# TESTING THE WEAK FORM OF EFFICIENT MARKET HYPOTHESIS: EMPIRICAL EVIDENCE IN THE CONTEXT OF THE COVID-19 PANDEMIC

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**Abstract:** *The COVID-19 outbreak caused several concerns all over the world. On January 30, 2020, the World Health Organization (WHO) declared it a global health emergency. This outbreak leads to a drastic change in people's lifestyles, causing lots of job losses all over the world and threaten the livelihood of millions of people since the firms closed to avoid virus propagation. In general, all economic activities were interrupted, and the stock markets had significant breaks. Due to these events, this essay pretends to analyse the efficiency, in its weak form, in the stock market indexes of France (CAC40), China (SSEC), South Korea (KOSPI), Germany (DAX 30), Italy (FTSE MID), Portugal (PSI 20), and Spain (IBEX 35), in the period of December 31, 2019, to August 10, 2020. To accomplish this research, different approaches were taken to analyse whether: (i) the countries affected by the global pandemic (COVID-19) caused (in) efficiency in their stock markets? The results suggest that the hypothesis of random walk in all the markets under study was rejected. Variance ratios' values are, in all cases, lower than the unity, which implies that the returns are auto correlated over time, and there is a reversion to the mean, in all indexes. The exponents Detrended Fluctuation Analysis (DFA), indicate significant long memories, i.e. they validate the results of the non-parametric test of Wright (2000), which comprises two types of tests, the Position test (Rankings) for homoscedastic series, and the Signal test for heteroscedastic series. These findings show that prices do not fully reflect the information available and that changes in prices are not independent and identically distributed. This situation has implications for investors since some returns can be expectable, creating opportunities for arbitrage and abnormal earnings. These conclusions also open space for market regulators to take measures to ensure better information in these regional markets.*

**Keywords:** *Global pandemic, Efficiency, Arbitrage.*

## 1. INTRODUCTION

In the last months, international financial markets have been seeing numerous successions of many setbacks, triggered by the COVID-19, followed by a series of collapses, the oil war, and currency fluctuations. The economic turbulence related to the pandemic of

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coronavirus in 2019-2020 has severe repercussions in the financial markets, specifically in the stock market, bonds, and commodities (including crude oil and gold). The main events were the oil price war between Russia and Saudi Arabia after the failure to reach an OPEC agreement, which led to the collapse of oil prices, and a significant fall in the stock markets in March (G.Sudha and V.Sornaganesh, 2020).

Investors who buy stocks in domestic and foreign markets seek to reduce risk through international diversification. Risk reduction occurs if the various markets are not perfectly correlated. The increasing correlation between markets during and after crises has restricted the possibilities for international diversification. From the investor's point of view, knowledge of the form and intensity of interdependence between different financial markets is vital for efficient hedging decisions to minimize the adverse effect of uncertainty on expected investment returns. Similarly, understanding the interdependence relationships between international stock markets facilitates the identification of diversification opportunities. The demise of barriers to investment in recent years has meant that many countries have undergone the process of integration both financially and economically. This leads to the benefits of international diversification being called into question mainly due to the various financial crises that have plagued financial markets around the world (Alexandre, Dias, and Heliodoro, 2020a; Alexandre et al., 2020b; Alexandre, Heliodoro, and Dias, 2019; Dias et al., 2020; Dias and Carvalho, 2020; Dias, da Silva, et al., 2019; Dias, Heliodoro, and Alexandre, 2020, 2019; Dias, Heliodoro, Alexandre, Santos, and Farinha, 2021; Dias, Heliodoro, Teixeira, and Godinho, 2020; Dias, Pardal, Teixeira, and Machová, 2020; Dias, Heliodoro, Alexandre, and Vasco, 2020b; Dias, Heliodoro, Alexandre, et al., 2020a; Dias and Pereira, 2021; Heliodoro, P., Dias, R., Alexandre, P., and Vasco, 2020; Heliodoro, P., Dias, R. and Alexandre, 2020; Heliodoro, Dias, and Alexandre, 2020; Pardal, P., Dias, R., Šuleř, P., Teixeira, N., and Krulický, 2020; Santos and Dias, 2020).

According to Şenol and Zeren (2020), the new coronavirus (Covid-19), puts human health at risk, increasing the perception of risk in financial markets. The impact of the 2020 pandemic causes big drops in the stock markets in a short period, the companies lost value, and the stock prices dropped. Because of these events, it is pertinent to study market efficiency, in its weak form, and test the predictability of stock market indexes in France (CAC40), China (SSEC), South Korea (KOSPI), Germany (DAX 30), Italy (FTSE MID), Portugal (PSI 20), and Spain (IBEX 35), from December 31, 2019, to August 10, 2020. The results reject the *random walk* hypothesis in all markets. Variance ratios are, in all cases, lower than the unit, which implies that the returns are auto correlated over time and, there is a reversion to the mean, in all indexes. The exponents *Detrended Fluctuation Analysis (DFA)*, indicate significant long memories, i.e. they validate the results of the non-parametric test of Wright (2000).

This investigation adds contributions to the literature, namely in the study on market efficiency, in its weak form, in-stock indexes from different regions, such as Asia and Europe. As far as we know, this is the first study that crosses European and Asian markets and estimates the possibility that these markets will have long memories, which may cause opportunities for arbitrage and abnormal earnings, without the investors incurring additional risk. Additionally, we identified studies that investigated the impact of the 2020 global pandemic on financial markets, namely from authors as He, Liu, Wang, and Yu (2020), Sansa (2020), Corbet, Larkin, and Lucey (2020), Ali, Alam, and Rizvi (2020), Naidenova, Parshakov, and Shakina (2020). However, their approach was very different from the one that we will follow in this essay.

In terms of structure, this essay consists of 5 sections. Section 2 presents a Literature Review regarding articles on the hypothesis of an efficient market in international financial markets. Section 3 describes the methodology and data. Section 4 contains the results and section 5 concludes.

## 2. LITERATURE REVIEW

The theme regarding the efficient market hypothesis (EMH) has motivated several studies to analyse the implications on the efficient market hypothesis, according to which the current price of the assets reflects all the information available, at a given moment. The price adjusts quickly, as new and unforeseen information comes to the market (Fama and French, 1988).

Ayentimi, Mensah, and Naa-Idar (2013), El Khamlichi, Sarkar, Arouri, and Teulon (2014), Sümer (2016) tested the *random walk* hypothesis in the financial markets. Ayentimi, Mensah, and Naa-Idar (2013) analysed the efficiency, in their weak form, in Ghana's value stock market (GSE), and show that the financial market data series exhibits volatility associated with GSE inefficiency. El Khamlichi et al. (2014) show that Islamic indices have the same level of (in) efficiency as benchmarks, but the MSCI and FTSE indices are less inefficient. Sümer (2016), on the other hand, shows that Turkey's financial markets, shares, foreign exchange, and the price of gold is efficient, in their weak form.

Robinson (2016), Fusthane and M (2017), Filipovski and Tevdovski (2018), Fernando and Gunasekara (2018), Chaker and Sabah (2018), shows signals of (in) efficiency, in their weak form in the financial markets. Robinson (2016) analysed the Jamaican stock market (JSE), and make clear that the *random walk* hypothesis was rejected. Fusthane and M (2017) examined the Johannesburg stock market in terms of market efficiency. The authors indicate hybrid results. Filipovski and Tevdovski (2018) looked into ten European financial markets, and their findings show that these markets show characteristics of inefficiency in specific periods. Fernando and Gunasekara (2018) examined the CSE market (All Share Price Index), and show that this market shows signs of inefficiency. Chaker and Sabah (2018) tested the efficiency, in their weak form, in the markets of the United Arad Emirates (UAE), Saudi Arabia, Oman, Kuwait and Bahrain, showing that none of the analysed markets follow the *random walk* hypothesis.

Atac and Tas (2019), Olubiyi and Olopade (2019), Mphoeng (2019) examined the market efficiency, in its weak form. Atac and Tas (2019) investigated the Istanbul stock exchange, and have shown that the efficiency hypothesis is rejected. Olubiyi and Olopade (2019) ) researched the stock markets of OPEC member countries. The authors demonstrate through parametric and non-parametric tests that only the Qatar stock market is efficient, in its weak form. Mphoeng (2019) tests the efficient market hypothesis (EMH) on the Botswana stock exchange and indicates the (in) efficiency of this market.

He, Liu, Wang, and Yu (2020) examined the effects and repercussion of COVID-19 in the stock markets from the People's Republic of China, Italy, South Korea, France, Spain, Germany, Japan, and the United States. The authors show that COVID-19 has a negative shock in the short term, and that impact on stock exchanges causes bidirectional shocks between Asian, European, and American markets. Khan (2020) investigated the effect of the COVID-19 pandemic in the stock markets of sixteen different countries. However, once human-to-human transmissibility was confirmed, all stock exchanges reacted negatively to the news in both the short and long term. The authors argue that the Shanghai Composite Index market,

which was severely affected by short-scale events, managed to readjust on long scales. This indicates that the Chinese government's drastic measures to contain the spread of the pandemic have led to investors' confidence in the Shanghai stock exchange.

In summary, this work aims to contribute to the provision of information to investors and regulators in international stock markets, where individual and institutional investors seek diversification benefits, as well as helping to promote the implementation of policies that contribute to the efficiency of global markets. Therefore, the context of this work is to examine the market efficiency, in its weak form, and the predictability of these stock markets during the global pandemic (COVID-19).

## 3. METHODOLOGY

### DATA

The analysed data are related to the stock indexes from France (CAC40), China (SSEC), South Korea (KOSPI), German (DAX 30), Italy (FTSE MID), Portugal (PSI 20), and Spain (IBEX 35), between the period of December 31, 2019, and August 10, 2020. The quotations are daily and obtained from the *Thomson Reuters* platform, and quoted in the local currency, to mitigate exchange rate distortions.

**Table 1.** The names of countries and their indices used in this paper

| Country | Index |
|---|---|
| France | CAC 40 |
| China | SSEC |
| South Korea | KOSPI |
| Germany | DAX 30 |
| Italy | FTSE MID |
| Portugal | PSI 20 |
| Spain | IBEX 35 |

**Source**: Own elaboration

### METHODOLOGY

The development of this research took place through different stages. At the first stage, we used a descriptive statistic, as well as Jarque and Bera (1980) adherence test, to verify if the data follow a normal distribution. To estimate the evolution of the markets under analysis, we made graphics in terms of levels and returns, and additionally, we tested the stability of the residuals. To verify the possible existence of structural breaks, we used Clemente et al. (1998) test. To examine the *random walk* hypothesis we used the non-parametric test developed by Wright (2000) because it is a more resilient test to time series that do not show normality and is entirely consistent when they show a series correlation. This author's methodology consists of two types of tests, the Position test (Rankings) for homoscedastic series, and the Signal test for heteroscedastic series. The ratio of variances is given by the relationship between the variance of $q$ periods and a single period, the same being equal to 1. Thus, in the test of the variance ratio, under the null hypothesis $VR(q) = 1$, the series follows a *random walk* type process. When the hypothesis of randomness is rejected and $VR(q) > 1$, the series indicates the existence of a positive correlation. When the null hypothesis is rejected and $VR(q) < 1$, the series shows a negative series correlation. In order to validate results, we will use *Detrended Fluctuation Analysis (DFA). DFA* is an analysis method that examines time dependency on

non-stationary data series. This technique, assuming that the time series are non-stationary, avoids spurious results when the analysis focuses on the relationships of the data series in the long run. The *Detrended Fluctuation Analysis (DFA)* presents the following interpretation:

**Table 2.** Detrended Fluctuation Analysis (DFA)

| Exponent | Type of signal |
|---|---|
| $\alpha_{DFA} < 0.5$ | long-range anti-persistent |
| $\alpha_{DFA} \simeq 0.5$ | uncorrelated, white noise |
| $\alpha_{DFA} > 0.5$ | long-range persistent |

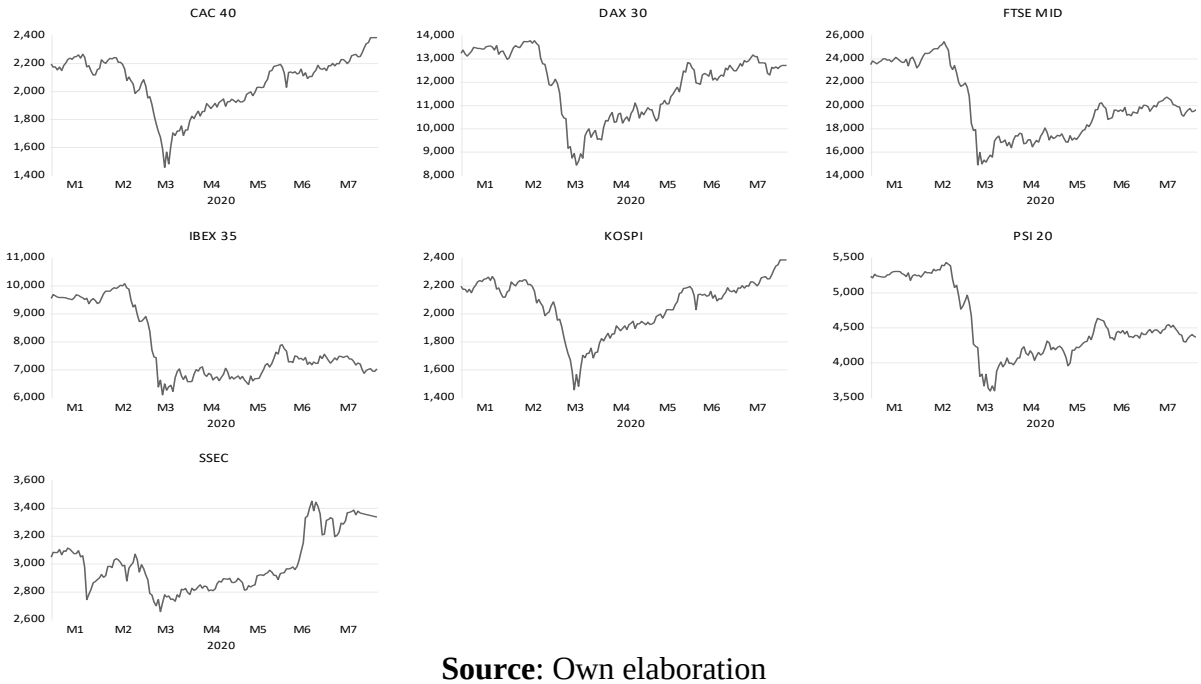
**Source**: Own elaboration

For a better analysis of the DFA methodology see the authors' articles Dias, da Silva, and Dionísio (2019), Dias, Heliodoro, Alexandre, and Vasco (2020), Dias, Heliodoro, and Alexandre (2020), Alexandre, Dias, and Heliodoro (2020), Santos and Dias (2020).

## 4. RESULTS

Figure 1 shows the evolution of the seven markets in the analysis by level. The data in the sample consists of the time-lapse between December 31, 2019, and August 10, 2020, which is a challenging period, due to understanding the outbreak of the global pandemic (COVID-19). Returns reveal volatility in February, March, and April 2020.

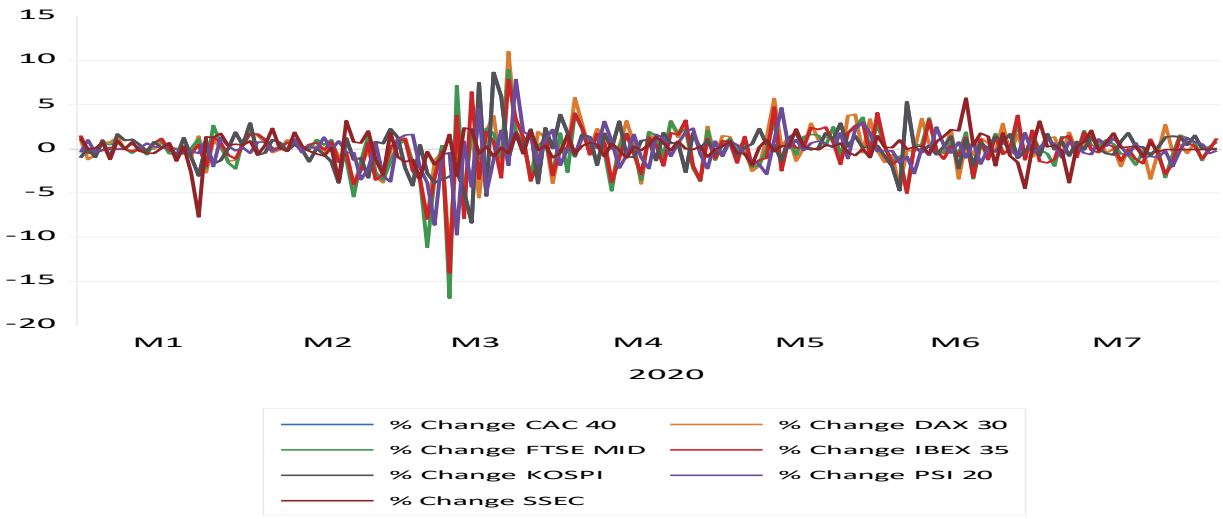
**Figure 1.** Evolution, in levels, of the 7 financial markets, in the period between 12/31/2019 to 8/10/2020.




**Source**: Own elaboration

Figure 2 shows the evolution, in %, of the differences of the 7 financial markets in analyses. In all series, there is a relatively high dispersion around the mean, as well as a relatively synchronized behaviour between the data series. Through graphical analysis, there is high volatility, especially in February, March, and April 2020.

**Figure 2.** Evolution, in% of the differences, of the 7 financial markets, in the period between 12/31/2019 to 8/10/2020




**Source**: Own elaboration

Table 3 presents the main descriptive statistics of the financial market under analysis and allows us to verify that the returns of the financial markets in Germany (DAX30), Italy, (FTSE MID), Spain (IBEX 35) and Portugal (PSI 20) show positive means daily. On the other hand, the stock indexes from France (CAC 40), South Korea (KOSPI), and China (SSEC) show negative means. Asymmetry characteristics are negative, with a greater emphasis on the Italian market (-2.5187). Additionally, the asymmetry and kurtosis coefficients are statistically different from those of a normal distribution, and these indications corroborate with the Jarque and Bera test (1980) where the hypothesis that the data follow a normal distribution is rejected at the level of significance of 1%.

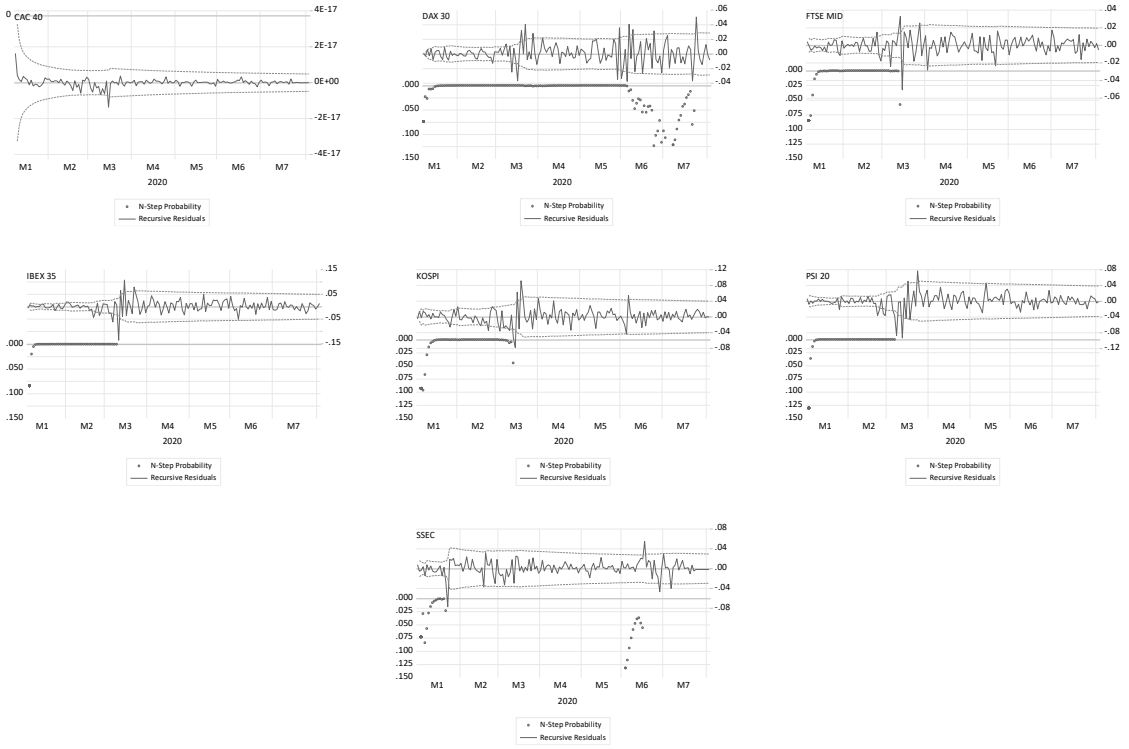
**Table 3.** Descriptive statistics, on returns, of the 7 financial markets under analysis, in the period between 12/31/2019 to 10/08/2020.

| | CAC 40 | DAX 30 | FTSE MID | IBEX 35 | KOSPI | PSI 20 | SSEC |
|---|---|---|---|---|---|---|---|
| Mean | 0.000528 | -0.000258 | -0.001146 | -0.001963 | 0.000528 | -0.001164 | 0.000577 |
| Std. Dev. | 0.020619 | 0.024387 | 0.026735 | 0.024760 | 0.020619 | 0.019281 | 0.014702 |
| Skewness | -0.146481 | -0.836405 | -2.518785 | -1.551275 | -0.146481 | -1.297632 | -1.172333 |
| Kurtosis | 7.059304 | 9.846145 | 18.87769 | 11.86179 | 7.059304 | 11.16042 | 9.844528 |
| Jarque-Bera | 107.6646*** | 322.8419*** | 1803.609*** | 573.0211*** | 107.6646*** | 476.6305*** | 340.2427*** |
| Sum | 0.082380 | -0.040262 | -0.178760 | -0.306157 | 0.082380 | -0.181523 | 0.089949 |
| Sum Sq. Dev. | 0.065896 | 0.092182 | 0.110792 | 0.095020 | 0.065896 | 0.057624 | 0.033504 |
| Observations | 156 | 156 | 156 | 156 | 156 | 156 | 156 |

**Source**: Own elaboration

Figure 3 shows the stability tests carried out on the residuals of Europe's stock markets to corroborate the presence of structural breaks. The determination of the structural break is relevant, as it has a potentially unwanted effect on that of the unit-roots. Through graphical analysis, we can gauge the existence of disturbances in the variation. Additionally, when examining the graphs and the 95% probability limits, we verified the presence of a violation of the probability limits. Therefore, the time series show unstable behaviour.

**Figure 3.** Stability tests performed on the residuals of the 7 financial markets, in the period between 12/31/2019 to 10/08/2020.




**Source**: Own elaboration

Table 4 shows the results of the unit root tests with structure breaks, by Clemente et al. (1998), and we can easily see that the financial markets showed structural breaks in March 2020, except for the Chinese market. The results are in line with the findings of the authors Alexandre, Dias, and Heliodoro (2020), Heliodoro, P., Dias, R., Alexandre, P., and Vasco (2020), Dias, Heliodoro, Alexandre, and Vasco (2020), Dias, Heliodoro, Teixeira, and Godinho (2020), Dias, Heliodoro, and Alexandre (2020), G.Sudha and V.Sornaganesh (2020), Lahmiri and Bekiros (2020), which indicate sharp declines in the international financial markets, resulting from the global pandemic (COVID-19).

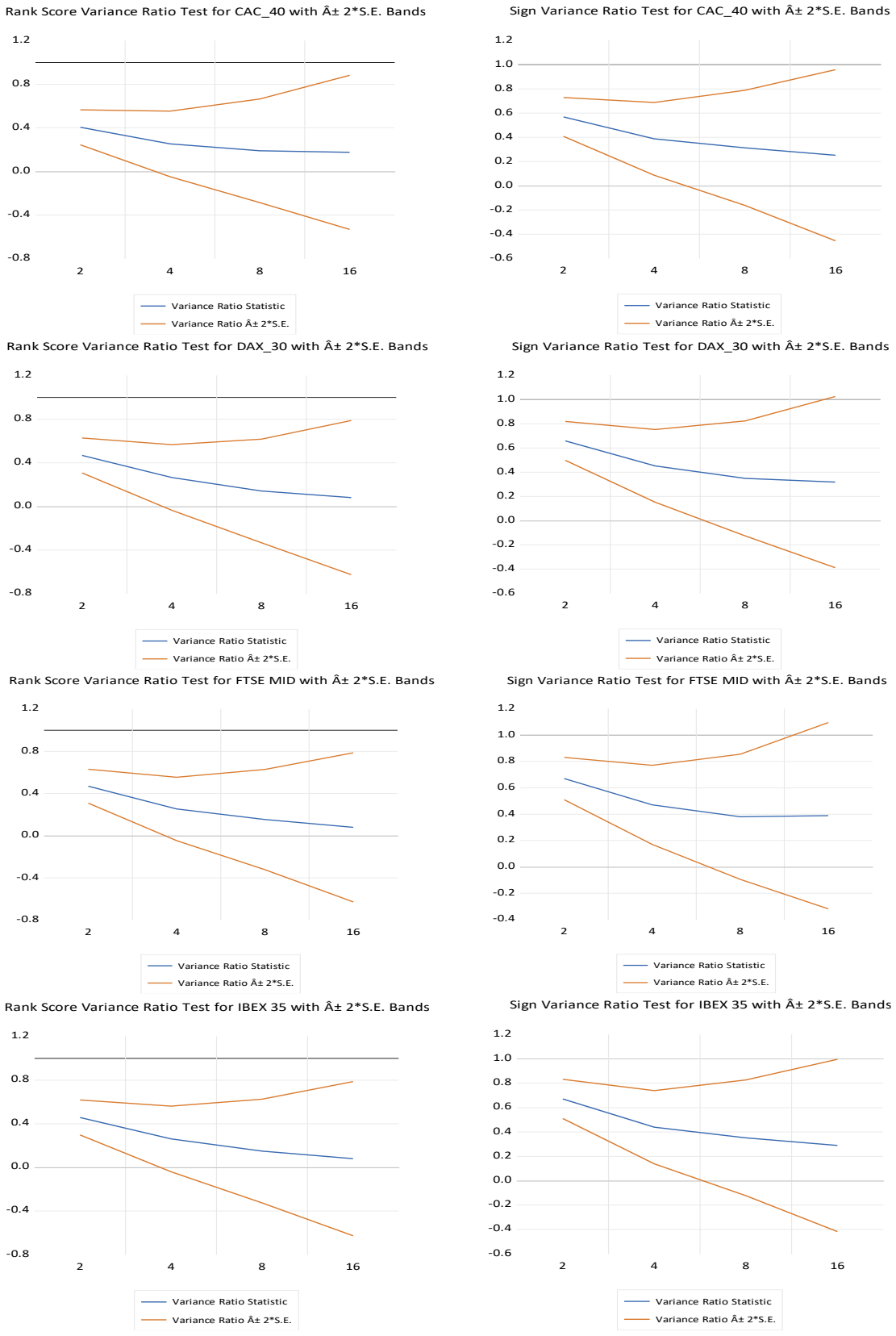
**Table 4.** Unit root tests, with structural breaks, by Clemente et al. (1998), referring to the 7 financial markets in the full period

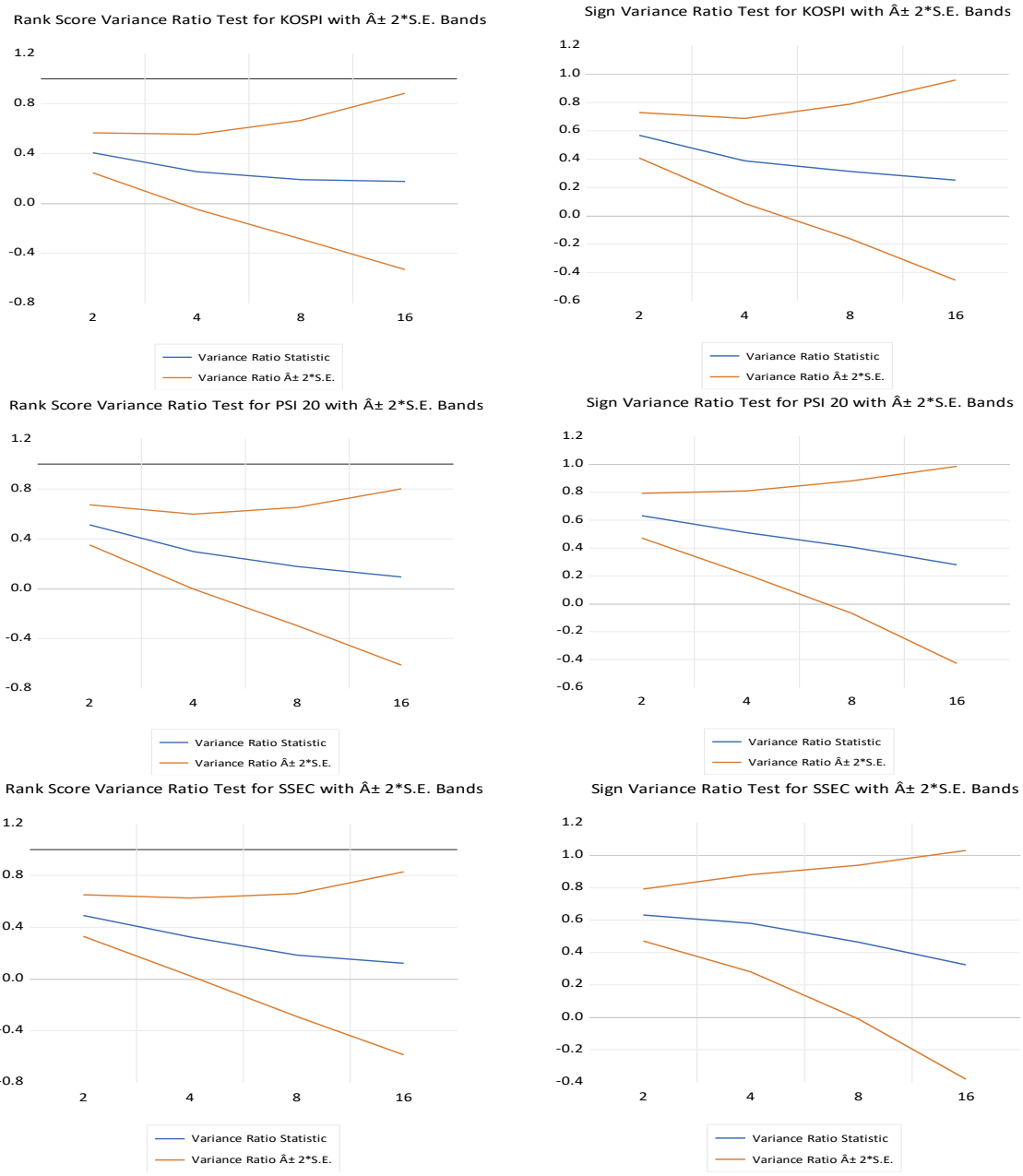
| Index | t-stat | Break Date |
|---|---|---|
| CAC 40 | -15.92(0)*** | 16/03/2020 |
| **SSEC** | **-13.69(0)*** ** | **23/01/2020** |
| KOSPI | -15.92(0)*** | 16/03/2020 |
| DAX 30 | -13.99(0)*** | 11/03/2020 |
| FTSE MID | -16.59(0)*** | 11/03/2020 |
| PSI 20 | -13.41(0)*** | 09/03/2020 |
| IBEX 35 | -14.01(0)*** | 13/03/2020 |

Note: Lag Length (Automatic Length based on SIC). Break Selection: Minimize Dickey-Fuller t-statistic. The lateral values in parentheses refer to lags. ***. **. *. represent significance at 1%. 5% and 10%. respectively.

**Source**: Own elaboration

**Figure 4.** Wright's (2000) Variance Ratio test of Rankings and Signals, referring to the 7 financial markets, in the full period.






**Source**: Own elaboration

Wright's (2000) non-parametric methodology, which includes the Variance-Ratio tests using Ranks and Signs, were calculated between the period of December 2019 and July 2020 for 2,4,8 and 16 days lags. Taking into account the results of the variance test by Rankings of Wright (2000), the hypothesis of *random walk* is rejected in all indexes. In turn, the Signal test also corroborates a rejection of the *random walk* hypothesis, in all data series. The values of the variance ratios are, in all cases, lower than the unit, which implies that the returns are autocorrelated over time and, there is a reversion to the mean, in all indexes. The results obtained allow the rejection of the *random walk* hypothesis and the informational efficiency hypothesis of the financial markets, being consistent with those obtained in other studies, namely the authors Robinson (2016), Fusthane and M (2017), Filipovski and Tevdovski (2018), Fernando and Gunasekara (2018), Chaker and Sabah (2018), who show signs of (in) efficiency, in their weak form, in the financial markets.

The results of the DFA exponents, which we can see in table 5, can verify that all financial markets indicate long memories, that is, there is a propensity for the forecast of the stock market yields. These findings imply that prices do not fully reflect the information available and that changes in prices are not independent and identically distributed. These findings are in line with the evidence suggested by the authors Atac and Tas (2019), Olubiyi and Olopade (2019), Mphoeng (2019) that show inefficiency, in its weak form, which allows investors to have abnormal gains without incurring increased risk.

**Table 5.** DFA exponent for index and return. The values of the linear adjustments for α DFA always had R2 > 0.99.

| Stock market | DFA exponent (Covid-19 period) |
|---|---|
| CAC 40 | 0.64 ≅ 0.0011*** |
| SSEC | 0.56 ≅ 0.0040*** |
| KOSPI | 0.63 ≅ 0.0059*** |
| DAX 30 | 0.63 ≅ 0.0048*** |
| FTSE MID | 0.66 ≅ 0.0060*** |
| PSI 20 | 0.67 ≅ 0.0002*** |
| IBEX 35 | 0.63 ≅ 0.0064*** |

Note: The hypotheses are $H_0$: α = 0.5 and $H_1$: α ≠ 0.5**.** ***. **. *. represent significance at 1%. 5% and 10%. respectively.

**Source**: Own elaboration

## 5. CONCLUSION

The general conclusion to be retained and supported by the results obtained, through tests carried out with econometric and mathematical models, demonstrate that the global pandemic has a significant impact on the memory properties of the analysed markets. The results suggest the rejection of the *random walk* hypothesis in all markets. The values of the variance ratios are, in all cases, lower than the unit, which implies that the series of returns show a correlation in a negative series, and there is a reversion to the mean, in all indexes. The *Detrended Fluctuation Analysis* (*DFA*) exponents indicate significant long memories; that is, they validate the results of Wright (2000) non-parametric test. In conclusion, we consider that prices do not fully reflect the information available and that changes in prices are not independent and identically distributed. This situation has implications for investors since some returns can be expectable, creating opportunities for arbitrage and abnormal earnings. These conclusions also open space for market regulators to take steps to ensure better informational information in these regional markets.

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