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Journal of Financial Risk Management

ISSN Print: 2167-9533

ISSN Online: 2167-9541

www.scirp.org/journal/jfrm

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Google-based Impact Factor: 1.92

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Leander Fritze, Otto Jockel

Journal of Financial Risk Management Vol.14 No.1, February 8, 2025

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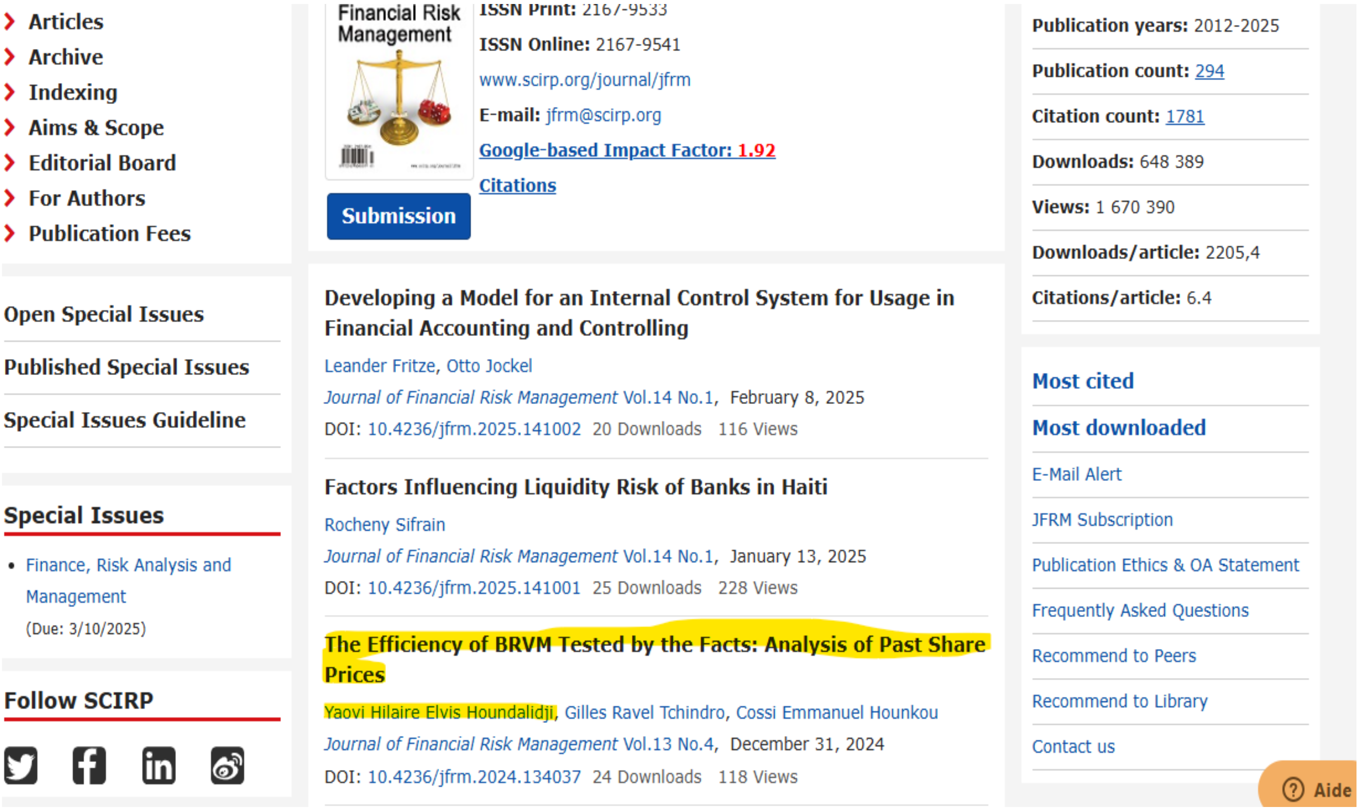

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DOI: 10.4236/jfrm.2025.141001 25 Downloads 228 Views

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Journal of Financial Risk Management Vol.13 No.4, December 31, 2024
DOI: 10.4236/jfrm.2024.134037 24 Downloads 118 Views

Publication years: 2012-2025
Publication count: 294
Citation count: 1781
Downloads: 648 389
Views: 1 670 390
Downloads/article: 2205,4
Citations/article: 6.4

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The Efficiency of BRVM Tested by the Facts: Analysis of Past Share Prices

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DOI: 10.4236/jfrm.2024.134037 **PDF** **HTML** **XML**

Abstract

In the 1980s with the financial crisis, the emergence of stock markets was far from being a fashionable phenomenon because it emanated from the demands of States who saw the establishment of stock markets as an efficient means of mobilization and allocation of domestic savings. The efficient market hypothesis has implications for investors. This efficiency, despite work on its validation, was called into question years later through behavioral finance. The conclusions of this theory have only known divergent points. We have noted an accumulation of scientific evidence of the random walk of stock prices, and the low efficiency hypothesis has become a true paradigm in the scientific community for having gained ground. The efficiency of financial markets being informational, it is worrying for the academic community since it conditions the attractiveness of research. On the regional stock market, few studies have been carried out on efficiency and have refuted the hypothesis in the weak sense. The objective of the study is to test the efficiency of the BRVM in the weak sense. Data collection was provided by the BRVM and the BCEAO, i.e. 45 values, the number of securities listed on June 30, 2022. This is the sample for which we have 1,618 daily data over a period going from January 4, 2016 to June 30, 2022. They were processed and prepared through the Box and Jenkins procedure in forecasting one-dimensional time series. According to the analyses, it appears that the regional stock market is inefficient, thus confirming the efficiency of the BRVM in the weak sense.

Keywords

Market Efficiency, Informational Efficiency of Financial Markets, Test Runs, Box and Jenkins Method, ARIMA Model

Share and Cite:

Houndalidji, Y. , Tchindro, G. and Hounkou, C. (2024) The Efficiency of BRVM Tested by the Facts: Analysis of Past Share Prices. *Journal of Financial Risk Management*, **13**, 769-797.
doi: 10.4236/jfrm.2024.134037.

Scientific Research Publishing

Journal of Financial Risk Management, 2024, 13, 769-797
https://www.scirp.org/journal/jfrm
ISSN Online: 2167-9541
ISSN Print: 2167-9533

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How to cite this paper: Houndalidji, Y. H. E., Tchindro, G. R., & Hounkou, C. E. (2024). The Efficiency of BRVM Tested by the Facts: Analysis of Past Share Prices. *Journal of Financial Risk Management, 13,* 769-797.
https://doi.org/10.4236/jfrm.2024.134037

Received: August 30, 2024
Accepted: December 28, 2024
Published: December 31, 2024

Abstract

In the 1980s with the financial crisis, the emergence of stock markets was far from being a fashionable phenomenon because it emanated from the demands of States who saw the establishment of stock markets as an efficient means of mobilization and allocation of domestic savings. The efficient market hypothesis has implications for investors. This efficiency, despite work on its validation, was called into question years later through behavioral finance. The conclusions of this theory have only known divergent points. We have noted an accumulation of scientific evidence of the random walk of stock prices, and the low efficiency hypothesis has become a true paradigm in the scientific community for having gained ground. The efficiency of financial markets being informational, it is worrying for the academic community since it conditions the attractiveness of research. On the regional stock market, few studies have been carried out on efficiency and have refuted the hypothesis in the weak sense. The objective of the study is to test the efficiency of the BRVM in the weak sense. Data collection was provided by the BRVM and the BCEAO, i.e. 45 values, the number of securities listed on June 30, 2022. This is the sample for which we have 1,618 daily data over a period going from January 4, 2016 to June 30, 2022. They were processed and prepared through the Box and Jenkins procedure in forecasting one-dimensional time series. According to the analyses, it appears that the regional stock market is inefficient, thus confirming the efficiency of the BRVM in the weak sense.

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1. Introduction

The emergence of stock markets in recent years in developing countries is far from being a fad because it emanates from various requests from States and local authorities who see the creation of stock markets as an efficient means of mobilization and allocation of domestic savings with the financial crisis of the 1980s (Nellor David, 2008). These stock exchanges are also a means of financing and investing in line with the hitherto unmet needs of businesses and economic operators. For Ross, Westerfield, & Jaffe (2007), the question of the hypothesis of market efficiency has important implications for investors and companies, which is why, despite numerous works on the validation of the hypothesis of efficiency of European and American financial markets, this was called into question years later through behavioral finance (Albouy, 2005).

The efficiency of the markets, which was indisputable, is today a subject of controversy which continues to call into question this widely verified hypothesis between those who are for and against (Chiny & Mir, 2015).

According to Chuard (2021), the efficient financial market hypothesis is one of the most controversial theories in the financial field. Thus, the economist John Maynard Keynes was already skeptical about the rationality of investors, one of the main assumptions of efficiency. This was the premise of the debates regarding this hypothesis, even before the publication of the theory by Eugene F. Fama in 1970. Academicians in finance began to become strongly divided, following the oil shock impacting financial markets in the 1970s, the stock market crash on "Black Monday" on October 19, 1987 and the numerous speculative bubbles since the 90s.

Two categories of researchers have emerged, classical finance theorists and empiricists. However, since 1980, several "empirical" scientists have begun to seriously question the theory of the efficiency of financial markets, and many research works have been published in order to highlight phenomena constituting anomalies with respect to the theory. Among the criticisms of this theory, it is interesting to cite the article by Grossman & Stiglitz (1980) entitled "On the impossibility of Informationally Efficient Markets" introducing the Grossman-Stiglitz paradox or the work of Malkiel (2003) entitled "The Efficient Market Hypothesis and Its Critics".

The list is not exhaustive, given the numerous researchers who have published empirical results largely on the United States market in order to test the theory of the efficiency of financial markets. All this research has thus challenged this theory in different ways, especially the postulates related to the behavior and rationality of investors. For Chuard (2021), although the theory of the efficiency of financial markets is one of the central concepts of modern financial theory, the latter is very controversial and is still subject to scientific debate between the different currents. Gillet (1991) is no exception when he concludes that the informational efficiency of the stock market is an area of modern finance that has been the most controversial. For him, it is not surprising that the hypothesis has given rise to an abundant empirical literature essentially relating to the main world financial centers and more particularly to the New York Stock Exchange.

For Lardic & Mignon (2006), there is no unanimity around the conclusions of this theory and even the opinions expressed by theoreticians are divergent. Scientific evidence of the random walk of stock prices has accumulated and the weak efficiency hypothesis has gradually gained ground and has become a real paradigm in the academic community (Ait Dani & Radi, 2017). With the latter, efficiency is today the concern of the supervisory authorities at the level of all financial markets throughout the world, since it conditions the attractiveness of these markets and their development. The efficiency of financial markets generally relates to informational efficiency (Dib et al., 2021).

The regional stock market has been the subject of a limited number of studies on its informational efficiency. Almost all of these studies have invalidated the hypothesis of the efficiency of the regional financial market in the weak and semi-strong sense. However, this limited research on the issue of financial markets remains, in our view, very insufficient. This is what justifies the choice of this study in the sub-regional context of the financial market. What about this efficiency with the regional financial market? Are the prices of securities on the BRVM market predictable based on past returns? The objective of this research is therefore to analyze the evolution of security prices based on information already known and published in the past. It is therefore a question of testing the efficiency of the BRVM in the weak sense.

As part of this work, data collection was provided by the BRVM and BCEAO market over a period from January 4, 2016 to June 30, 2022. The choice of such a period improves the robustness of the test efficiency. They have been processed and prepared largely by empirical testing. Thus, as of June 30, 2022, the number of listed securities is 45 values providing daily data. They constitute our sample size. Thus, this study period represents (1618) data and takes into account those concerning the general index of the stock market, namely the BRVM Composite index. They are analyzed with the procedure of Box and Jenkins in the prediction of one-dimensional time series.

For Abadié & Travers (1981), the ultimate objective of any time series analysis remains forecasting. It is an efficiency test that relies on the ARIMA process to find a model that best reproduces the behavior of the time series. This test makes it possible to verify the independence of successive variations in stock market prices. It is a test of runs on 1618 observations of the composite BRVM stock market index. It includes the stages of identification, estimation and diagnosis. Eviews.9, SPSS 25 and Excel are used to analyze data. The return of the index is calculated as follows on the basis of closing prices.

$R(m,t) = \ln(It/(It-1))*100$, with $R_{m,t}$ the return of the index m, It the value of the index at period t, It-1 the value of the index at period t-1. This is the same model used by Dib & Kharbouch (2021) in their work. According to the analyses, it appears that the regional stock market is inefficient. The objective of this work is to analyze the evolution of the prices of the securities according to the information already known and published in the past. It is therefore a question of testing the efficiency of the BRVM in the weak sense. To achieve this, this paper is structured as follows: the first section focuses on the theoretical review that underlies the informational efficiency of financial markets. The second part relates to the empirical review related to the question. As for the third part, it focuses on the methodology adopted in achieving the objectives. The fourth section focuses on the analysis of the results.

2. Theoretical Review

The concept of financial market efficiency generally relates to informational efficiency, i.e. the fact that stock prices instantly reflect all available information (Dib, Dahhou, & Kharbouch, 2021). However, the concept of efficiency is also linked to the concept of investor rationality and the economic efficiency of markets. According to Bauer (2004), the market for an asset demonstrates informational efficiency when the price includes all the information. Efficiency is a concept that can take on several dimensions. For Mignon (2008), informational efficiency is the essential pillar of modern finance theory. Eugene Fama, is considered the father of efficient market theory since his founding publication in 1965.

Grossman & Stiglitz (1980) consider that market efficiency can only be achieved when information costs and transaction amounts are zero. However, for Jensen (1978), efficiency occurs within the market when the marginal benefits that are extracted from certain information exceed the marginal costs of the latter.

For Fama (1965), in an efficient market, the price of a share is a good estimate of its fundamental value. The concept of efficiency is based on the arguments put forward by Samuelson (1965) who asserts that the price of a financial asset fluctuates randomly: future information is unpredictable and the evolution of the price of each financial asset follows a random pattern. According to Malkiel & Fama (1970), a financial market is efficient if prices fully reflect available information. If the price of an asset fully expresses all events occurring up to t, then only new information can change it. Three forms of efficiency have been defined by distinguishing different categories of information (Malkiel & Fama, 1970). The price of a share must react immediately and appropriately to any disclosure of relevant information (Mondher & Martinez, 2019).

According to the theory of market efficiency, financial markets are fundamentally associated with the prices of financial assets which constitute the vectors of transmission of information, supposed to represent the "fair value" of the assets, allowing investors to decide on their acquisition. or their transfer. The useful information included in this "fair value" concerns historical data, public data present revealed on the market (dividends, interest rates, income statement, PER, etc.) and finally the private information of companies which constitutes future expectations (acquisition projects, opening up of capital, hidden losses, etc.) and known only to well-informed investors.

In the ideal case where prices instantly reflect all of these three layers of available information, i.e. the consequences of past events (historical data), present (public data present on the market) and expectations (corporate private data) on future events, the market is described as an informationally efficient market. This character of informational efficiency is fundamental in the functioning of the markets because it gives them credibility and helps to attract investors. This is why all market authorities and stock exchanges seek to create the regulatory and organizational conditions to move closer to this state of informational efficiency. However, in reality, the transmission of useful information through the price channel is only partial and investors often find themselves in a situation of information deficit and act inefficiently.

2.1. The Three Forms of Efficiency According to Farma

Referring to Dib, Dahhou, & Kharbouch (2021), we can classify the forms of efficiency into three categories. But, for the latter, the concept of efficiency remains very controversial for several reasons, in particular the problems accorded to the definition of efficiency thus making any empirical verification very difficult, and the fact that efficiency is always particularized and explained. with reference to a course formation model. The hypothesis of the efficiency of financial markets allows for each course of action the simultaneous translation of all available information. For Gillet (1991), the three forms of efficiency defined by Roberts (1967) and Malkiel & Fama (1970) appear as an acceptable compromise between the desire to confer a progressive and operational character on this concept and the need to restrict the whole information for which the effect on stock prices is contemplated.

- **The weak form of informational efficiency**

According to the weak form of efficiency, the current price of a security fully incorporates the information contained in past price history, i.e. no one can "beat" the market by analyzing the evolution of past price. A market is said to be weak form efficient if the prices of financial assets reflect all historical information (Alexander, 2006). If there was a pattern of past prices, agents use it to predict future prices.

The weak form of efficiency got its name for the following reason: security prices are arguably some of the easiest information to obtain. Thus, no one is able to profit from the use of this information since it is known by all financial market participants. In order to obtain profit, and by exposing short-term trends, investors carry out precise studies from consulting past prices to examining transaction volumes. In the same sense, the principle of random walk (random walk) engenders that the regular increases and decreases in prices are autonomous and independent. This principle assumes that the future course does not depend on its present state or its past or the nearest.

To test the weak form of the efficiency of financial markets, it suffices to demonstrate that an investor cannot profitably anticipate future stock prices using the sequence of past prices. This situation exists if the level of autocorrelation in said sequence is negligible. The so-called random walk hypothesis is compatible with such a situation. It is represented as follows:

$R_{it} = \mu_i + \varepsilon_{it}$ Where Rit represents the expected rate of return of security i during period t, μi is a constant term and εit a random variable with zero mean and finite variance and whose autocorrelation coefficient is zero for lag k greater than or equal to 1. From the previous relation follows, this one. E (Rit\μi) = μ. Which stipulates that the best forecast of the rate of return of security i for a future period is its average past rate of return over a period of the same duration.

According to Sangare (2006), three types of tests make it possible to perform the random walk hypothesis of stock prices. The first types directly test the independence of successive variations in stock market prices. The latter check to what extent technical analysis methods (or chartism) based on the evolution of past prices allow investors to obtain better results than those which would result from a naive investment strategy. Finally, the third type of test, relatively recent, verifies the hypothesis of a chaotic progression of stock market series.

- **The semi-strong form of informational efficiency**

The second form of efficiency is efficiency in the semi-strong sense where the set of information includes all public information; This involves information concerning the issuing company such as annual reports, profit announcements, distributions of free shares, information provided by the press, etc. A market is efficient in the semi-strong sense if the prices observed in this market instantly reflect all publicly available information.

- **The strong form of informational efficiency**

Regarding the third form of efficiency, it is efficiency in the strong sense. This is naturally the most restrictive form of efficiency since the set of information includes in addition to public information any private information. A market is efficient in the strong sense, if all public and private information is fully reflected in the price. According to the strong form of efficiency, the availability of private information within the market makes it possible to inform the entire market about the occurrence or occurrence of a particular event (Alwathainani 2012). These forms of informational efficiency are presented in the following **Table 1**. It was developed by Solnik & Jacquillat (2014).

Table 1. Different forms of informational efficiency.

Weak form	Semi-strong form	Strong form
Past prices	All public information	All information that is possible to know
In an efficient market, past prices of securities cannot be used to beat the market or to obtain higher rates of return.	Public information includes in particular balance sheets, income statements, PER, capital increase, etc.	No one can outperform, not even those most likely to obtain inside information

Source B. Jacquelin and B. Solnik: Financial markets: portfolio and risk management.

2.2. The Concept of Informational Efficiency of Financial Markets

The study of the behavior of stock prices has long been a subject of interest to researchers in finance. It was triggered by Bachelier (1900) with the "Theory of speculation". Thus, for the latter, the mathematical expectation of a speculator's gain is equal to zero. This line of research devoted to stock prices is continued with Alexander (1961, 1964), Cootner (1964), Samuelson (1965), Fama (1965), Fama and Blume (1966), Fama, Fisher, Jensen, & Roll (1969). In 1970, Fama returned to the literature of these works and defined the term "Efficient Capital Market". "Informational efficiency of financial markets" Sewell (2008) which is becoming a very important concept in modern finance. It is linked to the organization of the market, portfolio management, transaction costs and the quality of order execution. All financial theories and models, such as the CAPM, are based on the efficiency Mignon (1998) hypothesis.

The initial definition of informational efficiency comes from Malkiel & Fama (1970) as follows: "*A market in which prices always fully reflect available information is called efficient*". Thus, in an efficient information market, the observed price instantly and fully reflects all available information. Malkiel & Fama (1970) thus identified three forms of efficiency characterized by the set of information contained: in the weak form, that is to say the set of information which contains only the history of prices; in the semi-strong form, which designates all public information; in the strong form, it contains all public and private information. Informational efficiency, in this sense, requires several conditions which, according to authors such as Leroy (1973) or Jensen (1978), are impossible to achieve.

3. Empirical Review

In their work, Mouallim & Chraibi (2020) used both parametric tests (autocorrelation tests and unit root tests) and non-parametric tests (runs test) on the main Moroccan stock indices (MASI and MADEX) and the five largest capitalizations of the Moroccan stock market (Maroc Telecom, Attijariwafa bank, BCP, BMCE Bank and Ciments du Maroc) for a study period going from January 2005 to October 2018. The results obtained clearly show the inefficiency in the weak sense of the different markets studied. Consequently, the hypothesis of the informational efficiency of the Moroccan stock market is not validated.

For Van Hoang (2009), the hypothesis of the informational efficiency of the weak form of the gold markets in Paris and London over the period from 1948 to 2008 is not accepted. It is with the help of Ljung-Box tests which attest the existence of an autocorrelation of order 1 in the series of monthly profitability of the Napoleon gold coin listed in Paris, as well as of the ounce of gold from the afternoon fixing in London that these results are obtained. The hypothesis that prices follow a random walk is not accepted by the Augmented Dickey-Fuller (ADF) test. For this author, tests of the weak form of the informational efficiency of financial markets are often associated with those of the random walk. By definition of the weak form, the observed price fully reflects: On the one hand, the consequences of past events (the history of the price of the asset in question and that of the other variables affecting the price of this asset); and on the other hand, the anticipations of future events. It follows that price variations can only be due to the occurrence of unanticipated events. The successive variations of the price are therefore random.

Elawad (1993), conducted a study to measure the degree of efficiency of the Moroccan stock market. With his analyses, he concludes that the Casablanca Stock Exchange (BVC) is not yet integrated into its main role of draining savings. It is characterized by a particular structure and by the relative inefficiency of its functioning. The absence of daily quotations limits the scope of application of the financial asset equilibrium model (MEDAF). Assumptions such as the normality or non-correlation of stock returns are not verified. The Casablanca Stock Exchange is characterized by its relative inefficiency in the sense of financial market theory.

Ibenrissoul & Aouragh (2023) attempted to test the informational efficiency of the Moroccan stock market in its weak form in a context marked by several successive events, in particular, the financial crisis of 2008, the Arab Spring of 2011, the Covid-19 crisis in 2020, ...etc., They used different tests proposed by the efficiency literature in order to test the weak form of informational efficiency of the Moroccan stock market. These are normality tests, runs test, stationarity test, unit root test, autocorrelation test and the variance ratio test. In terms of analyses, the results accept the hypothesis of informational inefficiency of the Moroccan stock market. Thus, the Moroccan stock market is not efficient despite the successive events which have impacted the evolution of the stock market. These results are identical to those of Derrabi (1998), El Bouhadi & El M'Kaddem (2003), Bakir (2002), El Khattab & Chourouk (2014), Chiny & Mir (2015), Hassainate & Bachisse (2016) and Faiteh & Najab (2020) who confirmed the inefficiency of the Moroccan stock market in its weak form.

Chiny & Mir (2015) worked on efficiency tests of the Moroccan financial market. The objective of their work was to test the weak form of informational efficiency of the Moroccan financial market through four main indices of the Casablanca Stock Exchange (MASI, banking sector, insurance sector and the real estate sector). In order to increase the relevance of their results, they diversified the tests by considering 4 tests most commonly used in empirical studies of financial markets, these are the autocorrelation test, unit root test, variance ratio and runs test.

It thus appears that all these tests reject the hypothesis of efficiency of the Moroccan financial market and the causes of this inefficiency are multiple. First of all, there is the youth of the Moroccan market, the level of capitalization which remains low as well as the volume of transactions which remains quite limited. Several more complex sources of inefficiency can be raised, such as El Khattab &

Chourouk (2014).

Similarly, for Fettouma & Loummo (2020), the empirical study on the modeling of the MASI time series during the period 2015-2019, reveals that the model studied does not respond to a random walk, which explains the rejection of the weak form of efficiency for the Casablanca stock market, and therefore, the systematic rejection of the other semi-strong and strong forms.

3.1. Efficiency Tests in Developed Markets

Well before the appearance of the concept of efficiency, the movements of stock prices aroused interest since the scientific community (Bachelier, 1900; Cowles, 1933; Kendall & Hill, 1953) became interested in the movements of stock prices and confirmed that the profitability series on the American market evolved randomly and unpredictably. The first empirical tests on the efficiency of markets were carried out on developed markets, and were generally concluded in favor of the low efficiency of these markets, taking into account the low autocorrelation of their profitability, and their low costs of transactions, work in this direction has been numerous, we can cite as a reference those carried out by (Kendall & Hill, 1953; Cootner, 1964; Fama, 1965) which focused on the stock markets in Australia, Europe and the United States, and which showed that prices in these markets followed a random walk (Malkiel, 2003; Jensen, 1978; French & Roll, 1986), have confirmed the efficiency of the stock, bond, options and commodity markets in these countries.

3.2. Efficiency Tests in Emerging and African Markets

Several authors have been interested in the question of market efficiency in emerging countries in order to understand the influence of the economic and political environment of these countries on the efficiency of their market. We can cite, among others, Harvey (1995), Urrutia (1995), Bekaert & Harvey (2002), who showed that the markets of emerging countries are less efficient than those of developed countries. It is easy to notice in these countries that emerging market returns have higher serial correlations than those observed in developed markets due to the low frequency of transactions, the slowness of adjustments and the legal environment. Technical analysis in emerging markets has predictive power that pays off. One can also note the disparity of the results according to the countries, the periods of analysis (daily, weekly, monthly or annual), samples and analysis and testing techniques. These disparities maintain the debate and controversy around this hypothesis of market efficiencies which is still one of the most important subjects of economic and financial theory.

3.3. Some studies on African Markets

African markets have been the subject of certain studies, particularly the work of Mlambo & Biekpe (2007), Batuo Enowbi et al. (2009), Al-Khazali et al. (2007) and Abdmoulah (2009), Dib, Dahhou, & Kharbouch (2021) to name but a few.

Indeed, Mlambo & Biekpe (2007), studied the hypothesis of efficiency in the weak sense of ten African stock markets using daily data for periods ranging from January 1997 to May 2002. The markets studied were that of Egypt, Kenya, Zimbabwe, Morocco, Mauritius, Tunisia, Ghana, Namibia, Botswana and Côte d'Ivoire. With the exception of Namibia, Kenya and Zimbabwe, for all other stock markets (including Morocco), the random walk hypothesis, and therefore efficiency, is rejected. Batuo Enowbi et al. (2009), also examined the weak form of the efficiency of four African stock markets namely Egypt, Morocco, South Africa and Tunisia, using daily data from January 4, 2000 to March 26, 2009. The results indicate that, with the exception of the South African stock market, the efficiency hypothesis is rejected. Al-Khazali et al. (2007), studied the behavior of the main indices of eight stock markets in the MENA region (Bahrain, Jordan, Kuwait, Morocco, Oman, Saudi Arabia, Tunisia and Egypt). They used weekly data from October 1994 to December 2003. They found that none of these markets responded positively to the random walk hypothesis. They attribute their results to the low number of trading operations and also to the youth of these markets. However, when the index returns were corrected (statistical bias), they could no longer reject the weak efficiency hypothesis for any of these markets.

Abdmoulah (2009), studied the financial markets of 11 Arab countries, Saudi Arabia, Kuwait, Tunisia, Dubai, Egypt, Qatar, Jordan, Abu Dhabi, Bahrain, Morocco and Oman, in using daily data from their main indices. All the Arab stock exchanges studied were inefficient in the weak sense and express a high sensitivity to past shocks. Omran & Farrar (2006) examined the markets of Egypt, Jordan, Morocco, Turkey and Israel using major stock indices. They used weekly data from January 1996 to April 2000. The results rejected the random walk hypothesis for all markets, except the stock market index of Israel (TA100), which seems to follow a random walk.

Dib, Dahhou, & Kharbouch (2021) in their work used empirical random walk tests to verify the existence of the weak form of informational efficiency in 11 African financial markets. To test the long-term behavior of stock prices on African markets, they carried out 4 tests, namely: the autocorrelation, Anderson Darling, unit root and Runs tests on the daily returns of the main stock indices of 11 African countries over the period from 04/03/2024 to 18/12/2020. On the basis of the three tests of autocorrelation, unit root (Dickey-Fuller) and normality (Anderson-Darling), they concluded that the African stock markets under study are inefficient in the weak sense. However, with the fourth test, that of the Runs, they discovered a difference compared to the other tests. The results admit the presence of random walks in 4 countries, namely Morocco, South Africa, Zambia and Tanzania, which makes it possible to validate the presence of the weak form of informational efficiency on these stock markets. We thus note that out of all the previous studies, few have been interested in the informational efficiency of the BRVM, and this is what we are trying to correct through this study.

4. Methodology

Tests of the weak form of the informational efficiency of financial markets are often associated with those of the random walk. By definition of the weak form, the observed price fully reflects: On the one hand, the consequences of past events (the history of the price of the asset in question and that of the other variables affecting the price of this asset); and on the other hand, anticipations of future events. It follows that price variations can only be due to the appearance of unanticipated events. Successive price variations are therefore random. The observed price then fluctuates randomly around the fundamental value. It therefore follows a random walk.

The price series Pt follows a random walk if it satisfies the following equation: $P_t = P_{t-1} + \varepsilon_t$ or in logarithmic form, we have $\ln(P_t) = \ln(P_{t-1}) + \varepsilon$ with P_t the price of l 'asset in period *t*, P_{t-1} the price of the asset in period $t-1$, ε_t the residual of the model responding to a white noise process with zero mean, constant variance and absence of autocorrelation ($E(\varepsilon_t) = 0$, $V(\varepsilon_t) = \sigma^2$ and $\operatorname{cov}(\varepsilon_{t-1}, \varepsilon_t) = 0$). According to Van Hoang (2009), the principles of testing the weak form of informational efficiency can be summarized in two points: prices that follow a random walk and successive variations of prices responding to a white noise process.

As part of writing a research work like this, several tests were carried out including direct tests, auto-correlation tests, unit root (or non-stationarity) tests for ARIMA processes (p,q) , variance ratio tests. According to Chiny & Mir (2015), several tests are used as part of the verification of the random walk of financial markets.

Indeed, direct tests are based on the intuitive idea that it is possible to design active strategies based on the graphical exploitation of price movements (chartism) that can beat the market. These active strategies are therefore supposed to provide greater gains than those obtained using a passive (naive) strategy consisting of buying the entire portfolio at a given moment and selling it entirely at the end of the period of the test (by and hold strategy). Fama & Blume (1966), carried out this type of test on the American market in using an active method of filters, consisting of buying when the price increases by X% or more and selling it when the price drops by more than X%. As for the autocorrelation tests, they reflect an intuitive way of verifying the random walk by testing whether the serial correlations ρk are zero.

$$\hat{\rho}_k = \frac{\sum_{t=k+1}^{T}\left(R_t - \bar{R}\right)\left(R_{t-k} - \bar{R}\right)}{\sum_{t=1}^{T}\left(R_t - \bar{R}\right)^2};\ 0 \le k \le T-1,\ \bar{R} = \frac{1}{T}\sum_{t=k+1}^{T}\left(R_t\right)$$

For Abadié & Travers (1981), the analysis of one-dimensional time series by the method of Box and Jenkins traditionally involves three stages: identification of the form of model best suited to the series studied; estimation of model parameters; validation. For these authors, at the validation stage, the residuals constitute a bleached noise and that the correlogram once again becomes a simple and useful tool, supplemented by the chi 2 test.

4.1. Box and Jenkins Method

According to Mecheri (2016), the methodology of Box and Jenkins makes it possible to determine the adequate ARIMA model for modeling a time series. It is therefore a question of building a model that reproduces the behavior of a time series as well as possible. This methodology suggests four steps: model identification, estimation, validation and prediction. A bit like Abadié & Travers (1981), Mecheri (2016) recognizes three stages in the application of the Box and Jenkins method, except that the latter also adds the stage of model forecasting. The different stages are presented as follows.

Model identification

The identification consists in specializing the three parameters p; d; q of the ARIMA model (p,d,q). The stationarity of the model is first tested by graphical study, correlogram and augmented dickey fuller test. If the series is not stationary, it should be transformed into stationary. The order of integration "d" is the number of times the initial series has been differentiated to obtain stationarity. The autocorrelations and the partial autocorrelations make it possible to estimate the orders p and q for the AR and MA models:

1- the partial autocorrelations are null beyond the order p.

2- the autocorrelations are null beyond the order q.

Simple Dickey Fuller test: Dickey and Fuller are the first to provide a set of formal statistical tools to detect the presence of a unit root in a first-order autoregressive process, this test allows to test the hypothesis.

H0: The model has a unit root;

H1: the model has no unit root. This test is grouped into 4 cases:

$y_t = \rho y_{t-1} + \epsilon_t$ H$_0$: $\rho = 1$

$y_t = \alpha + \rho y_{t-1} + \epsilon_t$ H$_0$: $\alpha = 0$ et $\rho = 1$

$y_t = \alpha + \rho y_{t-1} + \epsilon_t$ H$_0$: $\alpha \neq 0$ et $\rho = 1$

$y_t = \alpha + \beta t + \rho y_{t-1} + \epsilon_t$ H$_0$: $\alpha \neq 0$ et $\rho = 1$

Augmented Dickey Fuller test: Dickey and Fuller in 1981 then extend this test procedure to autoregressive processes of order p, it is then the ADF Augmented Dickey-Fuller tests.

This test tests:

H0: The model has a unit root;

H1: the model has no unit root. These tests can be grouped into 4 cases:

$y_t = \rho y_{t-1} + \sum_{i=1}^{p} \alpha_i y_{t-i} + \epsilon_t$ H$_0$: $\rho = 1$

$y_t = \alpha + \rho y_{t-1} + \sum_{i=1}^{p} \alpha_i y_{t-i} + \epsilon_t$ H$_0$: $\alpha = 0$ et $\rho = 1$

$y_t = \alpha + \rho y_{t-1} + \sum_{i=1}^{p} \alpha_i y_{t-i} + \epsilon_t$ H$_0$: $\alpha \neq 0$ et $\rho = 1$

$y_t = \alpha + \beta t + \rho y_{t-1} + \sum_{i=1}^{p} \alpha_i y_{t-i} + \epsilon_t$ H$_0$: $\alpha = 0, \beta = 0$ et $\rho = 1$

4.2. Estimation of the Parameters of an ARIMA Model

The estimation of the parameters of an ARIMA model (p, d, q) when p, d, q are assumed to be known can be achieved by different methods in the time domain, and among these methods we have:

1- Maximum likelihood.

2- In the case $q = 0$, we use Yule Walker's equations.

Several computer software programs implement these methods for estimating an ARIMA model (Eviews, SPSS, etc.), in particular maximum likelihood methods.

4.2.1. Model Selection Criteria

Often it is not easy to determine a single model. The model that is finally chosen is the one that minimizes one of the criteria from T observations.

Standard criteria

1- Mean Absolute Error: $\text{MAE} = \frac{1}{T}\sum_{t=1}^{T}|\varepsilon_t|$

2- Mean Squared Error: $\text{MSE} = \frac{1}{T}\sum_{t=1}^{T}\varepsilon_t^2$

3- Root Mean Square Error: $\text{MRSE} = \sqrt{\frac{1}{T}\sum_{t=1}^{T}\varepsilon_t^2}$

4- Mean Absolute Percent Error: $\text{MAPE} = \frac{100}{T}\sum_{t=1}^{T}\left|\frac{\varepsilon_t}{X_t}\right|$

The lower the value of these criteria, the closer the estimated model is to the observations.

Information criterion

1- Akaike (1969): $\text{AIC}(p;q) = \log\left(\hat{\sigma}_{\varepsilon}^2\right) + 2\frac{p+q}{T}$

2- Schwartz (1977): $\text{BIC}(p;q) = \log\left(\hat{\sigma}_{\varepsilon}^2\right) + (p+q)\frac{\log T}{T}$

3- Hannan & Quinn (1979): $\varphi(p,q) = \log\left(\hat{\sigma}_{\varepsilon}^2\right) + (p+q)c\frac{\log T}{T}$ avec $c > 2$

4.2.2. Model Validation

It is a question here of the tests of significance of the parameters and the analysis on the estimated residuals

Significance of parameters

The coefficients of the model must be significantly different from zero, to do this we use the classic student test.

We reject the null hypothesis Ho: $\theta_j = 0$, si $|tc| \succ \left|T_{T-Q}^{\alpha}\right|$ où $|tc| = \left|\frac{\grave{\theta}}{\dot{\sigma}_{\theta}}\right|$.

Note: If one or more model parameters are shown to be not significantly different from 0, the model is re-estimated.

4.2.3. Validation of the Residual White Noise Hypothesis

For the validity of the models, it is necessary to check that the estimated residuals follow a white noise.

White noise test

This test is based on the absence of the autocorrelation function of white noise.

There are several tests for the absence of autocorrelation: these are parametric and non-parametric tests, in particular the parametric Box Pierce test.

Box Pierce Statistics:

The Box Pierce test identifies white noise processes. This statistic allows us to test $\text{cov}(\epsilon_t, \epsilon_{t-h}) = 0$, for all h ($\rho(h) = 0$, $\forall h$). This test is written:

H0: $\rho(1) = \rho(2) = \cdots = \rho(h) = 0$

H1: There exists i such that $\rho(i) \neq 0$, to carry out this test, we use the statistics of Box and Pierce Q given by $Q = T\sum_{k=1}^{h} \rho_{(k)}^2$; Oˇ h is the number of lags, T is the number of observations and $\rho(k)$ the empirical autocorrelation. Asymptotically, Q follows a $\aleph^2$ with h degrees of freedom. We reject the hypothesis of white noise at threshold h if Q is greater than the quantile of order (1-α) of the law of $\aleph^2$ at h degree of freedom.

Normality tests:

Using the Bera and Jarque test, based on skewness (asymmetry coefficient of the distribution) and kurtosis (flattening of the tails). By noting μk the moment of order k of the distribution. $\mu_k = E\left(\left(X - E(X)\right)^k\right)$

We call skewness the coefficient $S = \mu_3 / \mu_2^{3/2}$ and Kurtosis $K = \mu_4 / \mu_2^2$

The Bera and Jarque test is based on the fact that, if the distribution follows a normal law. So the quantity BJ = $\frac{T}{6}S^2 + \frac{T}{24}(K-3)^2$ asymptotically follows a law of $\aleph^2$ at 2 degrees of freedom. If BJ ≥ $\aleph_{1-\alpha^2}^2$, we reject the hypothesis H0 of normality of the residues of the threshold α.

Prediction

This is the last step of the Box and Jenkins methodology.

Given a stationary series, observed between 1 and T, we seek to forecast at horizon h, and therefore to forecast $X_T+1, \ldots, X_T+h$.

This involves calculating the optimal forecasts of the estimated ARIMA model, namely $X_T(h)$ the forecast of X_{T+h} knowing the set of information available in T, denoted $\dot{X}_{T+h} = E(X_{T+h} / X_T, X_{T-1}, \cdots, X_1)$.

4.2.4. Stock Indices

The indices serve as a reference to measuring the general performance of a market or a sector and even seen as an economic indicator of a country. With modern finance, it has quickly become an essential instrument of portfolio management. According to Benga (2015), it is representative of the market thanks to CAPM, which identifies it as a general market factor that influences the price of all stocks. For the latter, indices constitute market barometers, index management tools and, in other measures, supports for futures and options. Since January 2, 2023, there have therefore been indices such as the BRVM 30 replacing the BRVM10, the BRVM prestige and the BRVM composite following notice no. 259-2022/BRVM/DG of December 30, 2022. The first includes the thirty most traded stocks over a quarter. It is more diversified and takes into account the evolution of market liquidity in recent years. The second, prestige, includes all the values listed in the prestige compartment. It is reviewed on an annual basis, according to the eligibility criteria for companies in the prestige compartment. It makes it possible to follow the evolution of the key values of the market. As for the last, it brings together all the companies listed on the BRVM as it already exists. The indices are automatically generated by the BRVM trading system and after each trading session.

The notion of liquidity occupying a fundamental place in the selection of the stocks composing the BRVM30 index above all, it is necessary that:

- the average amount of transactions during the three months preceding the quarterly review must not be less than the median of the average daily amounts of transactions for all securities;

- the frequency of transactions must always be greater than 50% and the security must be traded at least every other time, during a period of three months.

It should be remembered that the formulation and selection criteria of these indices are inspired by the main stock market indices of the world, more particularly the FCG index, of the International Financial Corporation, a company affiliated to the World Bank.

The indices are automatically generated by the BRVM trading system and after each trading session. It should be remembered that the BRVM30 is revised four times a year (the first Monday of January, April, July and October) and the BRVM Composite after each new company listing, so as to be adapted to changes in the regional financial market.

The index formula takes into account market capitalization, trading volume per session and trading frequency. In addition, only ordinary shares are used for the calculation of the indices. From an index, we retain the following formula:

$$\text{Hint} = \frac{1000 \times \text{sum of instantaneous market caps}}{\text{Base market cap}}$$

5. Data Analysis

In this part of data analysis, it is first a question of the presentation of the activities of the BRVM, before addressing the analysis of efficiency.

5.1. The Activities of the BRVM

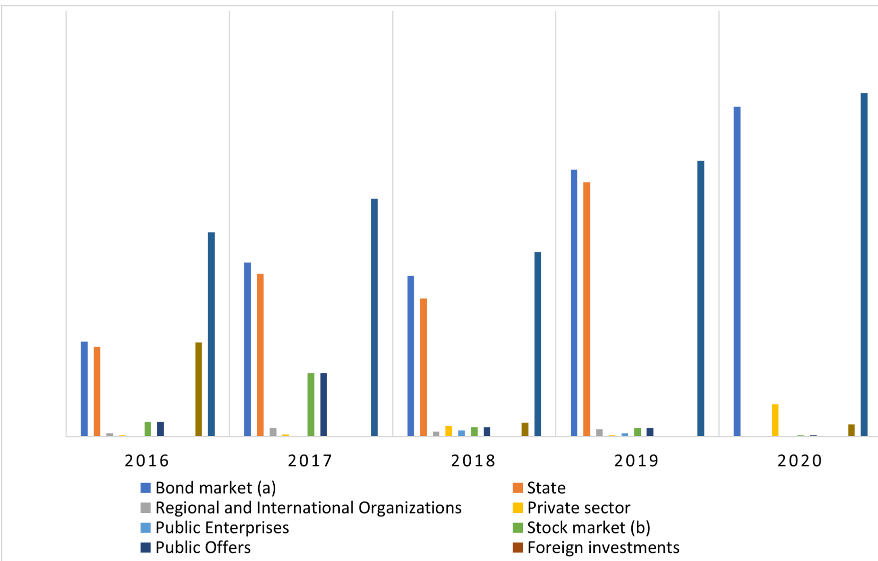
Since its creation in 1998, the regional financial market of the Union has made it possible to mobilize, as of December 31, 2020, a total amount of 12,234 billion FCFA, of which more than 887 billion FCFA through five (5) bond issues. Sukuk initiated by Senegal, Ivory Coast, Togo and Mali. As of December 31, 2020, the market has forty-six (46) listed companies and eighty-three (83) bond lines, sixty (60) of which are issued by the States of the Union, in particular the State of Côte d'Ivoire. with thirty-nine (39) lines. Government bonds remain predominant in the raising of resources on the regional financial market at more than 86%. Details of listed companies and bond lines can be found in the appendix.

The main transactions carried out on the regional financial market are carried out on the primary (AMF-UEMOA) and secondary (BRVM) markets. At the end of the last five years of activity, the financial market has recorded contrasting performances overall. Regarding the primary market, over the period from 2016 to 2020, the Regional Council authorized a total of 108 financial operations for a total mobilization of more than 7.319 billion FCFA. The following Table 2 brings together all the main operations carried out from 2016 to 2020 on the BRVM primary market.

Table 2. Evolution of fundraising from 2016 to 2020 (in billions of FCFA).

Resources	2016	2017	2018	2019	2020	Total
Bond market (a)	557,923	1,023,028	944,974	1,568,496	1,937,040	6,031,461
State	527,249	956,852	811,974	1,493,496	1,745,040	
Regional and International Organizations	21,374	51,126	30,200	45,000	-	
Private sector	9300	15,050	63,750	10,000	192,000	
Public Enterprises	_	0	38,250	20,000	_	
Stock market (b)	87,673	373,567	56,920	51,718	8605	578,483
Public Offers	87,547	373,269	56,920	51,134	8199	
Foreign investments	126	297	0	583	406	
Other capital transactions	-	-	0	0	_	
Collective savings (c)	554,448	-	83,550	0	72,800	710,798
Total (a) + (b) + (c)	1,200,043	1,396,595	1,084,644	1,620,214	2,018,445	7,319,941

Source: BRVM, 2022.



Source: Ourselves.

Figure 1. Distribution by category of actors of fundraising on the market from 2016 to 2020.

Table 2 presents the evolution of resources over the period from 2016 to 2020 on the BRVM. Indeed, unlike the bond market, whose trend is upward from 2018, the equity market as well as collective savings show a varied trend over the entire period from 2016 to 2020. **Figure 1** above presents more clearly the trend of fund-raising according to the different players on the market.

The secondary market remained marked in 2020 by the continued decline in the prices of listed companies that began in 2016 and which led to a general decline in indices and market capitalization. It should be noted that during 2020, the BRVM Composite index fell by 8.71%, in a context of Covid-19 with the post-ponement to the end of the year of the dates of the General Meetings of several listed companies.

However, at the end of December 2020, the total market capitalization increased by 16.11% to stand at 10,419.08 billion FCFA against 8,973.25 billion FCFA as of December 31, 2019. In detail, the market capitalization of the equity market stood at 4,367.68 billion FCFA as of December 31, 2020, down 7.87% compared to the end of December 2019. On the other hand, the capitalization of the bond market recorded an increase of 42.97% to stand at 6,051.41 billion FCFA.

This bond market performance is due to the admission of twenty-eight (28) new bond lines to the BRVM listing. The drop recorded in the equity market is, for its part, related to the general drop in prices over the year 2020, reflected in the contraction of the BRVM Composite index.

The BRVM Composite index fell by 8.71%, in particular due to the sharp drop in the Public Services Sector where the SONATEL SN share representing 30.91% of the capitalization of the equity market fell by 20.56%, registering the largest drop in the sector. As for the BRVM 30 index, it stood at 130.88 points, down 12.23% compared to its level at the end of December 2019. Over the whole of 2020, sixteen (16) listed companies recorded an increase in their prices. The three (3) largest increases are SICABLE CI (60.32%), CROWN SIEM CI (53.85%) and SMB CI (23.20%). On the other hand, the most remarkable decreases concerned UNIWAX CI (−42.03%), VIVO ENERGY CI (−25.00%) and SONATEL SN (−20.56%).

During 2020, the volume of transactions (all markets combined) stood at 82.35 million shares traded against 82.90 million in 2019, i.e. a slight decrease of 0.57%. It should be mentioned that the largest volume of transactions took place during the month of December 2020 which recorded 26.04 million securities traded.

The value of transactions, for its part, recorded an increase of 80.53% to 246.04 billion FCFA, compared to its level of 2019 when it stood at 136.29 billion FCFA. The month of December 2020 recorded the highest value of transactions with 73.22 billion FCFA, including 27.14 billion FCFA for the trading session of December 10, 2020. On average, 6.86 million securities for a value of 20.50 billion FCFA were traded monthly during 2020. The following **Table 3** shows the evolution of performance indicators from 2016 to 2020 on the BRVM.

This table shows a variation in performance indicators from one year to the next, illustrated by the following **Figure 2**. It is preceded by **Table 4** which illustrates the describable statistic of the composite BRVM.

Table 3. Performance indicators from 2016 to 2020.

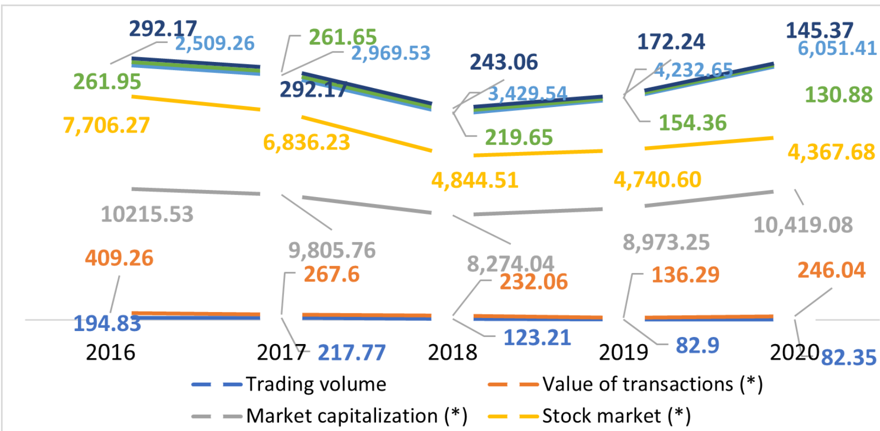
Indicators	2016	2017	2018	2019	2020
Trading volume	194.83	217.77	123.21	82.90	82.35
Value of transactions (*)	409.26	267.60	232.06	136.29	246.04
Market capitalization (*)	10215.53	9805.76	8274.04	8973.25	10419.08
Stock market (*)	7706.27	6836.23	4844.51	4740.60	4367.68
Bond market (*)	2509.26	2969.53	3429.54	4232.65	6051.41
BRVM 30	261.95	261.65	219.65	154.36	130.88
BRVM Composite	292.17	292.17	243.06	172.24	145.37
Number of listed companies	43	45	45	46	46
Number of bond lines	41	37	44	58	83

Source: BRVM (*) in billions of CFA francs.

Table 4. Descriptive statistics of the BRVM Composite index (RJIC).

average	minimum	maximum	Sd	number observation
229.002	145.37	292.17	4598.5639	05

Source: Ourselves.



Source: Ourselves from BRVM data (*) in billions of CFA francs.

Figure 2. Evolution of the main performance indicators.

We thus see that the market capitalization (*) is graduated on the secondary axis with an amplitude no less significant. From this Figure 2, it appears that the performance indicators show a varied evolution over the entire period of the study.

5.2. Analysis of the Efficiency of the BRVM

She is more interested in the empirical study of the efficiency of the stock market. It focuses much more on the daily returns of the BRVM Composite index (RJIC) and therefore provides a measure of the evolution of all the values of the rating.

The study period extends over approximately 5 years (from January 4, 2016 to June 30, 2022). The choice of such a period improves the robustness of the efficiency test because it takes into account 1618 observations.

The efficiency test consists of using the Box and Jenkins method, which is based on the ARIMA process, to find a model that best reproduces the behavior of the time series. Two results are possible:

- If the model corresponds to a random walk, that is to say: ***RJICt = RJICt-1 + Ɛt,*** where the disturbance Ɛ*t*, is white noise, then informational efficiency in its weak form will be confirmed for the BRVM.
- If the model found does not correspond to a random walk, then the informational efficiency in its weak form will not be verifiable for the BRVM.

However, a possible rejection of the hypothesis of efficiency in the weak sense for this market, will imply a systematic rejection of the semi-strong form which will no longer have reasons to be verified. Our model therefore uses the Box and Jenkins procedure, which has three essential steps including: identification, estimation and diagnosis.

5.3. The Box and Jenkins Procedure

It includes the following different steps

✓ **1st step: identification**

We first proceed to the study of the stationarity of the RJICt series by applying the strategy of augmented Dickey-Luller (ADL) tests, as presented by Bourbonnais.

The optimal number of lags is 2. The latter minimizes the information criteria of Akaike and Schwartz. Table 5 below, prepared using the "Eviews9" econometric software, summarizes all the results obtained:

Table 5. Study of stationarity through augmented Bickey-Fuller tests (ADF).

Null hypothesis	ADF cal.	ADF thé.	Conclusion
Model 6: Existence of a unit root	0.881197	−3.412723	No stationary
Model 5: Existence of a unit root	−1.424322	−2.863206	No stationary
Model 4: Existence of a unit root	−1.182494	−1.941029	No stationary

Source : Result obtained under Eviews 9.

With ADF cal.: ADF statistics calculated; ADF tea.: theoretical ADF statistics. They are useful in the stationarity test with ADF tea which gives an idea of the critical value of ADF.

From the above Table 5, it can be concluded that the RJICt series is a nonstationary process.

The identification of an ARIMA model (p, d, q) likely to explain the behavior of our RJICt series presupposes the stationarization of the latter.

In order to make our series stationary, we will differentiate it. The following transformation is therefore applied: ΔRJICt = RJICt − RJICt-1.

The following table presents the results of the stationarity test on the differentiated series.

ADF cal.	ADF tea.	Conclusion
−23.66348	−1.941049	Stationary

Source : Eviews 9.

With ADF cal.: ADF statistics calculated ADF tea.: theoretical ADF statistics.

The ADF test confirms the stationarity of the ΔRJICt series. Indeed, for a number of lag equal to 2, the stationarity hypothesis is accepted for model 4 because the calculated statistic of the ADF test (−23.66348) is lower than the critical value (−1.941049). Thus, the series ΔRJICt is a stationary process and the order of integration of the series is RJICt.

The analysis of the correlogram of the series allows us to identify the other parameters of the ARIMA model. Indeed, the correlogram shown in Table 6 allows us to visualize the tables of the autocorrelation function and partial autocorrelation.

Table 6. Correlogram of ARJICt series.

Autocorrelation	Partial Correlation	AC	PAC	Q-Stat	Prob
il i	il i	1 −0.01...	−0.01...	0.1506	0.698
• [i	1	2 0.062	0.062	6.1257	0.047
i	t	3 0.039	0.040	8.4578	0.037
▪ ▪	i ▪	4 0.000	−0.00...	8.4581	0.076
i P	□	5 0.136	0.132	37.107	0.000
fl ▪	C i	6 −0.04...	−0.04...	40.278	0.000
1 1	i i	7 0.010	−0.00...	40.435	0.000
i ▪	i i	8 0.015	0.011	40.799	0.000
1] 1	il	9 −0.04...	−0.04...	44.296	0.000
i □	▪ *1*	1... 0.134	0.118	72.361	0.000
1 ▪	i| i	1... −0.03...	−0.02...	74.572	0.000
I i	i	1... −0.02...	−0.04...	75.673	0.000
▪ i	I 1	[illegible]	0.009	76.059	0.000
il i	i i	1... −0.02...	−0.00...	76.768	0.000
▪ p		1... 0.088	0.056	88.949	0.000
i ▪	! 1	1... −0.00...	0.012	89.049	0.000

Continued

i ■	i i	1... −0.01...	−0.01...	89.388	0.000
i i	1 1	1... 0.007	−0.00...	89.474	0.000
il i	■ i	1... −0.01...	0.003	89.746	0.000
i P	■ *)*	2... 0,078	0.046	99.257	0.000
i ■	i i	2... −0.00...	0.006	99.296	0.000
i i	>	2... 0.019	0.026	99.876	0.000
i ■	i i	2... 0.011	−0.00...	100.07	0.000
i(i	i l	2... −0.00...	−0.00...	100.19	0.000
i *1*	p	2... 0.102	0.073	116.61	0.000
il ■	i	2... −0.01...	−0.01...	117.06	0.000
■)i	1	2... 0.040	0.037	119.61	0.000
i ■	i i	2... −0.01...	−0.02...	120.04	0.000
il i	il i	2... −0.01...	−0.01...	120.25	0.000
■ :	p	3... 0.086	0.052	131.91	0.000
1 ■	>1 ■	3... −0.03...	−0.02...	133.72	0.000
i ■	*i* i	3... −0.00...	−0.02...	133.78	0.000
i i	il i	3... −0.01...	−0.01...	134.32	0.000
C i	I 1	3... −0.01...	0.002	134.48	0.000
i]	■ 3	3... 0.080	0.043	144.64	0.000
i i	<| i	3... −0.04...	−0.02...	147.95	0.000

Source : Result obtained under Eviews 9.

The studied process presents several significant peaks (five peaks) at several lags of the correlogram of the autocorrelation function. This refers to the presence of a moving average process of order $q = 5$, denoted: MA (5).

The studied process also presents five significant peaks at several lags of the correlogram of the partial autocorrelation function. This refers to the presence of an autoregressive process of order $p = 5$, noted: AR (5). In order to make our series stationary, we resorted to a single differentiation. The stationarity of the series of first differences reveals the presence of an integrated process of order d = 1, denoted 1(1). From the above, it can be said that the series $\Delta RJIC_t$, combines three processes at once: an AR process (5), an I process (1) and an MA process (5). In other words, it is an ARIMA (5,1,5) model. The model therefore looks like this:

$$\Delta RJIC_t = a_1\Delta RJIC_{t-1} + a_2\Delta RJIC_{t-2} + a_3\Delta RJIC_{t-3} + a_4\Delta RJIC_{t-4} + a_5\Delta RJIC_{t-5} + a_6\mathcal{E}_{t-5} + a_7\mathcal{E}_{t-4} + a_8\mathcal{E}_{t-3} + a_9\mathcal{E}_{t-2} + a_{10}\mathcal{E}_{t-1} + \mathcal{E}_t + a_0$$

a_0 : a constant; the a_i are coefficients to be estimated; $\mathcal{E}_t$ is white noise.

✓ **2nd step: estimation of the coefficients of the ARIMA model (5,1,5)**

Table 7 below summarizes the estimation results of the model coefficients.

Table 7. Estimation of model coefficients.

Estimated coefficients	Statistics of Student	Probability associated with Student statistics	Conclusion at the critical threshold of 5%
a_1:. −0.117429* (0.059235)	−1.982417	0.0476	Significant
a_2 : −0.122301* (0.058792)	−2.080214	0.0377	Significant
a_3 : −0.117281* (0.058357)	−2.009720	0.0446	Significant
a_4: −0.119841* (0.058556)	−2.046612	0.0409	Significant
a_5: 0.861670* (0.058809)	14.65194	0.0000	Significant
a_6 0.149197* (0.067793)	2.200775	0.0279	Significant
a_7 : 0.167076* (0.067869)	2.461722	0.0139	Significant
a_8 : 0.160916* (0.066061)	2.435873	0.0150	Significant
a_9 : 0.154047* (0.066844)	2.304593	0.0213	Significant
a_{10}: −0.772977* (0.067116)	−11.51699	0.0000	Significant

Source : Result obtained under Eviews 9, with* coefficient significant at 5%.

Based on the estimation results, the final model looks like this

$$\begin{aligned}\Delta RJIC_t = &-0.117429\Delta RJIC_{t-1} - 0.122301\Delta RJIC_{t-2} - 0.117281\Delta RJIC_{t-3} \\ &- 0.119841\Delta RJIC_{t-4} + 0.861670\Delta RJIC_{t-5} + 0.149197\mathcal{E}_{t-5} \\ &+ 0.167076\mathcal{E}_{t-4} + 0.160916\mathcal{E}_{t-3} + 0.154047\mathcal{E}_{t-2} - 0.772977\mathcal{E}_{t-1} + \mathcal{E}_t\end{aligned}$$

✓ **3rd step: diagnosis**

The validation of our model is conditioned by the absence of autocorrelation of the errors, the latter must have the character of a white noise. The study of the existence or not of white noise is done through the correlogram. Table 8 below presents the correlogram of the residues of the series ΔRJICt.

Table 8. Correlogram of residuals.

Autocorrelation	Partial Correlation	AC	PAC	Q-Stat	Prob
il ▪	4 i	1 −0.02...	−0.02...	0.6333	
i &	1	2 0.035	0.035	2.5326	
i i	i i	3 0.004	0.005	2.5567	
i 1	i i	4 −0.00...	−0.00...	2.5630	
I I	i i	5 0.019	0.019	3.1425	

Continued

1 i	1 i	6 −0.03...	−0.03...	4.8319	
i i	4 i	7 −0.00...	−0.01...	4.9128	
i i	i i	8 −0.00...	0.001	4.9153	
11 i	i! 1	9 −0.03...	−0.03...	6.9838	
i i	li	T... 0.036	0.035	9.0355	
4 ▪	i i	1... −0.01...	−0.00...	9.2144	0.002
0 >	a i	1... −0.03...	−0,03...	11.091	0.004
1 1	l I	1... 0.006	0.004	11.141	0.011
i i	i i	1... 0.006	0.010	11.194	0.024
i i	l 1	1... −0.00...	−0.00...	11.208	0.047
▪ b	I1	1... 0.027	0.029	12.367	0.054
4 i	i i	1... −0.02...	−0.01...	12.985	0.072
i i	▪ i	1... 0.004	−0.00...	13.006	0.112
i ▪	i i	[illegible]	0.022	13.537	0.140
; >	▪i ▪	2... −0.01...	−0.01...	14.015	0.172
i li	)i	2... 0.031	0.026	15.476	0.162
i ▪	li	2... 0.018	0.026	15.989	0.192
▪ i	i I	2... 0.005	0.002	16.028	0.248
▪ i	l 1	2... 0.022	0.018	16.804	0.267
i i	▪ i	2... 0.014	0.019	17.114	0.312
i i	i i	2... 0.015	0.009	17.451	0.357
i 3	▪ i	2... 0.042	0.045	20.293	0.260
(▪	4 i	2... −0.02...	−0.02...	21.316	0.264
i i	i i	2... 0.020	0.011	21.916	0.288
i i	▪ ▪	3... −0.00...	0.007	21.916	0.345
i ▪	1 i	3... −0.00...	−0.00...	21.970	0.401
▪ i	▪ i	3... −0.00...	−0.00...	21.981	0.461
▪i ▪	il ▪	3... −0.02...	−0.01...	22.892	0.467
i i	i ▪	3... 0.024	0.023	23.830	0.471
l ▪	i i	3... −0.00...	−0.00...	23.859	0.528
i ▪	ij i	3... −0.02...	−0.01...	24.658	0.538

Source : Eviews 9.

The graph of the autocorrelation function like that of the partial autocorrelation function does not contain significant peaks. Therefore, at the level of the two functions, there are no autocorrelations significantly different from 0. Moreover Q (36) = 24.658 and prob = 0.538 > 0.05. Consequently, the residuals Ɛt form a white noise, which proves the validity of our model. The model specified above does not correspond to a random walk. This implies the rejection of the weak form of informational efficiency for the BRVM.

5.4. Run Test

The Runs test, also called Geary's test (1970), is a nonparametric test I which the sequence numbers of positive and negative returns are tabulated and compared to the sampling distribution under the random walk assumption. According to Dib et al. (2021), the Runs test is a powerful test because it is independent of the normality and constant variance of the data, and ignores the distribution properties. It can test and study the serial dependence of (random) stock price changes. The assumptions of this test are as follows:

H0 = stock market fluctuations follow a random walk;

H1 = stock market fluctuations do not follow a random walk.

Table 9 below presents the results of the Runs test.

Table 9. Runs test result.

Indicators	RJIC
Test value	−0.56082521
Observations < test value	809
Observations >= test value	809
Total number of observations	1618
Number of suites	7
Z	−39.938
sig. asymptotic (bilateral)	0.000

Source: Result obtained under SPSS 25.

From the analysis of the table, it appears that the stock market index is not efficient in the weak sense. Indeed, the probability is greater than the threshold of 0.05. Therefore, we can conclude that the fluctuations do not follow a random walk and the stock market index is inefficient in the weak sense.

The two different tests carried out to verify the hypothesis of a random walk give the same results. That of the rejection of the random walk hypothesis. The other two forms (semi-strong and strong) are therefore systematically rejected and, consequently, it is no longer interesting to test them.

In conclusion, to test the hypothesis of informational efficiency, there are several tests or methods. One of these methods is the verification of the random walk hypothesis. Thus, the hypothesis of informational efficiency will be accepted if the series obeys a random walk. It is for this reason that we tested the random walk hypothesis through the Box and Jenkins procedure. At the end of this three-step procedure: identification, estimation and diagnosis, it appears that our series is an ARIMA model (5,1,5).

This means that the series does not follow a random walk. The run test is also adopted to confirm or invalidate the random walk hypothesis for our case. He rejects the hypothesis. Thus, the stock market is inefficient. We therefore retain that the factors affecting the informational quality of the regional stock market and constituting the sources of inefficiency of the regional stock market are of various orders. We can cite the supervisory authorities. Indeed, the efficiency of the control bodies is a key element for strengthening market transparency. Within the framework of the BRVM, the independence of the Central Depository/Settlement Bank (DC/BR) vis-à-vis the regional council is one of the factors of inefficiency of the BRVM. We also note the channels for disseminating information and their influence on stock market investors. The Central Depository/Settlement Bank (DC/BR) is the body responsible for disseminating stock market information. This information is disseminated through brokerage companies. The latter monopolize the formulation of sell or buy recommendations through the issuance of research notes targeting the different values of the rating. These recommendations are often driven by company profitability policies and lead to inefficiency in the market.

6. Conclusion

The efficiency of a financial market depends on its ability to make information available in real time to all players in the system. Indeed, the monopolistic access of certain individuals or investors to information leads to the realization of abnormal profits. Thus, this work aims to test the hypothesis of efficiency of the regional financial market: the BRVM. To achieve this, we adopted a methodology based on the Box and Jenkins procedure to test the random walk hypothesis on the series of daily returns of the BRVM Composite index from January 2016 to June 2022 (1618 sightings). The results obtained following our analysis reject the random walk hypothesis. Consequently, stock prices are inefficient in the regional financial market: the BRVM. The Runs test was also used for this purpose and confirms the hypothesis of market inefficiency. Market inefficiency is linked to the organizational structure of the BRVM. The informational inefficiency of the BRVM financial market is tested in the weak sense. Our results confirmed those of Mouallim & Chraibi (2020), Dib, Dahhou, & Kharbouch (2021) on the inefficiency in the weak sense of the different Moroccan markets. It is the same as those of Van Hoang (2009), who focus on the informational inefficiency of the weak form of the gold markets in Paris and London over the period from 1948 to 2008. They also agree with those of Derrabi (1998), El Bouhadi & El M'Kaddem (2003), Bakir (2002), El Khattab & Moudine (2014), Chiny & Mir (2015), Hassainate & Bachisse (2016) and Faiteh & Najab (2020) who confirmed the inefficiency of the Moroccan stock market in its weak form. At the end of our analysis, we find ourselves in the conclusion of Chuard (2021), which states that, although the theory of the efficiency of financial markets is one of the central concepts of modern financial theory, the latter is very controversial, and is still subject to scientific debate between the different currents. For the interest we bring to the subject, our future research will focus on the analysis of events and the dependence of stock market returns over time, such as Bacmann, Dubois, & Isakov (2001).

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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