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Long-range Dependencies of Euronext Capital Markets: A Dynamic Detrended Analysis

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Abstract: This paper aims to test efficiency, in its weak form, in the capital markets of the Netherlands (AEX), Belgium (BEL 20), France (CAC 40), Ireland (ISEQ 20), Norway (OSEBX), Portugal (PSI 20), in the period from April 4, 2019 to April 1, 2021. The sample was partitioned into two subperiods, the first and second wave of the global pandemic: April 4, 2019 to April 30, 2020; May 4, 2020 to April 1, 2021. To carry out this analysis, different approaches were undertaken to analyze whether: (i) Euronext's stock markets have more significant long memories in the first or second wave of the global pandemic? The results show the presence of sharp long memories during the first wave of the global pandemic, particularly in the stock indices OSEBX (0.67), PSI 20 (0.67), AEX (0.66), BEL 20 (0.64), CAC 40 (0.62), ISEQ 20 (0.61), which implies that the yields are autocorrelated in time and, there is a reversal of the average, in all indexes. Regarding the second wave of the global pandemic, we found that most Euronext stock markets don't reject the random walk hypothesis, with the exception of the Norwegian (0.56) and Portugal (0.55) stock markets. These findings show that the impact of the Covid-19 pandemic was accentuated during the first wave, but from May 2020 the markets adjusted and showed balance. The authors believe that the results achieved will be a benefit to international investors seeking efficient diversification into their portfolios.

1. INTRODUCTION

International financial markets have seen a succession of major setbacks in recent months triggered by Covid-19, followed by a series of collapses, the oil war, and currency fluctuations. The economic turbulence associated with the coronavirus pandemic in 2019-2020 had serious repercussions on financial markets, notably in the stock, bond and commodity markets (including crude oil and gold). The main events were an oil price war between Russia and Saudi Arabia after an OPEC agreement wasn't reached, which led to the collapse of oil prices, and a significant drop in stock markets in March 2020 (G.Sudha and V.Sornaganesh, 2020).

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A market is designated as efficient when all relevant information about the stock price is reflected in the market price. The lack of consensus among economists and financial analysts regarding market efficiency requires the study of the efficient market hypothesis (HME). Another significant reason to study market efficiency is the role of stock markets acting as financial intermediaries between the saver and the borrower in the distribution of scarce resources via the price mechanism (Jain, 2020; Karasiński, 2020).

Given these events, it's appropriate to study the predictability of Euronext's capital markets, in particular, the Netherlands stock markets (AEX), Belgium (BEL 20), France (CAC 40), Ireland (ISEQ 20), Norway (OSEBX), Portugal (PSI 20), from April 4, 2019 to April 1, 2021. The results show the presence of sharp long memories during the first wave of the global pandemic, particularly in the stock indexes OSEBX (0.67), PSI 20 (0.67), AEX (0.66), BEL 20 (0.64), CAC 40 (0.62), ISEQ 20 (0.61), which implies that the yields are autocorrelated in time and that the price series aren't independent and identically distributed. Regarding the second wave of the global pandemic, we found that most Euronext stock markets don't reject the random walk hypothesis, except for the Norwegian (0.56) and Portugal (0.55) stock markets. These findings show that the capital markets analyzed were able to rebalance in the second wave, allowing international investors to diversify their portfolios more efficiently.

This research adds contributions to the literature, in particular the study on market efficiency, in its weak form, in Euronext stock indices, from April 4, 2019 to April 1, 2021. As far as we know this is the first study that analyzes the presence of long memories in these Euronext markets, having the first and second waves of the global pandemic as partitioned samples. In addition, we identified studies that investigated the impact of the 2020 global pandemic on financial markets, namely the authors Dias, Pardal, Teixeira, and Machová, (2020), Dias, Heliodoro, and Alexandre (2020), Alexandre, Dias, and Heliodoro (2020), Dias et al. (2020) , Pardal, P., Dias, R., Šuleř, P., Teixeira, N., and Krulický (2020), but the approach was quite different from the one followed in this paper.

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

2. LITERATURE REVIEW

Different studies have addressed the issue of market efficiency, analyzing the hypothesis of predictability of profitability, through the analysis of patterns of reversal of stock prices average, inspired by the seminal works of Poterba and Summers (1988), Fama and French (1988), which documented reversal to the average in the stock markets, in time horizons of more than one year.

Dias, da Silva, and Dionísio (2019), Dias and Carvalho (2020), Pardal, P., Dias, R., Šuleř, P., Teixeira, N., and Krulický (2020), Heliodoro, P., Dias, R., Alexandre, P., and Vasco (2020), Dias, Heliodoro, Alexandre, and Vasco (2020b), have tested whether portfolio rebalancing is feasible in international capital markets. Dias, da Silva, and Dionísio (2019) analyzed financial integration in emerging markets in Latin America during the Dot-com and subprime financial crises, showing that markets are partially integrated. Furthermore, the financial series doesn't present significant long memories arising from the subprime crisis, i.e. these markets show that the implementation of portfolio diversification strategies could be beneficial for investors operating in these regional markets. Dias and

Carvalho (2020) analyzed if whether gold (Gold Bullion: Zurich) and silver (Silver Paris Spot E/KG) will be a safe haven to diversify portfolios in Latin American stock markets, indices of the stock exchanges of Argentina (S&P Merval), Brazil (Ibovespa), Chile (S&P/CLX IGPA), Peru (S&P/BVL General IGBL), Mexico (IPC), USA (Dow Jones), gold (Gold Bullion: Zurich), and silver (Silver Paris Spot E/KG), from December 31, 2019 to September 2, 2020. The authors show that gold and silver don't function as safe havens for portfolio diversification in Latin American stock markets. Pardal, P., Dias, R., Šuleř, P., Teixeira, N., and Krulický (2020) analyzed financial integration in the capital markets of Austria (ATX), Slovenia (SBITOP), Hungary (BUDAPEST SE), Lithuania (OMX VILNIUS), Poland (WIG), the Czech Republic (PX PRAGUE), Russia (MOEX) and Serbia (BELEX 15), in the context of the global pandemic (Covid-19). The authors show very significant levels of integration, which decreases the chances of diversification in the long term. Heliodoro, P., Dias, R., Alexandre, P., and Vasco C. (2020) tested financial integration in the Brazilian, China, India and Russia (BRIC's) stock markets from July 2015 to June 2020. The results suggest very significant levels of integration in the global pandemic period of 2020; these findings bring into question the implementation of portfolio diversification strategies. Dias, Heliodoro, Alexandre, and Vasco (2020b) show that the WTI oil index causes the stock markets of Russia and India, while China does not cause any markets and Brazil is not caused by any market analyzed. On the other hand, short-term market shocks are relevant and create some arbitrage opportunities; these findings could also bring into question the implementation of portfolio diversification.

Dias, Heliodoro, Teixeira, and Godinho (2020), Dias, Teixeira, Machova, et al. (2020) , Heliodoro, Dias, and Alexandre (2020), analyzed the persistence of profitability in international capital markets. Dias, Heliodoro, Teixeira, and Godinho (2020) tested the hypothesis of an efficient market, in its weak form, in sixteen international capital markets, from January 2002 to July 2019. The authors show that the global financial crisis has intensified the level of integration of international financial markets. Concerning the random walk hypothesis, the results suggest the existence of a reversal of the average, showing that the price series are not independent and identically distributed in the developed and emerging markets, European and non-European. Dias, Teixeira, Machova, et al. (2020) analyzed capital market efficiency, in its weak form, using the Stock Indexes of Belgium (BEL 20 index), France (CAC 40 index), Germany (DAX 30 index), USA (DOW JONES index), Greece (FTSE Athex 20 index), Spain (IBEX 35 index), Ireland (ISEQ index), Portugal (PSI 20 index) and China (SSE index) in the period from December 2019 to May 2020. The authors suggest mixed evidence, i.e., the random walk hypothesis is rejected for the Dow Jones, SSE and PSI 20 capital markets, partially rejected in the BEL 20, CAC 40, Athex 20 and DAX 30 stock markets, while in the IBEX 35 and ISEQ stock markets the random walk hypothesis is not rejected showing the balance of these capital markets. Heliodoro, Dias, and Alexandre (2020) analyzed the six main markets in Latin America (Argentina, Brazil, Chile, Colombia, Mexico and Peru) and the USA in the period 2015-2020. The results of the autocorrelation tests are totally coincident with those obtained by the BDS test. The rejection of the null hypothesis, i.i.d. can be explained, among other factors, by the existence of autocorrelation or by the existence of heteroscedasticity in the series of stock indices, in which case the rejection of the null hypothesis is explained by the nonlinear dependence of the data, except the Argentine market. The authors show that these regional markets demonstrate persistence in their profitability, which could be beneficial for investors.

Dias and Pereira (2021), Dias, Heliodoro, Alexandre, Santos, and Farinha (2021) analyzed the impact of the 2020 global pandemic on the memory properties of European stock markets. Dias and Pereira (2021) analyzed whether the evolution of Covid-19 (confirmed cases and deaths) caused shocks in 8 European markets, from December 31, 2019 to July 23, 2020. The authors

show that the Covid-19 time series don't cause shocks in the stock markets analyzed, but the capital markets of Europe show the presence of long memories (0. 61-0. 73), i.e. profitability shows autocorrelation over time. Dias, Heliodoro, Alexandre, Santos, and Farinha (2021) analyzed the impact of the 2020 global pandemic on the memory properties of Eastern European stock markets, from January 1, 2016 to September 2, 2020; the sample was divided into two subperiods: January 1, 2016 to August 30, 2019 (before Covid-19) and September 2, 2019 to September 2, 2020 (after Covid-19). The authors show that daily returns don't have normal distributions, they have negative asymmetries, leptokurtic and also present conditional heteroscedasticity. DFA exponents, during the Covid-19 period, range from 0. 64 to 0. 75, showing significant long memories, with the exception of the capital market of Slovakia (0. 45).

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 to help to promote the implementation of policies that contribute to the efficiency of domestic markets. Therefore, the context of this work is to examine predictability in Euronext's stock markets during the first and second waves of the global pandemic Covid-19).

3. METHODOLOGY

3.1. Data

The data analyzed are the prices index of the stock markets of the Netherlands (AEX), Belgium (BEL 20), France (CAC 40), Ireland (ISEQ 20), Norway (OSEBX), Portugal (PSI 20), in the period from April 4, 2019 to April 1, 2021. The sample was partitioned into two sub-periods, the first and second wave of the global pandemic: April 4, 2019 to April 30, 2020; May 4, 2020 to April 1, 2021. The quotes are daily and were obtained from the Thomson Reuters platform.

Table 1. The name of countries and their indexes used in this paper

Country	Index
Holland	AEX
Belgium	BEL 20
France	CAC 40
Ireland	ISEQ 20
Norway	OSEBX
Portugal	PSI 20

Source: Own elaboration.

3.2. Methodology

The research will develop throughout several stages. Market graphs were carried out, at levels, to estimate the evolution of Euronext's stock markets. The characterization of the sample will be performed using descriptive statistics, to verify whether if the data follow a normal distribution. In order to assess if the time series follows a white noise (mean = 0; constant variance), we'll use the unit root tests as Hadri panel (2000) and Im, Pesaran, and Shin (2003) that postulate opposite null hypotheses. To measure the structure breaks, we'll estimate the test of Clemente et al (1998) which will determine the date of the main structural break in Euronext's capital markets. To answer the research question, we'll apply the methodology of the Detrended Fluctuation Analysis (DFA). DFA is an analysis method that examines temporal dependence on non-stationary data series. This technique assumes that time series are non-stationary to avoid spurious

results when the analysis focuses on the relationships of the data series in the long term. This methodology was developed by Peng et al. (1994) and it has origin in the study of the behavior of DNA. Later this method was used to examine the behavior of financial series. DFA has the following interpretation: $0 < \alpha < 0{,}5$: anti-persistent series; $\alpha = 0.5$ series features random walk; $0.5 < \alpha < 1$ persistent series.

The function of this technique is to examine the relationship between values x_k and x_{k+t} in different moments (Sukpitak and Hengpunya,2016).Considering a dataset x_k,,with equidistant observations $k = 1, \ldots, t$. DFA's first step is the construction of a new series:

$$x(t) = \sum_{k=1}^{t} x_k \tag{1}$$

The second step is to obtain the trend the $z(t)$ of each fraction, through the least-squares method, obtaining the subtracted series from the trend (detrended), i.e.

$$x_s(t) = x(t) - z(t) \tag{2}$$

The original application assumes that the trend present in each of the boxes is a linear trend,i.e. subsequent applications indicate that it's likely to contain other polynomial tendencies, (Kantelhardt, Koscielny-Bunde, Rego, Havlin, and Bunde, 2001). For each box, the value of the trend equation is obtained by the least squares method and later the root of the mean square deviation between the series is estimated, the *DFA* function being given by:

The original application assumes that the trend present in each of the boxes is a linear trend, $Z(t) = at + b$ i.e.subsequent applications indicate that it's likely to contain other polynomial tendencies,(Kantelhardt,Koscielny-Bunde,Rego,Havlin,and Bunde,2001).For each box,the value of the trend equation is obtained by the least squares method and later the root of the mean square deviation between the series $x(t)$ and $Z(t)$ is estimated, the DFA function being given by:

$$F(s) = \sqrt{\frac{1}{2N} \sum_{t=1}^{2N} [x_s(t)]^2} \tag{3}$$

Estimating the average F(s)for all centralized boxes in s generates the value of fluctuations $\langle F(s) \rangle$, depending on s. This estimation will be repeated for all distinct values of s, expecting a process of a power-law, i.e.,

$$\langle F(s) \rangle \sim s\alpha^{\alpha} \tag{4}$$

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

Table 2. Detrended Fluctuation Analysis (DFA)

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

Source: Own elaboration.

For a better analysis of this methodology see the articles of the authors 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, in levels, of the stock markets of the Netherlands (AEX), Belgium (BEL 20), France (CAC 40), Ireland (ISEQ 20), Norway (OSEBX), Portugal (PSI 20). The sample comprises the time lapse from April 4, 2019 to April 1, 2021, which is a period of great complexity, due to the outbreak of the global pandemic (Covid-19). Profitability clearly shows volatility in February, March and April 2020. These results are in line with the findings of the authors Dias, Heliodoro, Alexandre, and Vasco (2020), Dias, Heliodoro, and Alexandre (2020), Dias and Carvalho (2020) which show the existence of extreme volatility in the financial markets resulting from the global pandemic of 2020.

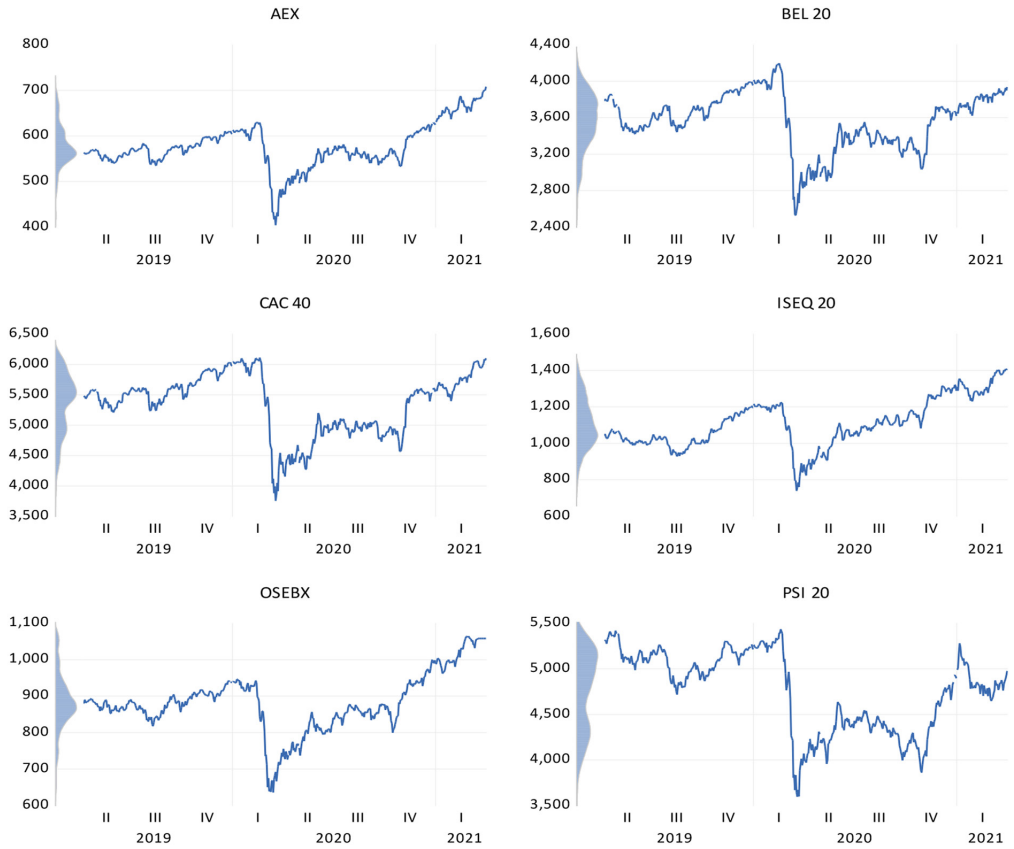


Figure 1. Evolution, in levels, of Euronext's 6 stock markets from April 6, 2019 to April 1, 2021.

Source: Own elaboration.

Notes: *DataStream*: April 4, 2019, 511-point data.

Table 3 shows the main descriptive statistics of Euronext's markets, namely the Netherlands (AEX), Belgium (BEL 20), France (CAC 40), Ireland (ISEQ 20), Norway (OSEBX), Portugal (PSI 20) stock markets. The markets under analysis show positive average yields with the exception of the PSI 20 stock index (-0.000130). The Belgian stock market has the standard deviation (0.016373), the asymmetry (-1.956358), and the sharpest shortness (20.78319). Additionally, the coefficients of asymmetry and kurtosis are statistically different from those of a normal distri-

bution; these indices are corroborated with the Jarque and Bera test (1980), where the chance that the data follow a normal distribution is rejected at the level of meaning of 1%.

Table 3: Descriptive statistics, return, of Euronext's 6 stock markets, from April 4, 2019 to April 1, 2021.

	AEX	BEL 20	CAC 40	ISEQ 20	OSEBX	PSI 20
Mean	0.000456	7.95E-05	0.000217	0.000593	0.000363	-0.000130
Std. Dev.	0.013901	0.016373	0.015735	0.016197	0.013429	0.013529
Skewness	-1.291213	-1.956358	-1.383687	-0.851653	-1.429240	-1.186823
Kurtosis	16.74827	20.78319	16.98572	10.58902	12.01404	15.14440
Jarque-Bera	4158.284***	7045.461***	4319.250***	1285.506***	1900.256***	3253.816***
Observations	510	510	510	510	510	510

Source: Own elaboration.

Notes: ***. **. *. represent significance at 1%. 5% and 10%, respectively.

As we are in the presence of time successions, we should study the stationary nature of the time series relating to Euronext markets, namely the Netherlands (AEX), Belgium (BEL 20), France (CAC 40), Ireland (ISEQ 20), Norway (OSEBX), Portugal (PSI 20) stock markets. For this, we used the tests of unitary roots in a panel of Im, Pesaran, and Shin (2003) that postulates unitary roots in the null hypothesis, while the Hadri test (2000) presents the stationarity in the null hypothesis. The intersection of the tests shows the time series are stationary, in the first differences; this means that we are facing a white noise (mean = 0; constant variance) (see tables 4 and 5).

Table 4. Panel Unit Root Test by Im, Pesaran, and Shin (2003), applied from Euronext's 6 stock markets, from April 4, 2019 to April 1, 2021.

Method		Statistic	Prob.**
Im, Pesaran and Shin W-stat		-57.7538	0.0000
Im, Pesaran and Shin t-bar		-21.7458	
T-bar critical values ***:	1% level	-2.33500	
	5% level	-2.10000	
	10% level	-1.97500	

Source: Own elaboration.

Note: ** Probabilities are computed assuming asymptotic normality.
*** Critical values from original paper.

Table 5. Panel Unit Root Test by Hadri (2000), applied to Euronext's 6 stock markets from April 4, 2019 to April 1, 2021.

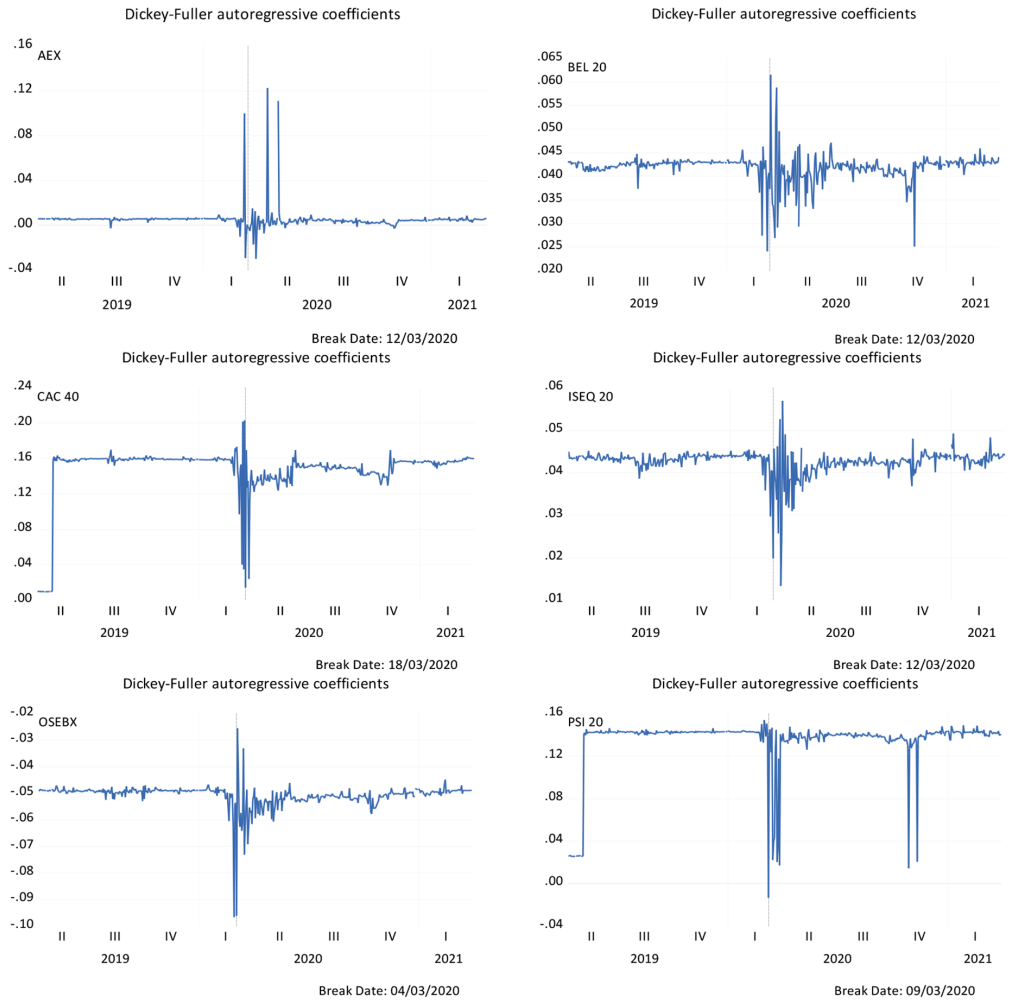
Method			Statistic	Prob.**
Hadri Z-stat			-0.83509	0.7982
Heteroscedastic Consistent Z-stat			-0.49851	0.6909
		Variance		
Series	Lm	Hac	Bandwidth	Note
D(AEX)	0.1637	69.63054	9.0	509
D(BEL 20)	0.0979	3871.401	9.0	509
D(CAC 40)	0.1231	7846.040	9.0	509
D(ISEQ 20)	0.1461	331.8674	6.0	509
D(OSEBX)	0.1732	154.5611	10.0	509
D(PSI 20)	0.1140	5285.594	9.0	509

Source: Own elaboration.

Note: ** Probabilities for Fisher tests are computed using an asymptotic Chi-square distribution.
All other tests assume asymptotic normality.

Figure 2 shows the results of unitary root tests, with structural breaks, by Clemente et al. (1998), relating to Euronext's stock markets. The stock indexes OSEBX (04/03/2020), PSI 20 (09/03/2020), AEX (12/03/2020), ISEQ 20 (12/03/2020), BEL 20 (12/03/2020), CAC 40 (18/03/2020) show significant declines in March 2020, which was expected due to the evolution of the global pandemic (Covid-19). These findings are corroborated by the authors Dias and Carvalho (2020), Dias and Pereira (2021), Dias, Heliodoro, Alexandre, Santos, and Farinha (2021) which show structural breakdowns in international financial markets.

Figure 2. Stationary tests with structural breaks by Clemente et al. (1998), relating to Euronext's 6 stock markets, from April 4, 2019 to April 1, 2021.



Source: Own elaboration.

Notes: *DataStream*: April 4, 2019, 510-point data.

Table 6 shows the results of the detrended fluctuation analysis (DFA*)* exponents for the Netherlands (AEX), Belgium (BEL 20), France (CAC 40), Ireland (ISEQ 20), Norway (OSEBX), Portugal (PSI 20) stock markets. When we look at the first wave of the global pandemic, i.e. from April 4, 2019 to April 30, 2020, the results show that the stock indexes OSEBX (0.67), PSI 20 (0.67), AEX (0.66), BEL 20 (0.64), CAC 40 (0.62), ISEQ 20 (0.61) have long memories and persistence in profitability, which implies that profitability is auto-correlated over time, that prices don't fully reflect the information available, and that changes in prices are not i.i.d. When we looked at the second wave of the pandemic, from May 4, 2020 to April 1, 2021, we found that the persistence decreased significantly,

i.e., the stock markets of the Netherlands (AEX), Belgium (BEL 20), France (CAC 40), Ireland (ISEQ 20) don't reject the random walk hypothesis, i.e., these markets adjusted from May 2020. In the case of the stock markets of Norway (OSEBX), Portugal (PSI 20) we found that they present some persistence, but it's lower when compared to the first wave of the global pandemic (0.56-0.55). These findings show that the capital markets analyzed show balance during the second wave of the pandemic, i.e., investors will not be able to achieve above-average yields without incurring additional risk.

Table 6. DFA exponent for index and return. The values of the linear adjustments for α_{DFA} always had $R_2 > 0.99$.

Stock market	Exponent DFA (1 Vacancy)	Exponent DFA (2 Vacancy)
AEX	0.66 ≅ 0.0017***	0.44 ≅ 0.0318
BEL 20	0.64 ≅ 0.0011***	0.53 ≅ 0.0124
CAC 40	0.62 ≅ 0.0016***	0.54 ≅ 0.0128
ISEQ 20	0.61 ≅ 0.0012***	0.46 ≅ 0.0365
OSEBX	0.67 ≅ 0.0013***	0.56 ≅ 0.0018**
PSI 20	0.67 ≅ 0.0014***	0.55 ≅ 0.0011**

Source: Own elaboration.

Note: The hypotheses are: $H_0\alpha = 0.5$ and: $H_1\alpha \neq 0.5$. ***. **. *. represents significance at 1%. 5% and 10%, respectively.

5. CONCLUSION

The general conclusion to be withheld and sustained in the results obtained, through tests carried out with econometric and econophysical models, show that during the first wave of the global pandemic the stock markets of the Netherlands (AEX), Belgium (BEL 20), France (CAC 40), Ireland (ISEQ 20), Norway (OSEBX), Portugal (PSI 20) have some challenges. These results bring into question the hypothesis of market efficiency, in its weak form, showing that investors can obtain advantages without incurring additional risk. In the second wave, we found that the persistence decreased significantly, that is, the stock markets of the Netherlands (AEX), Belgium (BEL 20), France (CAC 40), Ireland (ISEQ 20) don't reject the random walk hypothesis, that is, these markets adjusted from May 2020. In the case of the stock markets of Norway (OSEBX), Portugal (PSI 20) we found that they present some persistence, but it is lower when compared to the first wave of the global pandemic (0.56-0.55). These findings show that the capital markets analyzed show balance during the second wave of the pandemic, that is, investors will not be able to achieve above-average yields without incurring additional risk.

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