and it is present as follows:

$$R_t = \text{diag}(q_{1,t}^{\frac{-1}{2}}, \ldots q_{n,t}^{-\frac{1}{2}}) Q_t \text{diag}(q_{1,t}^{\frac{-1}{2}}, \ldots q_{n,t}^{-\frac{1}{2}}) \quad (12)$$

The components of H_t matrix is expressed as follows:

$$h_{i,t} = \omega_i + \alpha_i \varepsilon_{i,t-1}^2 + \beta_i h_{i,t-1} \quad (13)$$

The asymmetric positive definite matrix Q_t in (3) is expressed as

$$Q_t = (1 - \theta_1 - \theta_2)\underline{Q} + \theta_1 z_{t-1} + \theta_2 Q_{t-1} \quad (14)$$

where $\underline{Q}$ is the standard residuals $n \times n$ unconditional correlation matrix $z_{i,t}$ $\left(z_{i,t} = \frac{\varepsilon_{i,t}}{\sqrt{h_{i,t}}} \right)$. The non-negative θ_1 and θ_2 parameters are linked by the exponential smoothing process of the DCC model.

3. Results

We present the results of the descriptive statistics in Table 1. The results of the Kurtosis and Skewness as presented show that the series is skewed towards the right. Evidence from the Jarque-Bera normality test show that the series is non-normally distributed an indication that the series are fat-tailed with a probability of extreme values higher than the normal distribution.

Table 1. Descriptive Statistics.

Parameters/Series	South Africa	Nigeria	Egypt	Botswana	Morocco	Ghana	Kenya	Mauritius
Mean	49.139	43.314	48.241	49.931	47.99	48.18	48.41	44.016
Standard Deviation	28.456	29.521	27.411	31.481	30.354	30.411	31.210	27.382
Minimum	10.345	10.511	10.811	11.1901	9.284	9.678	10.211	11.011
Maximum	157.83	158.711	158.012	156.97	156.93	190.211	158.114	158.62
Skewness	1.190	1.2141	1.3421	1.341	1.0121	1.592	1.299	1.923
Kurtosis	0.158	0.168	0.166	0.174	0.1750	0.1701	0.1711	0.1734
Jarque-Bera	1648.3960 ***	1649.416 ***	1647.341 ***	1644.304 ***	1640.311 ***	1647.312 ***	1639.311 ***	1661.011 ***
Ljung–Box Q-statistics	24.093 *** (12)	32.088 *** (15)	25.107 *** (12)	18.765 *** (15)	22.982 ** (12)	19.644 *** (12)	26.055 *** (18)	23.053 *** (15)
Engle (1982) ARCH test	55.022 *** (12)	62.044 *** (12)	25.107 *** (18)	38.115 *** (12)	47.112 ** (12)	8.906 *** (16)	46.026 *** (12)	31.073 *** (12)

Lag length in parentheses. ***, ** represents 1%, 5% significance levels respectively.

First, we examine the presence of a unit root in the series by employing the traditional unit root tests, ADF, PP, & KPSS. We also examined the existence of cointegration among the series. If we reject the null hypothesis of non-cointegration, then rational bubbles do not exist, acceptance of the null hypothesis of non-cointegration suggests that rational bubbles do exist (Lawal et al. 2022; Khan et al. 2022).

The results of the unit root test for the studied African economies are presented in Table 2. The results suggest that the null hypothesis of a unit root is not rejected for all the series in level, and they are stationary in the first difference. The results rule out the possibility of a speculative bubble in these economies. The results suggest that the series follows the random walk procedure.

Table 2. Univariate unit root tests.

Series	Levels			First Differences		
	ADF	PP	KPSS	ADF	PP	KPSS
South Africa	−2.503	−2.115	0.622 ***	−10.443 ***	−10.107 ***	0.083
Nigeria	−2.771	−2.453	0.559 ***	−10.094 ***	−10.155 ***	0.076
Egypt	−2.288	−2.267	0.889 ***	−11.037 ***	−11.094 ***	0.049
Botswana	−2.104	−2.780	0.903 ***	−13.098 ***	−14.055 ***	0.055
Morocco	−2.255	−2.098	0.917 ***	−11.098 ***	−13.077 ***	0.069
Ghana	−2.088	−2.304	0.443 ***	−10.098 ***	−10.177 ***	0.167
Kenya	−2.509	−2.408	0.089 ***	−12.098 ***	−12.039 ***	0.087
Mauritius	−2.155	−2.006	0.459 ***	−13.078 ***	−13.655 ***	0.085

Note: *** represents 1% significance level.

Extant literature notes that traditional unit root tests failed to account for structural breaks, are weak in detecting rational bubbles in stock prices, that when structural breaks exist, the power to reject a unit root decreases, and that when we ignore structural breaks, we will erroneously accept the null hypothesis of a unit root. To address this, we followed (Jun et al. 2019; Lawal et al. 2022) to employ the Fourier function unit root test. The study began with a search for the best frequency, based on the fact that we have no prior knowledge as to the number of structure breaks in the series. Enders and Lee (2009) noted that a single frequency is capable of capturing a series of large breaks, therefore our Fourier function is estimated for each integer K = 1, . . ., 5.

The results of the Fourier unit estimate are presented in Table 3. In the table, the residual sum of squares (RSS) shows that a single frequency (1) is appropriate for the series. Similarly, both the sine and cosine term are fit for the model, based on the significant f(k) statistic. The (TLM (k)) suggests that non-stationary is established in the model. The results also show that own bubble transmission is statistically significant for the series.

It can also be deduced that the current conditional volatility for each of the series is significantly influenced by past values and innovations from other economies. The results have implications for arbitrage in the economies studied.

Table 3. Unit root test with a nonlinear Fourier function.

Series	Residual Sum of Squares (RSS)	k	F(k)	Number of Lags of ΔS_t	$\tau LM^{(k)}$
South Africa	0.148	1	173.803 ***	3	−1.866
Nigeria	0.655	1	205.554 ***	2	−1.409
Egypt	0.877	1	155.033 ***	3	−1.402
Botswana	0.165	1	161.275 ***	3	−1.711
Morocco	0.544	1	180.332 ***	2	−1.455
Ghana	0.787	1	206.098 ***	3	−1.806
Kenya	0.771	1	165.099 ***	3	−1.564
Mauritius	0.634	1	183.087 ***	3	−1.733

Note: *** represents 1% significance level.

Having suspect the existence of random walk in the series, the study further examined the validity of rational bubbles in these markets, by employing the econophysics frequency domain estimates, as outlined in Equation (8), which is the crux of our study.

The results of the beginning and end dates of the identified bubbles in the series are presented in Table 4. From the results, it can be deduced that the pattern of bubbles in each of these series differs from one another, though the dates or periods appear to be similar. For instance, though Egypt, Kenya, Ghana, Nigeria, and South Africa markets exhibit bubbles in the early 1990s, the underlying factors responsible for bubbles in these markets differ. The first Egyptian market bubble spanned from 1991M3 to 2004M10. This could be traced to the implementation of a series of reforms aimed at meeting the terms of international institutions, lenders and donors which translate to an increase in GDP per capita (PPP) from USD1355 in 1981 to USD2525 in 1991, USD3686 in 2001 to USD4051 in 2004. The identified increase in GDP per capita snowballed into the capital market with upward shifts in asset prices for these periods. The bubble hitherto experienced burst by the effect of the global economic meltdown of 2008–2009 that resulted in foreign investors exists the Egypt stock market, surging domestic inflationary pressure that led to upward movement in overnight spending by the monetary authority by 0.25% on 10th Feb. 2008 and subsequent 0.5% increase every month and the Arab-uprising of 2011.

Table 4. Results of the Econophysics frequency domain estimates (Equation (8)).

Series	Beginning Dates	Ending Dates
Egypt	13 March 1999 2 February 2009 4 November 2016	24 October 2004 18 December 2010 28 May 2018
Morocco	13 January1999 1 August 1996 2 February 2000	15 May 2000 18 December 1996 9 December 2001
Botswana	9 February 2000 1 February 2010	6 August 2005 30 November 2015
Ghana	3 April 2005 1 June 2010	3 May 2008 3 November 2014
Nigeria	8 August 1999 1 December 2004 5 May 2012	21 December 2002 8 August 2007 8 August 2014

Table 4. *Cont.*

Series	Beginning Dates	Ending Dates
South Africa	3 April 1998 4 June 2001 10 March 2003 11 September 2008 4 February 2016	10 October 1998 12 October 2001 13 August 2003 12 October 2008 10 October 2016
Kenya	4 September 1996 1 July 2000 5 May 2003 6 June 2014	12 December 1996 11 December 2001 12 October 2008 12 August 2018
Mauritius	5 February 2000 6 October 2007 7 March 2012	16 October 2005 30 September 2010 10 October 2015

The bubble noted in the 2016 M11 to 2018M5 coincided with the announcement by the monetary authority to adjust a floating exchange rate regime which attracts foreign trade in the stock market.

4. Discussion

The 1999–2000 and 2002–2004 bubble dates for Morocco coincide with reforms introduced by the government that among other things opened the economy for foreign investors' participation, and lowered the inflation rate. Other possible influence includes privatization of state-owned enterprises, large government spending, exchange rate anchor initiatives and well- managed monetary policy that saw inflation in 2002 quite below 2%.

The bubble dates of 1996M3 to 1996M12 coincided with the effect of major economic reforms like the elimination of price controls, import licensing, removal of foreign exchange controls, and privatization of state-owned entities among others in 1993, which leads to an increase in GDP growth rate to about 4% for the studied period. The second bubble dates from 2000M2 to 2001M12 and coincided with another economic reform which attracted USD307 million facilities from both the World Bank and the International Monetary Fund (IMF) to the Kenyan economy, which stimulate investment into the stock exchange. Another bubble was witnessed from 2003M2 to 2008M11. It also coincided with upward swings in the economy resulting from a series of economic reforms initiated by the Mwai Kibaki-led administration that opened the economy to foreign participation, especially the stock market.

For Botswana, the expansion in the Orapa 2000 project opened the economy, such that the GDP and per capita doubled with a snowball effect on the capital market, this bubble burst due to slow economic growth recorded in the years 2005 to 2008. The 2008/2009 global economic meltdown severely affected the economy and the stock market, this almost eroded the gains of the earlier bubble periods with a contraction of about 5.2% in the economy. From 2010M2 to 2015M11, the stock market witnessed some bubbles. During this period, the market experienced about a 24% increase in stock return, which coincided with some reforms such as stable currency and lack of exchange rate control. Other supporting factors include the implementation of a Central Securities Depository by the Security Exchange Commission, which aided the flow of remittance from abroad, and the role of the Southern African Development Community (SADC), which eliminates all tariffs and non-tariff barriers to trade in 2012 among the 11 signatory economies, this aided inflows of fund into the stock market.

The bubble periods noted to exist for Ghana were from 2005 to 2008 and 2010 to 2014. These periods also coincided with some key events in the Ghanaian economy. For instance, the 2005–2008 period coincided with the impact of the 2005 debt cancellation by creditors' nations to Ghana, the re-denomination of the Ghana's currency in 2007, and the Banking Amendment Act of 2007, which offers a general banking license to qualified banks in Ghana. The 2010 to 2014 bubbles were largely influenced by an increased in market capitalization to about GH₵57.2 billion in 2012. These events among others increased investors' confidence in the economy and rubbed on the stock market.

For Nigeria, the 1999–2002 bubble coincided with the change in power (movement from military to democratic rule) which boast investors' confidence in the Nigerian economy. It also coincides with an aggressive drive by public policy makers to attain privatization of government entities. The bubble period of 2004–2007 coincides with the banking sector recapitalization exercise of 2004–2005, which led to upward movement in stock returns. Though 2004 to 2007 was almost short-lived by the impact of the 2007/2008 global financial crisis, another bubble was triggered from 2012 to 2014 largely by reforms in the economy. Another contributing factor was the effort to re-base the Nigerian economy in the year 2014.

The South African stock market is the largest in the regime. The results as presented in Table 2, shows that bubbles were noted at five (5) different periods. 1998, 2001, 2003, 2008, and 2016 unlike other economies where bubbles lag across years, bubbles in the S/A market are short-lived and last within a year. This suggests that the South African market is relatively efficient compared with others (Balcilar et al. 2016).

Discussing our results within the context of existing literature, it can be deduced that our results contradict the finding of Ye et al. (2011), Cho and McCallum (2015), Chen et al. (2016), Caspi and Graham (2018) for the G7 stock markets, for a typical market, some selected economies including the US, Belgium, Denmark and Finland, and the Israeli market respectively. However, our results support the earlier findings of Chang et al. (2016) for South Africa, Balcilar et al. (2016) also for South Africa, Tran (2017) for Asian and Latin American economies, and Fry (2018) for Bitcoin prices.

Robustness Check

For the robustness check, we employed the non-parametric rank test for cointegration that captures both the linear and nonlinear properties of the series (Hou et al. 2024; Chaouali et al. 2024). For the Rank tests, the null hypothesis is rejected in favour of the alternatives hypothesis, if the critical value exceeds the test statistics. We present the results in Table 5; the length was selected by using the Akaike information criteria (AIC). The results as presented suggest that evidence abounds to show that rational bubbles exist in the series. We accept the null hypothesis for the studied market because the test statistics are larger than the critical values at 1% level of significance. It therefore, established the existence of a cointegrating relationship between prices and fundamentals of the eight African stock markets. The results of the non-parametric rank test are in line with that of our main model-The Econophysics frequency domain unit root test, and validate our results.

As displayed in Tables 1 and 2, for both mean and variance, the series are non-linear, with evidence suggesting problems of heteroscedasticity and serial autocorrelation. This provides good ground for the employment of the DCC-MGARCH model to account for bubble clustering in asset prices. Besides, the model can account for market dynamics (Lean and Teng 2013).

Given the results from our econophysics frequency domain model suggest the existence of bubbles in the studied economies, we proceed to investigate the existence of a correlation of bubbles among the markets by employing a DCC-MGARCH model. Panel A of Table 6 presents the results of the DCC-MGARCH model. From the results, it can be deduced that all the correlations among ARCH(1), GARCH(1) and ARCH are positive and statistically significant at 1% in line with the GARCH(1,1) conditions. The implication is that higher errors and error variances in the previous period are associated with higher error variances in the current period. Furthermore, the value of ARCH(1) is quite larger than the values of GARCH(1) suggesting that the market volatility at present is largely influenced by previous period volatility. Panel B of Table 3 presents the results of the quasi-correlations between the DCC-MGARCH. From the results, it can be deduced that the correlation among the series is high and positive, suggesting that African markets are not efficiently diversified. The results presented show that the correlation among bubbles in the series is less than the unconditional correlations. This play down the possibility of the existence of interdependence among the bubble periods across the economies studied as well as evidence of clusters of prices, these markets seem to operate independently of one another in terms of exposure to bubble periods and the shocks that affect these markets differ.

Table 5. Results of rank test estimates.

Panel A: Linear Model		
Series	**Rank Test Statistic**	**Linear Score Test Statistic**
South Africa	1.10561 ***	4.0087603 ***
Nigeria	0.97633 ***	0.7865509 *
Egypt	0.91089 ***	1.954407 ***
Botswana	0.81712 ***	4.006591 ***
Morocco	0.82771 ***	0.754493 ***
Ghana	0.52433 ***	2.876601 ***
Kenya	0.71891 ***	0.743388 ***
Mauritius	0.71166 ***	1.89056 ***
Critical value (%)		
10	0.0514	3.05
5	0.0951	4.62
1	0.0433	6.76
Panel B: Nonlinear Model		
Series	**Rank Test Statistics**	**Nonlinear Score Test Statistic**
South Africa	0.82935 ***	4.006629 ***
Nigeria	0.89169 **	0.677702 ***
Egypt	0.90322 **	1.872034 ***
Botswana	0.94625 **	0.987232 ***
Morocco	0.82999 ***	1.908821 ***
Ghana	0.744662 ***	0.788292 ***
Kenya	0.964461 ***	1.872209 ***
Mauritius	0.983385 *	1.859663 ***
Critical value (%)		
10	0.0356	3.99
5	0.0198	4.73
1	0.0177	7.06

Note: *, **, *** represents 1%, 5%, 10% significance levels.

Table 6. DCC-MGARCH model results.

Panel A: Dynamic Conditional Correlation MGARCH Model								
Series	**South Africa**	**Nigeria**	**Egypt**	**Botswana**	**Morocco**	**Ghana**	**Kenya**	**Mauritius**
Cons	1.292 [a] [0.007]	1.261 [a] [0.006]	1.241 [a] [0.022]	1.206 [0.006]	1.401 [a] [0.014]	1.014 [a] [0.020]	1.414 [a] [0.012]	1.843 [a] [0.016]
L1arch	0.941 [a] [0.038]	0.913 [a] [0.038]	0.849 [a] [0.030]	0.914 [a] [0.029]	0.941 [0.051]	0.721 [a] [0.039]	0.821 [a] [0.044]	0.928 [a] [0.042]
L2garch	0.250 [a] [0.023]	0.2419 [0.024]	0.214 [a] [0.014]	0.239 [a] [0.023]	0.204 [a] [0.024]	0.341 [a] [0.017]	0.290 [a] [0.019]	0.214 [a] [0.027]
Cons arch	0.008 [a] [0.001]	0.009 [a] [0.001]	0.016 [a] [0.002]	0.007 [a] [0.001]	0.061 [a] [0.005]	0.042 [0.005]	0.009 [a] [0.001]	0.044 [a] [0.004]
N								
Log likelihood	3994.7							
Lamda1 (0.006)	0.289 [a]							
Lamda2 (0.006)	0.711 [a]							

Table 6. *Cont.*

Panel B: The Estimated Conditional Quasi-Correlation in DCC MGARCH Model								
Correlations	**South Africa**	**Nigeria**	**Egypt**	**Botswana**	**Morocco**	**Ghana**	**Kenya**	**Mauritius**
South Africa	-							
Nigeria	0.764 [a] [0.031]	-						
Egypt	0.643 [a] [0.036]	0.614 [a] [0.049]	-					
Botswana	0.624 [a] [0.040]	0.572 [a] [0.051]	0.643 [a] [0.052]	-				
Morocco	0.562 [a] [0.041]	0.561 [a] [0.061]	0.610 [a] [0.048]	0.622 [a] [0.041]	-			
Ghana	0.598 [a] [0.043]	0.621 [a] [0.070]	0.572 [a] [0.081]	0.601 [a] [0.048]	0.524 [a] [0.058]	-		
Kenya	0.608 [a] [0.041]	0.591 [a] [0.046]	0.589 [a] [0.052]	0.548 [a] [0.064]	0.701 [a] [0.062]	0.543 [a] [0.0049]	-	
Mauritius	0.566 [0.042]	0.553 [0.054]	0.543 [0.053]	0.540 [0.0501]	0.538 [0.0498]	0.531 [0.0477]	0.511 [0.049]	-

[a] represents 1% significance level.

Figure 1 presents a graphical explanation of the behaviour of the African stock market over the studied period. A threshold above 100 basis points (10%) is the threshold for identifying a bubble. A critical look at the figure shows that some economies took large values from 2000 to 2001 and around 2016. These extreme values coincide with reforms and innovations in the economies studied, pointing to the existence of bubbles. For instance, the extreme spark in curve peaking at 1.4 for Botswana, coincides with the expansion of the Orapa 2000 project that opened up the economy (the stock market inclusive), to the influx of foreign capital. The 2015/2016 surge/peaking at 0.4 resulted from an unprecedented increase in market return to the tune of 24%, thanks to stable currency, among others.

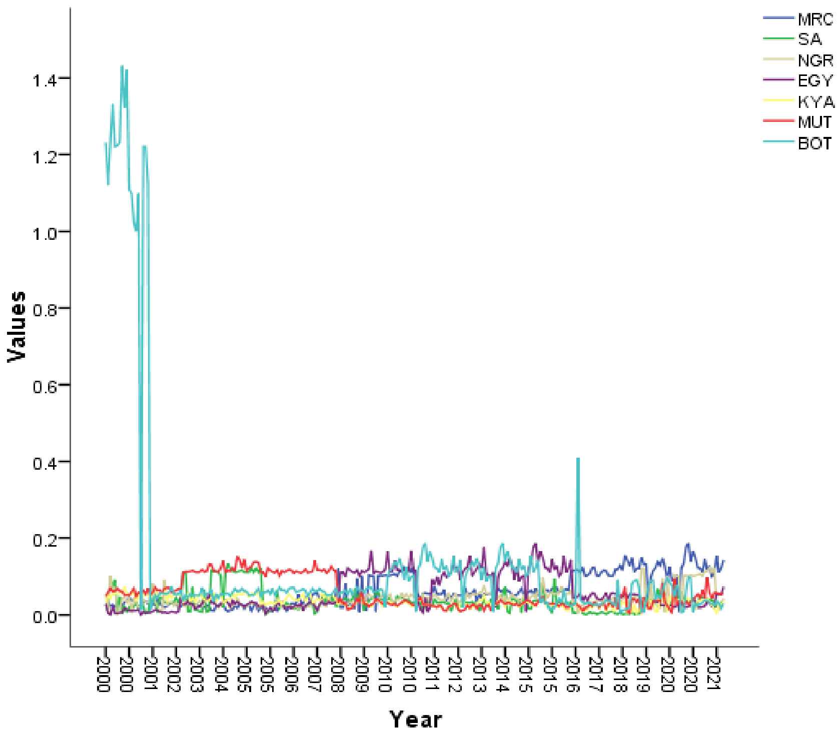

Figure 1. Bubbles in African Stock Markets.

For Mauritius, the upward movement in the years 2002 to 2008 coincided with the political crisis that comove with the economy. This impact seriously on the Africa's most developed economy. Egypt spark as captured in the figure suggest that the basis point increased during the periods 2008 to 2010, 2011 to 2013, 2014 to 2015. These periods coincide with the global financial crisis of the year 2007/2008, the Arab Spring of 2010/2011, the Syrian civil war, and the Lehman shock, among others. It can be deduced that bubbles in these markets follow a pattern, and no evidence exists to show the presence of spillover in these markets. This aligns with the findings of (Lean and Teng 2013).

5. Conclusions

This study examined the existence of bubbles in the stock markets of eight Africa's largest markets. We employed econophysics based financial bubbles techniques and DCC MGARCH estimation techniques to a dataset sourced from 04 January1996 to 31 December 2022. The study observed that the studied markets are thin in nature and are characterized by some measure of illiquidity. The study contributes to the existing literature in three folds; Methodology, Data coverage; and policy implications.

Previous studies focus on the aftermath of bubbles: burst or structural breaks, whereas understanding bubble behaviour entails knowing the buildup dates, based on the fact that it is easier to manipulate the effect of a bubble burst at the bubble build-up stage than after a market crash. The result shows that African stock markets at various stages experience bubbles which were followed by a burst. We also noted that bubbles coincide with significant changes in the economic growth of the studied economies suggesting that crashes in the market do not only relate to the financial system but the entire economy.

The results obtained in the current study have some policy implications for various economic agents. As earlier noted, when asset prices bubble burst, its effects impact negatively on the financial system, and of course the aggregate economy. Policy makers are therefore expected to pay attention to the growth rate of asset prices. Following (Borio 2003; Dudley 2010; Evanoff et al. 2012), this study recommends five clear-cut policy options for the monetary authorities in Africa. First, the bully pulpit approach advocates the need to identify the assumptions that drive the rapid increase in stock prices and challenge the accuracy of these assumptions. The effectiveness of this policy instrument depends on the credibility of the monetary policy authority in the eyes of the economic agents in the economy (Virtanen et al. 2018). If the monetary policy makers are perceived as experts who know their onions and can carefully explain the risks associated with the perceived bubble, chances are high that overreaction-induced investments will be reduced, thus mitigating the bubble-building process.

The second policy option is to adopt the use of monetary policy[3] tools that 'lean against' incipient stock price bubbles by pursuing a slightly tighter measure. This could be by a way of taking out insurance against the risk that an increase in stock prices is a bubble, which when burst will have a significant impact on the economy (Chang et al. 2016; Bejan and Parkin 2015; Bejan and Bidian 2014). The third policy option is the use of macroprudential tools (like countercyclical capital requirements, credit constraints, credit-to-gross domestic product (credit-to-GDP) ratio monitoring as well as margin requirements) which aim at protecting against disruption in the financial system. This could be by way of enhancing the capacity of financial system resilience when a bubble burst. The macroprudential tools could also be tailored to limit the magnitude of prospective bubbles.

Fourth, the investing public is advised to employ a conscious approach to investment during bubble periods, to mitigate welfare loss arising from the burst that usually follows a bubble.

Fifth, the existence of bubbles in these markets suggest that the markets are inefficient, hence provides room for arbitrage, with the possibility of investors making abnormal profit. This sounds good for the investing public. It is also important to note that the existence of a bubble points to the inefficient nature of the markets studied. This suggest that the markets can serve as catalyst for growth in the studied economies. Policymakers are therefore encouraged to develop policies that will stimulate the markets, and provide safety nets that will mitigate the effects of bubble bursts, which always succeed bubbles. As noted by Jahan-Parvar and Waters (2010), proper policy response is crucial to asset bubbles given the recent financial crises, hence policymakers should go beyond monitoring market fundamentals in conducting monetary policy, as proactive positive policy actions are required.

The academic community is encouraged to deploy more efforts to understand the presence and causes of bubbles in asset bubbles and their impact on the economy.

On the interconnectivity between the markets, as evidenced by the results of the DCC-MGARCH model, investors in these markets tend to have an informational advantage in their home markets. As noted by Brennan and Cao (1997), and Ye et al. (2011), when favourable news becomes more available in the home market, foreign investors raise their valuation more than domestic investors, because domestic investors naturally have precise information, and may receive the market news earlier.

The study is without limitations, for instance, it only focused on bubbles in African stock markets. Future research may look into stock market behaviour in other economies, energy prices in Africa and other economies, and other commodity prices related to the bubble, among others. Besides, the methodology employed could be expanded. Other estimation techniques could also be employed to examine the existence of a bubble in asset prices.

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Notes

1 Botswana, Egypt, Ghana, Kenya, Mauritius, Morocco, Nigeria and South Africa (BRVM (Bourse Régionale des Valeurs Mobilières) and Dar es Salaam Stock Exchange were dropped because of too many missing values for some years)). S&P started recording daily data for most African stock markets in the mid-1995.

2 A jump simply implies a trading stop or news.

3 Experts have raised concern about the ability of monetary policy tools effectiveness in tackling bubbles because they are blunt instruments designed to influence the aggregate level of economic activities and not usually sectorial activities.

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