Master in Actuarial and Financial Sciences

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Title: Market efficiency, behavioral finance and decision making: evidence from Europe and Latin America

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“Behavioral finance is no longer as controversial a subject as it once was. As financial economists become accustomed to thinking about the role of human behavior in driving stock prices, people will look back at the articles published in the past 15 years and wonder what the fuss was about. I predict that in the not-too-distant future, the term “behavioral finance” will be correctly viewed as a redundant phrase. What other kind of finance is there? In their enlightenment, economists will routinely incorporate as much “behavior” into their models as they observe in the real world. After all, to do otherwise would be irrational.”

Thaler, R. H. (2010). The end of behavioral finance.

Abstract

The paradigm of the efficient markets is assumed in classical economic models. Nevertheless, unpredictable financial crises raised doubts on the objectivity of market efficiency and its capacity to resemble the decision-making of the interacting agents. This paper studies the concept of market efficiency and its implications; and tests empirically whether there is evidence of weak-form efficiency in multiple European and Latin American markets. Additionally, the paper studies the decision making among inefficient markets and highlights the contribution of behavioral economics in understanding investors' reasoning and cognitive biases, and in explaining the lack of efficiency in real financial markets.

Keywords: efficient markets model, behavioral finance, stock markets, weak-form efficiency tests, decision making

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Acronyms

ADF test	Augmented Dickey-Fuller test
CAPM	Capital Asset Pricing Model
EMH	Efficient Market Hypothesis
KPSS test	Kwiatkowski, Phillips, Schmidt and Shin test
L-B test	Ljung-Box test
MILA	Latin American's Integrated Market
PP test	Phillips-Perron test
RWH	Random Walk Hypothesis

1. Introduction

The Efficient Markets Hypothesis (EMH) has a very important place in the classical economic models and it has been studied and supported by many well-known economists such as Harry Markovitz, Merton Miller, William Sharpe and Eugene Fama. Nevertheless, it became a subject to discussion among the economists after the Great Recession lived between 2008 and 2010, which was characterized by a lack of accuracy setting the correct value of assets, poor capital allocation and the creation of bubbles in the markets. With the introduction of the *behavioral finance* theory incentivized by the growing critiques to the EMH, economists started studying the markets within a psychological and sociological perspective (Shiller, 2003) that focused on explaining how agents in the economy could make 'irrational' decisions that therefore lead to incorrect values of assets and the consequent existence of bubbles. Although these theories made by the behavioral economists do appear to expose a failure in the EMH and contribute causes, they have not proposed a way to replace EMH. As Richard Thaler, Nobel Prize winner in economics in 2017 once said, "in some ways, we behavioral economists have won by default, because we have been less arrogant" (The Economist, 2009). After all that we have seen, those who deny the possible existence of bubbles "look foolish". However, "to say something has failed you must have something to replace it, and so far we don't have a new paradigm to replace efficient markets".

The concept of *efficient markets* refers to the quick rational reaction of the agents in the market given the available information, setting asset prices to their value of efficient equilibrium. Thus, prices always reach the price of efficiency in a very short time and there is no possibility of bubbles since agents are fully rational and the market corrects prices very quickly. According to Eugene Fama (1969), one of the most renowned authors among this subject, the whole concept is about a "market in which prices provide accurate signals for resource allocation", and thus, a market where prices always "fully reflect" available information is considered efficient.

The key factors motivating this research are the vast importance of understanding market efficiency for decision making in investments; the evaluation of the transparency levels of highly influential information flows in the different economies; and of utilizing it as an indicator of the markets' sizes regarding transactional volumes. Therefore, this paper aims to answer the following research questions: Are Latin American and European markets weak-form efficient? How does the market efficiency affect investors' decision making? How does behavioral finance theory explain the existence of market inefficiency?

To answer these questions this paper will test the weak form of market efficiency in the financial markets of Latin America and Europe, by reviewing the bibliography of different tests and applying some of them to prove empirically whether the markets behaved as a random walk, which implies that future prices cannot be predicted by studying their previous behavior. Also, the paper aims to investigate the concept of market efficiency, its assumptions, and its consequences in all weak, semi-strong and strong forms, which is still of high relevance and applied in most models; and discuss the contributions made by the behavioral economists when explaining the inefficiency related with financial market anomalies.

This paper will base its empirical study on the historical prices of stock indexes from the countries that constitute the Latin America's Integrated Market (MILA), which gathers the stock markets of Mexico, Colombia, Peru and Chile; and the indices from four European countries, Spain, Germany, France and the United Kingdom. With this data, I test whether these markets show signs of efficiency in a weak form (prices follow a random walk) in the whole period of the data available and also discriminated by different moments in time, such as during the years of the crisis of 2008 and the years post-crisis. Furthermore, this study will contribute in contrasting which market is less efficient and therefore offers better options to make profit by speculation and in testing the weak form of efficiency in both markets for the periods *pre-crisis* and *post-crisis* as well as during the *crisis*.

Additionally, the differences identified between the market efficiencies of the two regions (Latin America and Europe), which also can be associated to a comparison between the situation in the markets from emerging and developed countries in terms of different variables of interest such as transparency of relevant information, volatility, decision making, efficiency and which market offers better opportunities for investors to make profit by performing speculative operations. Moreover, the study also explains the significant factors that impact the level of efficiency within a behavioral finance perspective, which is focused on how regular investors make decisions that do not necessarily follow the description of the representative rational agent that is considered in the standard economic models. These imperfectly rational actions therefore lead to certain levels of inefficiency that should be taken in consideration to understand the reality of the markets and how people make their investment decisions.

There is evidence for and against the weak and semi-strong EMH, whereas there is strong evidence against the existence of the strong-form of market efficiency in real stock markets. Due to the paper's main objective of testing empirically whether the hypothesis of weak form of efficiency is fulfilled or not in the stock markets of Latin America and Europe, the review of literature is focused mostly on papers that have tested the Random Walk Hypothesis (RWH) to determine the existence of this form of efficiency.

2. Conceptualization

2.1. Financial markets

A financial market by definition is an aggregate of possible buyers and sellers in which people trade financial securities (stocks and bonds) at a low transaction cost and where the prices of the assets reflect the levels of supply and demand (Calvo et al, 2010). There are several types of financial markets, such as for example, to trade commodities, derivatives or foreign currency exchange. This paper will focus on stock markets, because of the public access to data and the high volume of transactions, studying one index from the MILA and another from the European markets, both which include the most representative companies from the regions.

The MILA, as Mellado and Garcia (2014) describes, "is the virtual integration" of the Lima Stock Exchange, the Santiago Stock Exchange, the Colombia Stock Exchange and Mexican Stock Exchange. It is a "unique model of integration of the equity markets" created to "combine markets in different countries to facilitate international transactions" and increase the potential of diversification. This paper will study the efficiency of the MILA by analyzing individual indexes from the four countries that constitute this integrated market. The mentioned indexes are: the COLCAP from Colombia, the IPSA from Chile, the S&P BMV IPC from Mexico, and the S&P Lima General from Peru. All of them include the companies considered *blue chips* from each country.

In the case of the European markets, where there is no integration, and each country has an independent stock market, the analysis will be carried out by using the stock indexes from Spain, the IBEX 35; Germany, the DAX; France, the CAC 40; and the United Kingdom, the FTSE 100. The companies in the best financial situation comprise each of these indexes and the indexes are the most well-known from each country.

2.2. Efficient markets model

As Statman (2010) stated, the definition of market efficiency implies that the "price of a stock is always equal to its intrinsic value", where the intrinsic value refers to "the present value of cash flows the stock can reasonable expect generate, such as dividends". Thus, a stock can be neither undervalued nor overvalued and bubbles could not possibly exist. This conclusion could be easily extrapolated to every type of asset, where its value depends of the expected future cash flows. From this point we can immediately conclude that the concept does not fully fit to the reality of the markets. Indeed, one does not need to go far into the past for an example of the failure of this hypothesis. The last profound global crisis, which began around 2008, was mainly a consequence of the inability of agents to settle on an accurate price, risk wise, to the assets that they were buying and selling, leading to a massive default of overvalued assets, which in this particular case were mortgages.

According to Fama (1991), "it is easy to determine sufficient conditions for capital market efficiency" and he postulates that the conditions needed for this are (i) a market in which there are no costs for the transactions of trading securities, (ii) all the information is available freely for all the market participants and (iii) all the agents in the market agree on the implications of available information on the current prices and its impact on the future prices, which, in other words, means that all the agents in the market know how to react in the face of the available information and make completely rational decisions always maximizing their utility. Continuing with Fama's statement (1991), "in such a market, the current price of a security obviously fully reflects all available information".

The above conditions are taken in this paper as the fundamental conditions for the fulfillment of the EMH in its more extreme version. Nevertheless, it is not difficult to collect evidence (such as the existence of transaction costs) which shows that a market in which this efficiency would take place does not match with the real financial markets. Fama himself (1991) admits that "a frictionless market in which all information is freely available and investors agree on its implications is, of course, not descriptive of the markets met in practice". However, Fama, the biggest defender of this theory, argues that even though these conditions are sufficient for the efficiency in the markets, they are "not necessary". The problem however is that even taking into account that the markets do not behave according to the above fundamental conditions, further assumptions detailed by Fama (1991) are, as well difficult to identify in the real markets.

2.2.1. Weak, semi-strong and strong forms of market efficiency

As said, there is evidence against the most extreme version of the market efficiency, but Fama (1991) deepened the model to take into account different levels of efficiency. According to the efficient markets model, markets could have different forms of efficiency. Knowing that the model has an extreme null hypothesis, the categorization of the different forms into weak, semi-strong and strong serves the useful purpose of testing the level at which the hypothesis breaks down. If a market is *weak form efficient*, past prices do not contain any information about the future changes, implying that changes in prices follow a random walk and can't be predicted by analyzing prices from the past; in the case of a the *semi-strong form*, prices reflect all obviously public information; and finally, if a market shows a *strong form* of efficiency, all available information, even information that only certain groups of people can access, is fully reflected in the prices. This is all based on the assumption that investors are well informed and that all their decisions are rational. According to Fama (1969), "there is no important evidence against the hypothesis in the weak and semi-strong form tests and only limited evidence against the hypothesis in the strong form tests". Naturally, the evidence against the hypothesis of the model has grown significantly during the past years.

The strong form, which is the hypothesis of perfectly efficient markets and is assumed as true in several well-known classical economic models, implies that well-informed investors will adjust the price of the asset immediately after the information is available. This, as an article of the newspaper The Economist (2009) mentions, means that "trying to beat the market was a fool's errand for almost everyone". Although, this leads to a paradox in the whole concept of the efficiency since, as they also mention, quoting Joseph Stiglitz, "a little inefficiency is necessary to give informed investors an incentive to drive prices towards efficiency".

2.3. Introduction to behavioral finance

The central idea when speaking about behavioral finance is the distinction between a rational investor and a 'normal' one. For the scheme where all investors are rational, markets are efficient; and in the other case, when assuming 'normal' investors, markets do not necessarily fulfil efficiency. As Thaler (2010) mentions, modern financial economic theory is based on the assumption that the *representative agent* in the economy is rational in two ways: makes decisions according to the axioms of expected utility theory and makes unbiased forecasts about the future. Most economists recognize this extreme version as unrealistic.

According to standard financial models, investors are to always make rational decisions. Following Miller and Modigliani's definition quoted by Statman (1995), "investors always prefer more wealth to less and never get confused by the form of wealth". Thus, markets are efficient and expected returns are a function of one variable: risk.

In contrast, the behavioral finance theory takes in account that investors are also normal people and that they do not always act rationally. 'Normal' investors are bound to have problems at realizing losses; they are affected by cognitive biases, such as loss aversion, which can lead to poor decisions; and emotions, that often interfere on the optimal decision making. Another difference between a rational investor and a normal one is the form of wealth. We all agree that the more wealth the better, but for 'normal' people, wealth could differ from the concept assumed by standard financial models. According to Statman (2010), "sometimes normal people want more status or more social responsibility and are willing to sacrifice wealth for them".

The theory of behavioral finance has introduced important concepts to studying the markets and the behavior of the decision makers within a psychological and sociological point of view, revealing that the traditional financial economic theories are far from explaining the real behavior of the agents in a market. As Thaler (2010) stated, "perhaps the most important contribution of the behavioral finance on the theory side is the careful investigation of the role of markets in aggregating a variety of behaviors". Nevertheless, as mentioned before, behavioral economists haven't proposed a robust model to replace the assumptions made by the standard economic theories.

2.3.1. Evidence against the EMH

The premise of behavioral finance is that cognitive biases may influence investor's decisions and therefore affect asset prices, but there is more evidence highlighted by behavioral economists against the EMH. Based on what Richard Thaler wrote in 2010 about certain areas in which the real world seem to differ with the classical economic theories, some of this evidence is presented hereafter:

- According to classical models of asset markets, in a world where everyone is rational, and everyone knows that everyone is rational, the volume of transactions would be very low. The reason is that if someone offers to buy an asset and someone else offers to sell it, the buyer would wonder what information has the seller that he does not. Although it is difficult to estimate how much would be the exact volume in this efficient world, the extremely high amount of money that real financial markets register would definitely be more than what these models would predict.
- In an efficient market, the prices of the assets would only change with news, but as one can observe in real markets, the stock prices appear to vary substantially more than can be justified only by sporadic news. Thus, financial assets prices are more volatile than what the efficient market theory would predict.
- The standard models assume that the difference between the return offered by assets is dependent only on the risk. Nevertheless, although it is logical that the expected return of equities is higher than bonds, in reality the return differential is too high to justify only by risk.

3. Review of tests for weak form efficiency

As previously stated, the concept of market efficiency is particularly relevant among the study of economic finance. The high difficulty in empirically measuring with accuracy the strong and semi-strong forms of efficiency has led to a growing appreciation of the importance of the psychological and sociological theories contributed by behavioral economists. However, in the case of the weak form of efficiency, there are various empirical tests destined to contrast whether the markets behave as a random walk and therefore the impossibility of predicting future prices or returns based of the historical series.

In this following subsections the paper reviews the mostly used tests when contrasting the weak form of efficiency, which as mentioned above suggests that past prices are not an indicator of future prices, and choose some of them to contrast the efficiency in a weak form in the stock markets of Latin America and Europe. The tests generally used in studies are the following ones.

3.1. Random Walk Hypothesis

Economic theory has made a big effort in verifying whether the return series of financial assets behave as a random walk or not. Thus, various random walk hypothesis with different perspectives have been proposed by researchers to evaluate this paradigm. The hypothesis explained below considers one of the most used ways of evaluating if returns can be forecasted.

According to this hypothesis, a market is weak form efficient in the case that the most recent price is the best predictor of the future prices. The test considers the following process of random walk with[1]:

$$P_t = P_{t-1} + \beta + \varepsilon_t,$$

Or the similar one,

$$r_t = \Delta P_t = \beta + \varepsilon_t$$

Where:

P_t : Index's price observed in t
r_t : Change of the index's price
β : Arbitrary drift parameter
ε_t : Random disturbance term. White noise

[1] See Worthington and Higgs, 2004 for further details about the Random Walk Test.

3.2. Autocorrelation test

Also known as the serial correlation coefficient test, it is a widely employed procedure that tests the relationship between returns in the current period and the ones in previous periods. If no significant autocorrelations are found, the series are assumed to follow a random walk.

Ljung and Box (1978) contributed with their Q-statistic to test the joint hypothesis that all the autocorrelation coefficients ρ_k are simultaneously equal to zero. The test statistic is defined as follows:

$$LB = n(n+2)\sum_{k=1}^{m}\left(\frac{\hat{\rho}_k^{\,2}}{n-k}\right)$$

Where,

n : Number of observations

m : Lag length

The test follows a chi-square X^2 distribution.

3.3. Unit root tests

Another efficient way of testing whether the weak form of the EMH is applicable for a stock index is to test the stationarity of the time series of returns. If a series is stationary, the mean and auto covariance are independent of time, and this can be extrapolated to a fulfilment of the weak form efficiency. The commonly used unit root tests to contrast the stationarity are: the Augmented Dickey Fuller test (ADF test), proposed by Dickey and Fuller (1979), Phillips-Perron (PP test), test proposed by Phillips and Perron (1988); and the Kwiatkowski, Phillips, Schmidt and Shin test (KPSS test), stated by Kwiatkowski, et al. (1992). All these mentioned tests contrast whether the time series contains a unit root, which means non-stationarity. A unit root, also called a "difference stationary process" is a stochastic trend in a time series. If a time series has a unit root, it shows a systematic pattern.

The equation of the unit root tests is the following:

$$\Delta R_t = \alpha_0 + \alpha_1 t + \sum_{i=1}^{k}\beta_i \Delta R_{t-1} + \varepsilon_t$$

Where:
R_t : Daily return of the index at time t
$R_t = \{ P_t , P_{t-1}$: daily closing price at day t and t-1$\} = \log(P_t / P_{t-1})$
α_0 : Constant
α_1 : Estimated coefficient for the trend
k : Number of lagged terms

β_i : Coefficient to estimate
ε_t : Random disturbance term. White noise σ^2

The null hypothesis both in the ADF and PP tests is $H_0 : \beta_i = 1$, and the alternative hypothesis is $H_1 : \beta_i < 1$. Thus, in these cases if the null hypothesis of a unit root is accepted, the time series is non-stationary; and in the alternative case, if the null hypothesis is rejected, the time series is stationary. In the case of the KPSS test, the null hypothesis $H_0 : \beta_i < 1$ and the alternative is $H_1 : \beta_i = 1$. Hence, if the null hypothesis is accepted, the time series is stationary. For all the tests the null hypothesis is rejected if the test statistic is lower than the critical value. As non-stationarity is a requirement for the fulfillment of the RWH, if the return series are found to be stationary one can conclude that there is evidence against the EMH.

It is important to note that some authors, such as Ruiz-Porras and Ruiz-Robles (2015), associate the weak form of market efficiency with the non-stationarity of the price series. Nevertheless, as the weak form efficiency suggests that the variation of the prices is random and unpredictable, authors such as Worthington and Higgs (2003) and Srinivasan (2010) investigate the non-stationarity on the return series in order to find stronger evidence in favor of the weak form efficiency. Thus, as observed above, this paper will execute the study from the perspective that non-stationarity on the return series supports the EMH.

3.4. Runs test

The runs test developed by Berenson and Levine (2002) determines whether successive returns are independent and, unlike the Autocorrelation test, is a non-parametric test and does not require the series of returns to distribute as a normal. The number of *runs* refers to the sequence of successive price changes with the same sign. Observing the *runs*, the null hypothesis of randomness of the series is tested.

To employ this test, each return is classified according to its position with respect to the mean return. Thus, a positive change is when the return is higher than the median, a negative change is when the return is lower than the median, and zero change then the return equals the mean of the series.

To perform the test A is assigned to each return that is above or equal to the mean return, and B to the items that are below the mean. When using a large size of sample (more than 30 observations), the test statistic is approximately normally distributed and is found as follows:

$$Z = \frac{U - \mu_U}{\sigma_U}$$

Where,

U : Number of runs

$$\mu_U = \frac{2n_A n_B}{n} + 1$$

$$\sigma_U = \sqrt{\frac{2n_A n_B(2n_A n_B - n)}{n^2(n-1)}}$$

And,

$n =$ { Sample sizes of items A and B} $= n_A + n_B$

The runs test employs an intuitive methodology in order to contrast the randomness of the return series. If a series shows the same amount of runs of both positive and negative returns, it would imply that the probability of a positive return in the future is the same as that of a negative return, equal to 50%.

3.5. Variance ratio test

The variance ratio test is another interesting and widely applied method to investigate the existence of market efficiency. However, due to time constraints and the scope of this paper, this test will only be reviewed in this section but not applied further in the empirical study.

The variance ratio test was proposed by Lo and MacKinlay (1988). This test compares the variance of the returns measured in two periods. When the RWH is found true, the variance of a multi-period return is equal to the sum of the single period variances. Thus, assuming the return at t as R_t, the variance ratio, $VR_{(q)}$, is defined as the following expression:

$$VR_{(q)} = \frac{\sigma^2(q)}{\sigma^2(1)}$$

The standard normal test statistics $Z(q)$ and $Z^*(q)$ are expressed as:

$$Z(q) = \frac{VR\ (q)-1}{[\psi(q)]^{\ 1/2}} \approx \mathrm{N}(0,1)$$

$$Z^*(q) = \frac{VR\ (q)-1}{[\psi^*(q)]^{\ 1/2}} \approx \mathrm{N}(0,1)$$

Where $\psi(q)$, $\psi^*(q)$ are the asymptotic variance of the variance ratio and the assumptions of homoscedasticity (constant variance) and heteroscedasticity (non-constant variance), respectively. And they are computed as follows:

$$\psi(q) = \frac{2(2q-1)(q-1}{3q(nq)}$$

$$\psi^*(q) = \sum_{j=1}^{q-1} \left[\frac{2(2q-j)}{q}\right]^2_{\Upsilon(j)}$$

Where $\Upsilon(j)$ is the heteroscedasticity - consistent estimator, defined as:

$$\Upsilon(j) = \frac{\sum_{t=j+1}^{nq}(P_t - P_{t-1} - \mu)^2 (P_{t-j} - P_{t-j-1} - \mu)^2}{\sum_{t=1}^{nq}(P_t - P_{t-1-\mu})^2}$$

It is important to realize that both the standard normal Z – statistics and Z^* - statistics are approaching N(0,1).

4. Literature review

Fama (1991) declared that market efficiency in its most extreme version is not per se testable and therefore, to be tested it must be together with an asset pricing model, such as the CAPM. Thus, assuming the CAPM is a good model, if it is possible to prove that there is an excess of returns relative to the CAPM, there might be evidence that the market is not efficient. Otherwise, in case that the returns follow the results obtained by the pricing model, the evidence would be for the existence of market efficiency. Nevertheless, the EMH can also be tested by levels, beginning from the weak-form efficiency, which this paper will test for with the mentioned indexes from Latin American and European stock markets.

The first important tests of efficiency were return-forecasting regressions, which implicitly gave an idea of whether stock prices follow a random walk. Their successors are Euler-equation tests, which are fundamentally discounted return-forecasting regressions. These kinds of tests were strongly criticized for not being pure tests of efficiency but tests of joint hypotheses that include constant discount rates or investment opportunities. Additionally, if there are unpredictable *booms* or *crashes* that are not related to subsequent events, the return regression will not take them in account. Although landscaping these tests to provide a general overview of the first ideas of efficiency tests, this paper will not study them further in detail.

Many studies have been carried out in different stock exchanges in the world in order to test the weak form EHM[2]. The empirical results have been obtained both by using parametric tests, such as the autocorrelation test and the Breusch-Godfrey test; and non-parametric tests, such as the Block, Dechert and Sheinkman test and run tests. Other authors have utilized univariate unit root tests to check the stationarity of the time series. These tests are traditionally the ADF test, the PP test and the KPSS test.

The study of the RWH is still of great concern to many researchers and there are differing opinions and results defending both that stock markets follow a random walk and others that stock prices have a predictable component by analyzing the information from past prices, not behaving as a random walk. A market that follows a random walk means consistency in prices, an equilibrium level; and in the opposite case, when it is found that a market does not follow a random walk, there are distortions in the pricing of the relation between capital and risk. This has very important consequences within the allocation of capital.

[2] These studies include research on the stock exchanges in China, Hong Kong and Singapore (Araújo Lima and Tabak, 2004), China (Groenewold, Tang, and Wu, 2003), Tanzania (Njuguna, 2016), Canada (Shiller and Radikoko, 2014), India (Srinivasan, 2010), Latin America (Worthington and Higgs, 2003) and Europe (Worthington and Higgs, 2004).

4.1. Studies in emerging countries

Some of the many empirical studies on weak form efficiency in Asian stock markets (i.e. emerging countries) such as the one made by Groenewold et al. (2003) of the Shanghai and Shenzhen stock exchanges found that these markets are not weak form efficient. However, other authors have concluded that the hypothesis cannot be rejected for some shares indexes in these two stock exchanges, as suggested for example by the results of Araújo and Tabak (2004). Moreover, Seddighi and Nian (2004) found that the Shanghai Stock Exchange is weak form efficient for the period from January to December of the 2000.

Srinivasan (2010) found by using the unit root tests ADF and PP that two of the major indexes in the Indian stock exchange are not weak form efficient. In addition, Alam et al. (1999) reported that the RWH cannot be rejected for the returns of the markets on the Bombay (India) and Dhaka (Bangladesh) stock exchanges.

Australian professors Worthington and Higgs (2003) examined the weak form market efficiency in seven Latin American stock markets, Argentina, Brazil, Chile, Colombia, Mexico, Peru and Venezuela. All their results were obtained by applying serial independence tests, unit root tests and multiple variance ratio tests, and agreed on rejecting the presence of random walks in the daily returns collected from all these stock markets. Also, professors Worthington and Higgs (2004) tested the weak form efficiency in four European emerging markets, Czech Republic, Hungary, Poland and Russia with the previously mentioned tests, finding that the only market in which the RWH is accepted is the Hungarian, meaning that the other three were found inefficient in the weak form.

4.2. Studies in developed countries

Even though lately researchers have worked frequently to test inefficiency in emerging markets on a regional basis, other studies have focused on the testing of the weak form efficiency in stock markets from developed countries, which in theory should show higher levels of efficiency given the high level of transactions, volumes of capital and the advanced technological algorithms utilized for transactions, that influence the prices to adjust faster to their efficient levels. This fast correction by the markets leads to fewer opportunities to make profit by speculative operations when “beating” the market.

Worthington and Higgs (2004) tested the weak form EMH in sixteen developed stock markets in Europe: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom. This study concludes that “among the developed markets, only Germany, Ireland, Portugal, Sweden and the United Kingdom satisfy the most stringent random walk criteria with France, Finland, the Netherlands, Norway and Spain meeting at least some of the requirements of an strict random walk”.

Another study about the validity of the weak form EMH in a developed market is the one that Shiller (2014) carried out on the Canadian stock markets. The author tested seven indexes of the North American country with both parametric and non-parametric tests: auto-correlation test; three unit root tests, the ADF test, the PP test and the KPSS test; run tests; and serial correlation coefficient tests. The results of the tests gave an evidence of a general weak form Canadian stock market inefficiency.

5. Methodology

5.1. Data selection

All the data analysis and the empirical study will be carried out by using the software for programming language R-Studio and the data bases utilized will be the historical daily returns from July 15st of 2002 to February 19st of 2018 of the indexes COLCAP, IPSA, S&P BMV IPC and S&P Lima General, from Latin America; and the indexes IBEX 35, DAX, CAC 40 and FTSE 100, from Europe. Since the extracted data also contains nonworking days (e.g. weekends, local holidays) during which markets are closed, these have been excluded from the series in order to avoid null returns that could act as a noise when executing the tests. This data is made publicly available by law to maintain the transparency within the market.

5.2. Data analysis

In order to examine whether the time series of the indexes' returns, $\log(P_t / P_{t-1})$, fulfill the requirements to be considered efficient in a weak form, three different tests, among the most commonly used in the academic world, will be applied. Firstly, to measure the stationarity of the series of returns, which means that the mean and the auto covariance of the series do not depend on time, this study will consider three popular unit root tests: the ADF test, the PP test and the KPSS test. Secondly, another widely employed procedure that tests the relationship between returns, the Ljung-Box test (L-B test), which gives information about the autocorrelation of the series; and finally, the runs test will be also applied with the objective of contrasting the existence of weak form efficiency. With the information provided by this three tests we will definitely be able to have an idea of the level of efficiency presented in the two stock markets.

These particular tests were chosen because they are widely used among researchers when analyzing the weak-form efficiency and are proven to contribute to the contrast of whether the series of returns of financial assets show the characteristics of a random walk. Additionally, this paper aims to investigate the market efficiency from different perspectives:

- The unit root tests provide an explanation of whether series exhibit a trend and therefore are predictable. By testing the stationarity, these tests reveal if the series of returns show to behave as a random walk. If a series is found to be stationary, it is assumed to be predictable as it fluctuates around a constant value and thus, not weak-for efficient.
- The autocorrelation test focuses on testing the linear correlation between the observations. If it is not possible to reject that the series has no lineal correlation, then there is evidence to believe that the series follows a random walk.
- The runs test studies the return series by converting it to a binary series, where 1 contains the returns above the median and 0 the returns below it. Through checking the *runs*, or in other words, the amount of periods without changing from

1 to 0 or vice versa, the test evaluates the persistence of returns, which could lead to an indicator of non-randomness. This test contrast per se the null hypothesis of randomness in the series.

Additionally, the paper will not only study the series of returns as one, but also intends to contrast the weak form efficiency dividing the series in three different spaces of time. From July 15st of 2002 to December 31stof 2007, period that will be called *pre-crisis*; from January 1st of 2008 to December 31st of 2010, period where the *crisis* was most pronounced; and finally, the period that in the paper will be referred as *post-crisis*, from January 1st of 2011 to February 19th of 2018.

Following the assessment of the market efficiency in the mentioned indexes, the paper will make a comparison between the results in the different countries, aiming to contribute to the decision making for investors and to reveal the implications of investing in inefficient markets. Finally, to conclude the study and understand more deeply the reasons of the market inefficiency, there will be a section to explain briefly the main theories of Behavioral Economics theory and to explain the 'irrational' decision making that leads to inefficient markets.

6. Empirical Study

6.1. Expectations a priori

Prior to testing the weak form efficiency in the return series and building on the previous discussions of the potential efficiency in the different financial markets, the expectations *a priori* are that the European markets will be more weak form efficient than the Latin American ones. The latter countries, members of the MILA and potent emerging markets, are growing gradually towards an organized stock market. Nevertheless, the expectations *a priori* are that the efficiency levels will be inferior to the developed markets. Furthermore, the British market is expected to show the highest levels of efficiency. These expectations are founded on the size of the markets in terms of transactional volume and the transparent flow of relevant information.

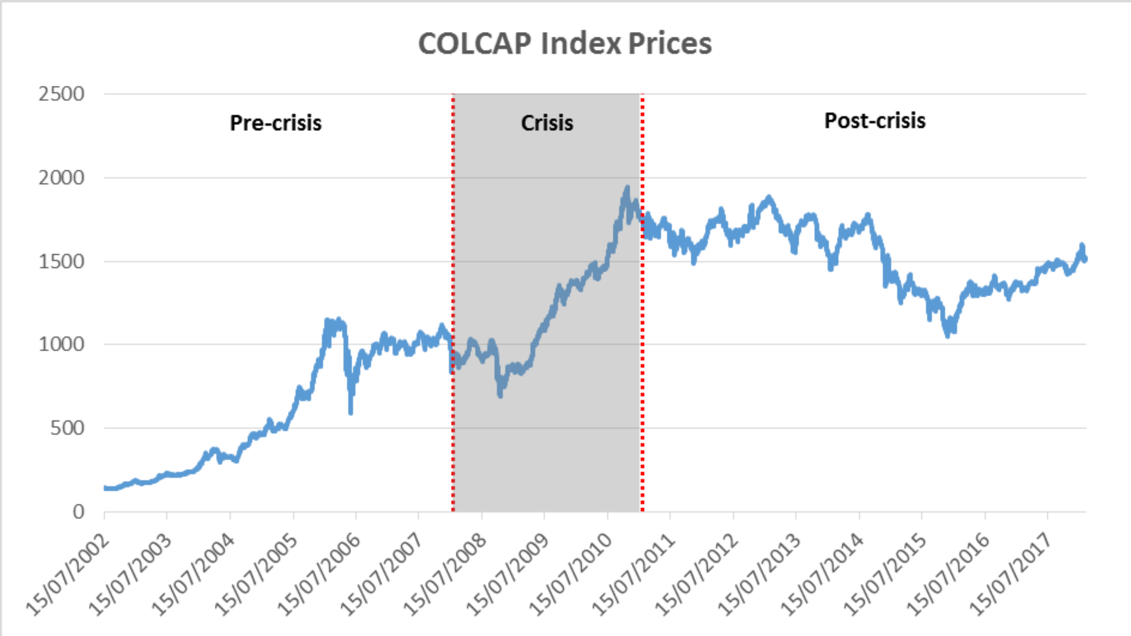
6.2. Descriptive analysis of the series

This section is relevant for the study as it facilitates the understanding of the results stemming from the performed tests for market efficiency. Foremost, it contains the graphs of the prices from each index, in which we observe the evolution of those prices along three different periods: *pre-crisis*, *crisis* and *post-crisis*. These graphs demonstrate visually the volatility that the indexes exhibited in each period, highlighting the performance during the *crisis*.

As the paper focuses its main analysis on the series of logarithmic returns, used to test the efficiency, this section also includes the descriptive analysis of these series. The most relevant information provided by this descriptive analysis is the minimum and maximum daily returns; the mean, which should tend to be very close to zero; the symmetry and the kurtosis of the series. Additionally, the histogram provides graphic information on the frequency of positive and negative returns.

When going more into detail for each of the series it became apparent that the following elements were similar in all series. Firstly, the negative impact of the crisis appears to have affected the developed countries more, as the uncertainty among the investors in these countries drove an influx of investments to the developing countries. This is supported by the figures that show the behavior of the series of prices of each index, presented in Annex A – Descriptive analysis support, or as can be seen below in Figure 1 for the Colombian index. Secondly, looking at the descriptive statistics and the histograms of the logarithmic returns of the series of each index, that the distribution of the series shows a longer positive tail than the negative tail demonstrates that in the best scenario for investors they would receive a higher return than what they would lose in absolute terms in the worst case scenario. This asymmetry indicates an incentive for investors and provides preliminary evidence against the theory of efficient markets. Additionally, all series of returns are characterized as being leptokurtic, which means that the kurtosis' coefficient is higher than zero and therefore these series exhibit thicker tails than the Normal distribution. Lastly, in all cases the positive returns displayed a higher frequency than the negative returns. However, although the mean is positive, it is noticeably close to zero. The evidence of these particularities is illustrated for the Colombian index in this section as an example (see below Table 1 and Figure 2). Similar support for the other series is provided in Annex A – Descriptive analysis support.

Figure 1: Graph COLCAP Index Prices



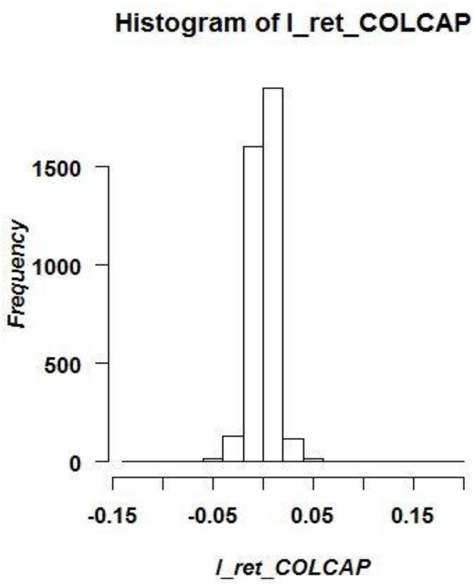
Source: Own elaboration

Table 1: Descriptive Statistics of the COLCAP Index Return Series

	l_ret_COLCAP
nobs	3802.000000
NAs	0.000000
Minimum	-0.132538
Maximum	0.181263
1. Quartile	-0.004492
3. Quartile	0.006494
Mean	0.000624
Median	0.000806
Sum	2.373362
SE Mean	0.000206
LCL Mean	0.000221
UCL Mean	0.001028
Variance	0.000161
Stdev	0.012688
Skewness	-0.108576
Kurtosis	21.929333

Source: Own elaboration

Figure 2: Histogram COLCAP Index Prices



Source: Own elaboration

6.3. Result analysis of weak form market efficiency tests

As mentioned in the methodology, the tests were applied to the return series of each index in four different space times: the complete series, the *pre-crisis* series, the *crisis* series and the *post-crisis* series. As the interpretation can be extrapolated to the results of the rest of the series, this section only includes Table 2 with the overview of the results for the Colombian index COLCAP. The other overview tables can be found Annex C – Overview Tests and Autocorrelation Tables of Return Series.

Analyzing the results of the unit root tests, the ADF and the PP tests find that in every case the null hypothesis of non-stationarity is rejected with 99% confidence level. The critical value for rejecting the null hypothesis with a confidence level of 99% is -3,43 and the closest result to this critical value is the statistic value of -13,089 found in the United Kingdom during the *crisis* period, the other ones are even more negative. Thus, according to both these tests, the series are stationary. After observing these results in both the ADF and PP tests, it is expected that the other unit root test applied, the KPSS, would show similar results. However, in the case of this test, the results are more diverse: the test rejects the null hypothesis of stationarity with a confidence level of 99% in the cases of Colombia in every period (Table 2), and with a 90% of confidence level in Chile during the *post-crisis* period (Table 11) and in Germany during the *crisis* (Table 15). In the rest of the cases, the test fails to reject the null hypothesis, which indicates stationarity in the series. The non-stationarity is a requisite for the fulfillment of the RWH, and therefore, these tests give signals of a general weak form inefficiency in the case of all the return series, except for the mentioned cases where the KPSS fails to reject its null hypothesis. Although, the KPSS test gives signals of weak form efficiency in some cases, it is considered contradictory due to the results given by the other two unit root tests.

The Ljung-Box test was applied to contrast whether the series show autocorrelation between the current period and the previous ones, and therefore future prices are a function of the previous periods. The result in this case, according to the EMH, should be that the autocorrelation between all the periods is equal to zero, which in the L-B test is the null hypothesis. Thus, a failure in rejecting the null hypothesis will be considered as evidence in favor of the EMH. Having said this, reviewing the results it is found that the L-B test failed to reject the null hypothesis in the cases of Mexico during the *pre-crisis* (Table 12) and the United Kingdom during the *post-crisis* (Table 17); in the rest of the cases the null hypothesis was rejected. Nevertheless, the level of confidence to reject the null hypothesis was not always 99%, in the cases of Spain during the *pre-crisis* (Table 14), Germany during the *crisis* and *post-crisis*, and France during the *post-crisis* (Table 16), the test rejected the null hypothesis with a confidence level of 95%; and during the period of *crisis* in Colombia and Spain, it rejected the null hypothesis with a confidence level of 90%.

The runs test contrasts in a direct way the randomness of the series, this being the null hypothesis. Therefore the failure in rejecting the null hypothesis can be interpreted as an evidence in favor of the EMH. This test is widely used by researchers in order to verify whether a variable behaves as a random walk, not only in the context of economic or financial variables, but in different fields of study as well. Thus, the evidence that this test contributes to testing the randomness of the return series, and therefore the weak form efficiency, is considered highly relevant.

The results of the runs test show an interesting diversity between continents, countries and periods. The null hypothesis of randomness was accepted in the cases of Mexico during the *pre-crisis*, *crisis* and *post-crisis*; in Spain, Germany and the United Kingdom during the *crisis* and *post-crisis*; and in France during the *crisis*. In the rest of the cases the null hypothesis was rejected. The confidence level for rejecting the null hypothesis was of 99% in the cases of the *pre-crisis* in Colombia, Spain, Germany and France, and in every period in both Chile and Peru; of 95% in the cases of the *crisis* and *post-crisis* in Colombia; and of 90% in the cases of the *pre-crisis* in the United Kingdom and the *post-crisis* in France.

The tables contain the overview of the test results for the periods of *pre-crisis*, *crisis* and *post-crisis*. Nevertheless, all the tests were applied for the complete series (from July 15st of 2002 to February 19st of 2018), where it was found that the ADF and PP tests rejected the null hypothesis for every return series; the KPSS rejected the null hypothesis with a 99% of confidence level for Colombia and Spain; for Peru with 95%; and for Mexico a 90%. The test of autocorrelation rejected the null hypothesis for every return series with a confidence level of 99%; and the runs test rejected the null hypothesis with 99% of confidence level for Colombia, Chile, Peru, Germany and France; with a 95% for Mexico; and failed to reject the null hypothesis in the cases of Spain and the United Kingdom.

Thus, when testing the complete series, there are signals of weak form efficiency in Spain and the United Kingdom due to the results found with the runs test. The KPSS test gave signals of weak form efficiency for Colombia, Chile and Peru. However, as it was said previously, it seems to give confusing signals as it contradicts the results found by the other two unit root tests.

Table 2: Overview of the COLCAP Index weak form efficiency tests

		ADF Test	PP Test	KPSS Test	L-B Test	Runs Test
Null Hypothesis (H_0)		Non-stationarity	Non-stationarity	Stationarity	No serial correlation up to 20 lags	The return series behaves as a random walk
Pre- Crisis	Statistic	-24,1045 ***	-29,7558 ***	0,2068***	-	-
	P-value	-	-	-	$2{,}22e^{-16}$ ***	$2{,}2e^{-16}$ ***
	Conclusion	Reject the H_0	Reject the H_0	Reject the H_0	Reject the H_0	Reject the H_0
Crisis	Statistic	-18,2554 ***	-25,3996 ***	0,3708***	-	-
	P-value			-	0,05425 *	0,04179 **
	Conclusion	Reject the H_0	Reject the H_0	Reject the H_0	Reject the H_0	Reject the H_0
Post-Crisis	Statistic	-26,6792 ***	-35,7603 ***	0,1127***	-	-
	P-value	-	-	-	$1.014e^{-6}$ ***	0,01103 **
	Conclusion	Reject the H_0	Reject the H_0	Reject the H_0	Reject the H_0	Reject the H_0
Note: * indicates significance level at 10%; ** indicates significance level at 5%; *** indicates significance level at 1%.						

Source: Own elaboration

6.4. Comparison of weak form efficiency between countries

This section includes a graphic representation of the evidence given by the tests mentioned previously. The objective is to display in a clear way the differences found between the countries and the continents and compare the results. Therefore, Table 3 contains all the countries studied, with every temporal division and every test applied. The color green represents evidence that supports weak form efficiency; and the red color when the evidence is against it. The first page of the table shows the evidence in the Latin American countries members of the MILA; and the second page has the European countries.

The first two columns are all red because, as it was said in the previous section, both the ADF test and PP test rejected the null hypothesis of non-stationarity, which is an evidence against the weak form efficiency. The other unit root test, the KPSS shows evidence supporting weak form efficiency in some cases, mostly in Colombia, where every period is appears to be green.

Now, in the case of the Latin American countries, the L-B test and the runs test gave evidence for weak form efficiency only in Mexico. Thus, Mexico is considered to be the most efficient market of the four countries of the MILA. The other three countries seem to have strong evidence against the weak form efficiency.

As it could be foreseen, the second page of the table, which contains the European countries, has more boxes in green, and thus, there is more evidence supporting the weak form efficiency. There is only one green box in the column of the L-B test associated to the period of *post-crisis* in the United Kingdom. However, the column of the runs test shows several green boxes: in Spain and the United Kingdom for every temporal division but in the *pre-crisis*; in Germany for the *crisis* and *post-crisis*; and in France only for the *crisis*.

The runs test appears to be the most accurate test to measure weak form efficiency, not only because of the intuitive procedure that uses to contrast its null hypothesis of randomness, but also because of the evidence that shows. As expected, the European markets demonstrate more evidence for weak form efficiency than the Latin American ones. In Europe, Spain and the United Kingdom appear to be the most weak efficient markets; and France the least efficient one. The British market was expected to be the most efficient as it is the biggest market in volume of transactions, it has high standards of information transparency and a large number of *blue chip* companies listed on the stock market.

Table 3: Overview of evidence for weak form efficiency

		ADF Test	PP Test	KPSS Test	L-B Test	Runs Test
Colombia	Pre- Crisis					
	Crisis					
	Post-Crisis					
	Complete series					
Chile	Pre- Crisis					
	Crisis					
	Post-Crisis					
	Complete series					
Mexico	Pre- Crisis					
	Crisis					
	Post-Crisis					
	Complete series					
Peru	Pre- Crisis					
	Crisis					
	Post-Crisis					
	Complete series					

		ADF Test	PP Test	KPSS Test	L-B Test	Runs Test
Spain	Pre- Crisis					
	Crisis					
	Post-Crisis					
	Complete series					
Germany	Pre- Crisis					
	Crisis					
	Post-Crisis					
	Complete series					
France	Pre- Crisis					
	Crisis					
	Post-Crisis					
	Complete series					
United Kingdom	Pre- Crisis					
	Crisis					
	Post-Crisis					
	Complete series					
Legend: **Evidence against EMH** **Evidence in support of EMH**						

Source: Own elaboration

7. Decision making: implications of market inefficiency

As shown in this study, there is important evidence against the market efficiency, even in its weak form. This section will discuss some of the implications of investing in an inefficient market. As it was mentioned previously, if a market is efficient, prices follow a random walk, and therefore cannot be predicted by studying previous prices. Thus, if a market shows inefficiency, one can make the following observations:

- The prices of the financial assets do not adjust quickly enough to forbid investors to make profits when the *intrinsic value* of the stocks (which is measured as the present value of the probable flows that the asset will generate) does not match with market value. This is an important strategy utilized in Fundamental Analysis. Nevertheless, although this is an implication of market inefficiency that works when following trends, it is important to mention that in reality the market stock prices often do not equal the *intrinsic value*.
- The Technical Analysis is widely used among the investors in order to find the most efficient moments to execute or leave investments, and to predict future prices by establishing probable scenarios analysing statistics and patters of the historical prices. Accepting the EMH by definition would then render Technical Analysis a worthless effort. Techniques such as Mobile Means and all type of trends would not contain any significant information to predict the future behaviour of the price series. Therefore, rejecting the hypothesis that markets are efficient is the first step when considering utilizing Technical Analysis.

  An inefficient market opens the opportunity for investors to use Technical Analysis.
- *Insider trading* is an illegal activity that consists of taking advantage of privileged information in order to make financial benefits on investing operations. Since one of the assumptions of the EMH is that all the available information is instantaneously reflected in the prices, not even people with monopolistic relevant information would have the opportunity to beat the market. However, as mentioned, in reality markets are not efficient, making *insider trading* possible.

8. Behavioral finance against the EMH

The concept and a brief description of the behavioral finance theory was mentioned in previous sections of the paper. This section contains a further detail into the theory and how it explains the absence of efficient markets in an extreme version in real financial markets by taking in account anomalies in the behavior of investors not taken in account in economic models.

As Statman (2010) described, "the standard finance has four foundation blocks": investors make rational decisions, markets are fully efficient, the design of portfolios is made according to the rules of the mean-variance portfolio theory; and the expectation of future returns is in function only of the risk. Although all these assumptions are difficult to fulfill, considering that all investors act rationally following the principles of wellness and utility is the most arbitrary one. This assumption also leads to efficiency in the markets together with the underlying consideration that expected returns only depend on risk and no more than that. An extremely valuable contribution made by the behavioral economists has to do with the redefinition of decision making theory, leading to analyzing investors within a psychological and sociological perspective. Quoting Statman (2010), "according to behavioral finance, investors are normal, not rational". Normal investors have emotions, pride and sometimes lack of relevant knowledge to make appropriate decisions, "normal investors are you and me, and even wealthy and famous people such as Martha Stewart. We are not stupid, but neither are we rational by Miller and Modigliani's definition".

8.1. Irrational investors

It is intuitively not difficult to realize that the *representative agent*, the one that makes unbiased forecasts of the future and makes decisions following the axioms of the expected utility theory, is unrealistic. According to behavioral economics, there are several cognitive biases that could affect the decisions made by the investors and cause what economic theory would consider an 'irrational' behavior.

Investors, even the trained ones, suffer of cognitive biases based on emotions such as pride, frustration, fear or even excessive confidence; on 'irrational' preferences when considering wellness; and on interpreting patterns. Thus, there are particular situations in which investors can make wrong decisions, or fail to correctly interpret the signals that the market sends. As there are several potential situations, a few examples are described below:

- An example of cognitive bias based on emotions could be when an investor does not execute an investment only because he believes the advisor is not properly informed and follows his own mind. Thereby, relying on his own confidence and pride, resulting into not investing at the most efficient moment.
- Secondly, an example of 'irrational' preferences of wellness is when an investor not only considers a financial return but also is interested in the non-financial

returns of the investment (e.g. a green bond investor that attributes more importance to the project behind the investment than the expected returns).

- And lastly, an example of cognitive bias when interpreting patterns is when an investor only bases his decision on similar past behaviors, such as considering as an investment strategy a pattern showed on the prices of an asset (e.g. when the graph of the price series portrays an ‘M’, it is time to execute the investment as the price will go up again). Often, prices actually follow a random walk, and are unpredictable by this type of assumptions.

Modeling different scenarios of human behavior is extremely difficult, but should be one of the most important goals of economic theory. Quoting Thaler (2010), “A drunk walking through a field can create a random walk, despite the fact that no one would call his choice of direction rational. Still, if asset prices depended on the path the drunk adopted, it would be a good idea to study how drunks navigate.”

9. Conclusions

This paper studies the concept and the implications of the EMH, and examines empirically the validity of the weak form efficiency on the Latin American and European markets. Moreover, it explains significant factors that affect market efficiency based on agents' behavior; and the premise that there are cognitive anomalies that influence investors' decision making leading to market inefficiency. Thereby, this study makes a contribution to financial theory in understanding the behavior of the markets. Additionally, it supports the urge of economic science to incorporate objective and factual-based assumptions in its theories by providing evidence against the general fulfilment of the EMH, which on the contrary is based on the arbitrary premise of the *representative agent*.

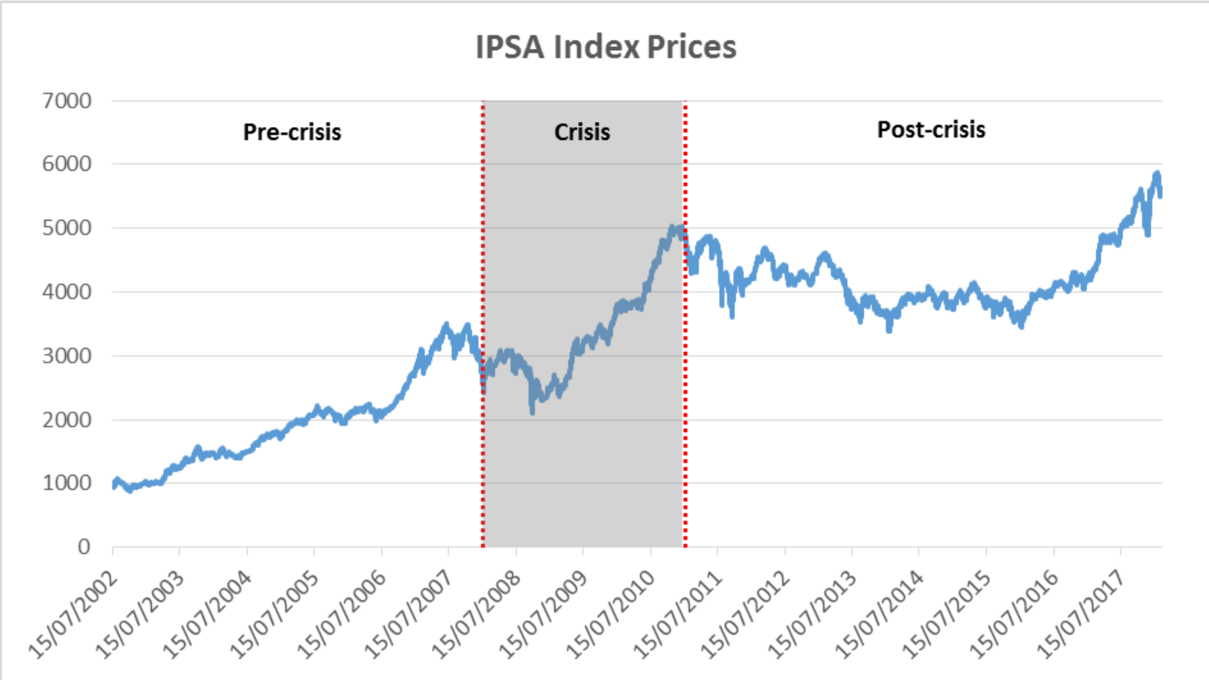
The empirical study focused on contrasting the weak form efficiency by applying three unit root tests, an autocorrelation test and the runs test on four indexes from Latin America and four from Europe over a period of 16 years, divided in sub-periods of *pre-crisis, crisis* and *post-crisis*. The expectation of results was to find that some markets are weak form efficient and that overall European markets are more efficient than the Latin American ones, founded on the fact that higher transactional volume and information transparency lead to higher market efficiency. Thus, it is considered that the runs test is the most appropriate test due to the evidence found with it, which resulted in evidence in favor of market efficiency in Europe in both Spain and the United Kingdom and in the Latin America in Mexico.

As a final point, this paper argues that the vision of the standard economic asset models is too narrow. The idea that the paradigm of the efficient markets fails to resemble the reality of the markets is supported by the evidence of this research, which indicated market inefficiency in all of the markets during at least one period of time. However, the difficulty of incorporating complex parameters of behavior in economic models is notorious. Nevertheless, in order to align the real behavior of the world with the theoretical one, economists need to continue studying a way of giving more flexibility to the models and thereby allow different scenarios of human behavior.

Annex A – Descriptive analysis support

Chilean index IPSA

Figure 3: Graph IPSA Index Prices



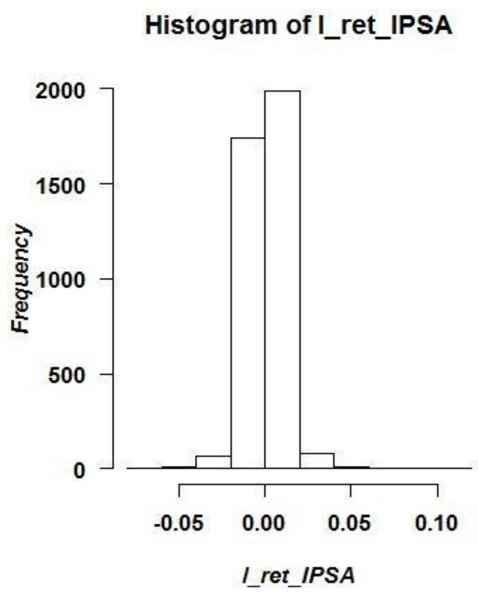
Source: Own elaboration

Table 4: Descriptive Statistics of the IPSA Index Return Series

	l_ret_IPSA
nobs	3892.000000
NAs	0.000000
Minimum	-0.071728
Maximum	0.118034
1. Quartile	-0.004473
3. Quartile	0.005666
Mean	0.000454
Median	0.000631
Sum	1.767990
SE Mean	0.000158
LCL Mean	0.000144
UCL Mean	0.000765
Variance	0.000098
Stdev	0.009876
Skewness	0.007708
Kurtosis	10.262029

Source: Own elaboration

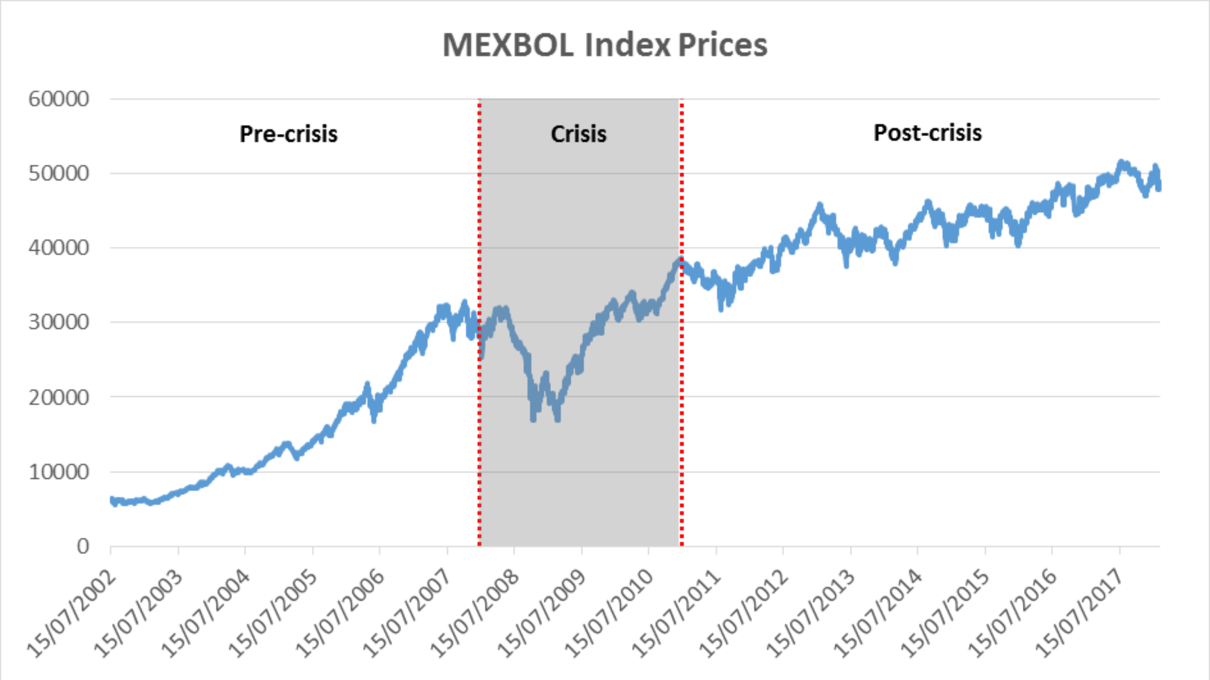
Figure 4: Histogram IPSA Index Prices



Source: Own elaboration

Mexican index S&P BMV IPC

Figure 5: Graph S&P BMV IPC Index Prices



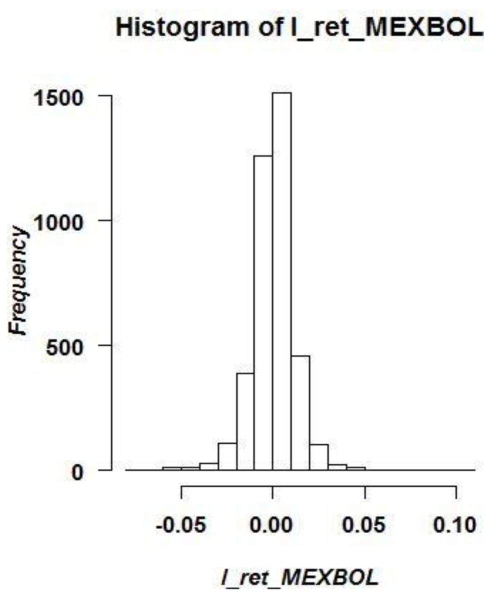
Source: Own elaboration

Table 5: Descriptive Statistics of the S&P BMV IPC Return Series

	l_ret_MEXBOL
nobs	3928.000000
NAs	0.000000
Minimum	-0.072661
Maximum	0.104407
1. Quartile	-0.005192
3. Quartile	0.006648
Mean	0.000519
Median	0.000856
Sum	2.037499
SE Mean	0.000192
LCL Mean	0.000143
UCL Mean	0.000894
Variance	0.000144
Stdev	0.012012
Skewness	0.036549
Kurtosis	6.473790

Source: Own elaboration

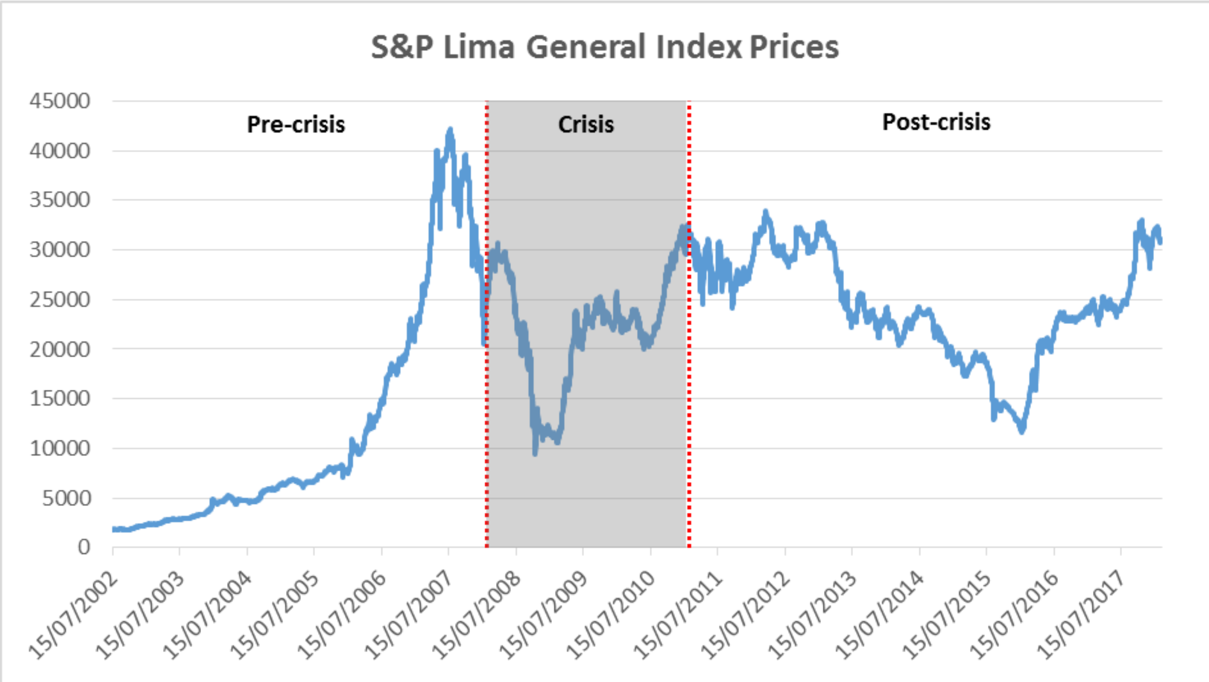
Figure 6: Histogram S&P BMV IPC Index Prices



Source: Own elaboration

Peruvian index S&P Lima General

Figure 7: Graph S&P Lima General Index Prices



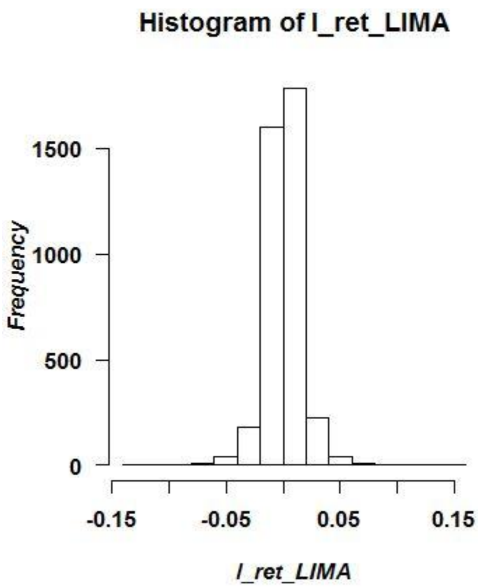
Source: Own elaboration

Table 6: Descriptive Statistics of the S&P Lima General Index Return Series

	l_ret_LIMA
nobs	3900.000000
NAs	0.000000
Minimum	-0.138558
Maximum	0.147389
1. Quartile	-0.005892
3. Quartile	0.007704
Mean	0.000727
Median	0.000713
Sum	2.833934
SE Mean	0.000257
LCL Mean	0.000224
UCL Mean	0.001230
Variance	0.000257
Stdev	0.016020
Skewness	-0.371512
Kurtosis	11.414993

Source: Own elaboration

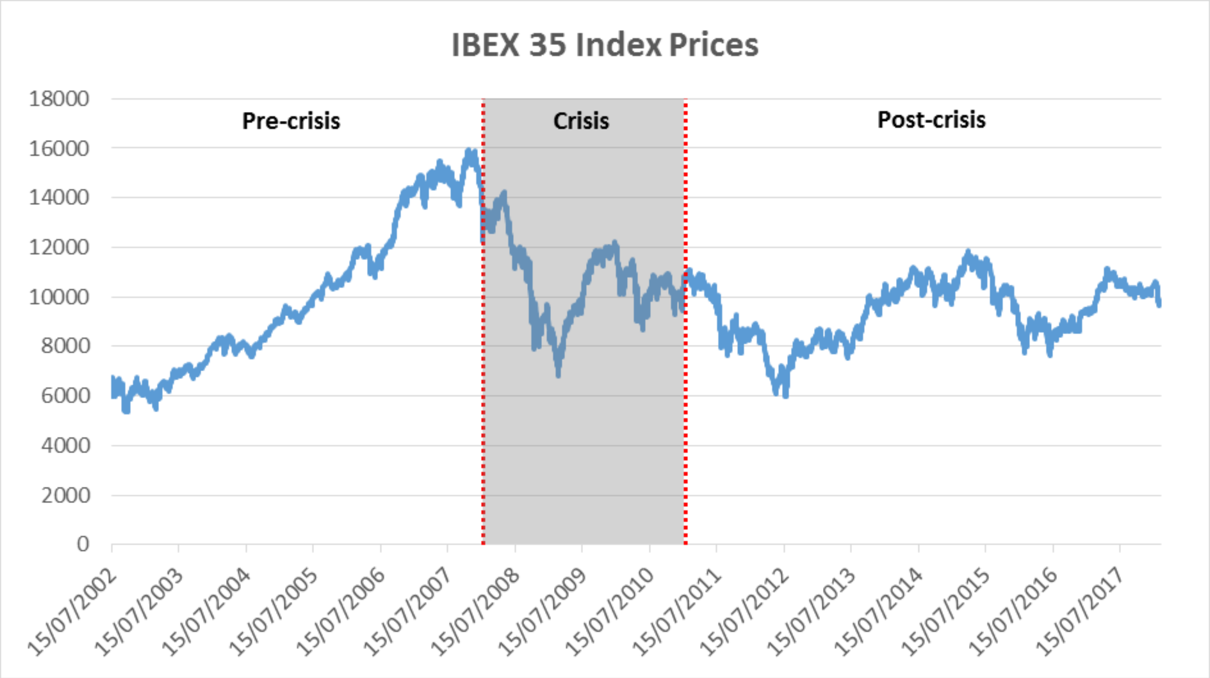
Figure 8: Histogram S&P Lima General Index Prices



Source: Own elaboration

Spanish index IBEX 35

Figure 9: Graph IBEX 35 Index Prices



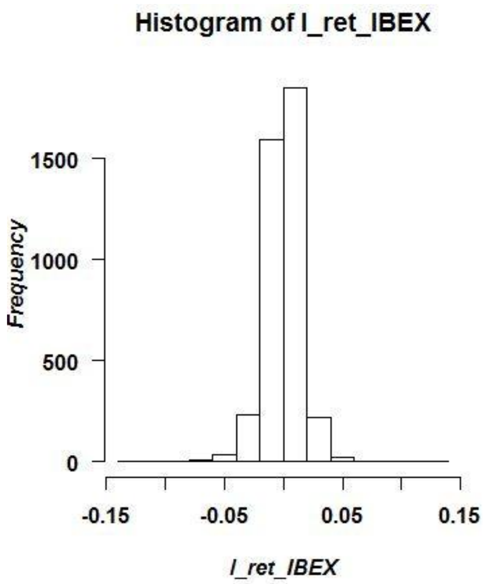
Source: Own elaboration

Table 7: Descriptive Statistics of the IBEX 35 Return Series

	l_ret_IBEX
nobs	3966.000000
NAs	0.000000
Minimum	-0.131853
Maximum	0.134836
1. Quartile	-0.006899
3. Quartile	0.007201
Mean	0.000107
Median	0.000738
Sum	0.425341
SE Mean	0.000233
LCL Mean	-0.000349
UCL Mean	0.000564
Variance	0.000215
Stdev	0.014669
Skewness	-0.090567
Kurtosis	7.057989

Source: Own elaboration

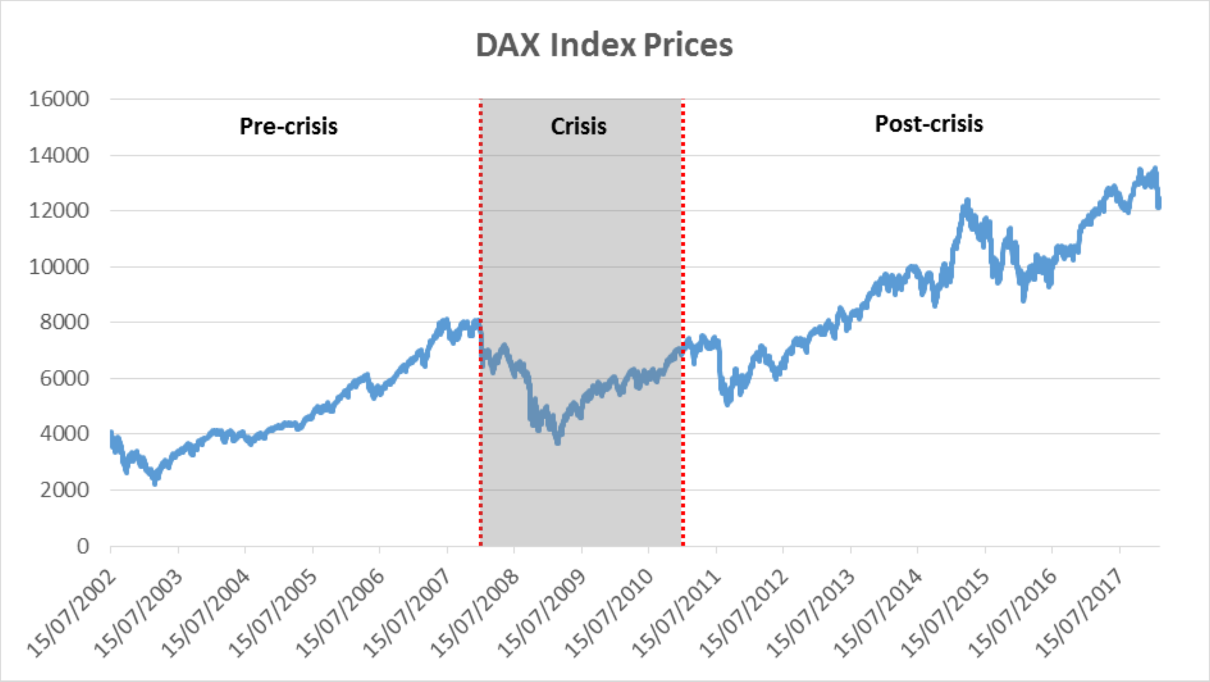
Figure 10: Histogram IBEX 35 Index Prices



Source: Own elaboration

German index DAX

Figure 11: Graph DAX Index Prices



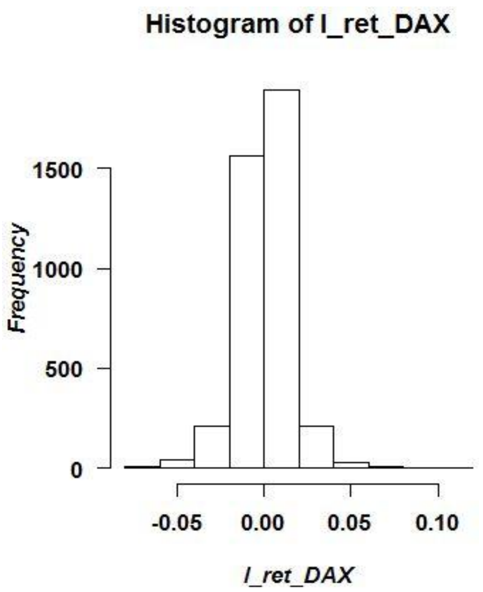
Source: Own elaboration

Table 8: Descriptive Statistics of the DAX Return Series

	l_ret_DAX
nobs	3966.000000
NAs	0.000000
Minimum	-0.074335
Maximum	0.107975
1. Quartile	-0.006193
3. Quartile	0.007215
Mean	0.000291
Median	0.000895
Sum	1.154465
SE Mean	0.000233
LCL Mean	-0.000165
UCL Mean	0.000747
Variance	0.000215
Stdev	0.014657
Skewness	-0.009454
Kurtosis	5.156913

Source: Own elaboration

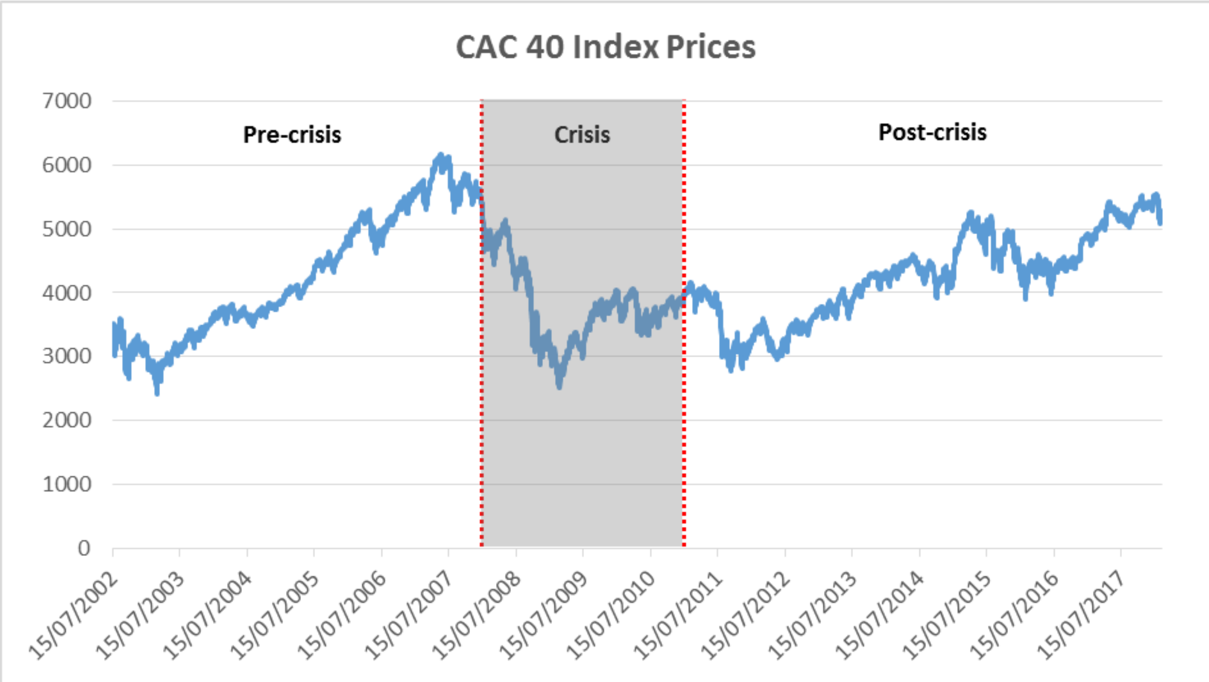
Figure 12: Histogram DAX index Prices



Source: Own elaboration

French index CAC 40

Figure 13: Graph CAC 40 Index Prices



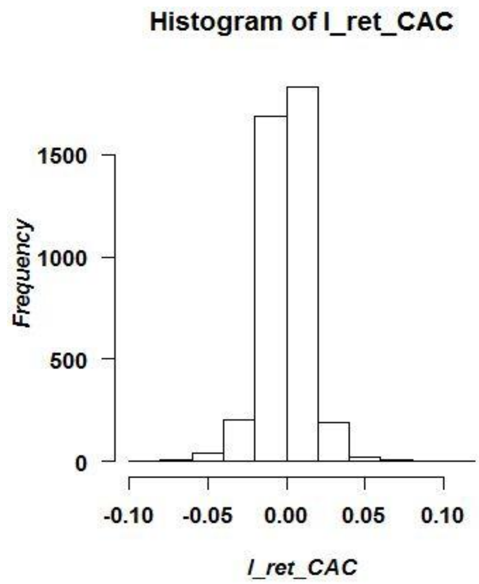
Source: Own elaboration

Table 9: Descriptive Statistics of the CAC 40 Return Series

	l_ret_CAC
nobs	3994.000000
NAs	0.000000
Minimum	-0.094715
Maximum	0.105946
1. Quartile	-0.006502
3. Quartile	0.007094
Mean	0.000115
Median	0.000391
Sum	0.460725
SE Mean	0.000227
LCL Mean	-0.000330
UCL Mean	0.000560
Variance	0.000206
Stdev	0.014342
Skewness	0.010885
Kurtosis	5.813497

Source: Own elaboration

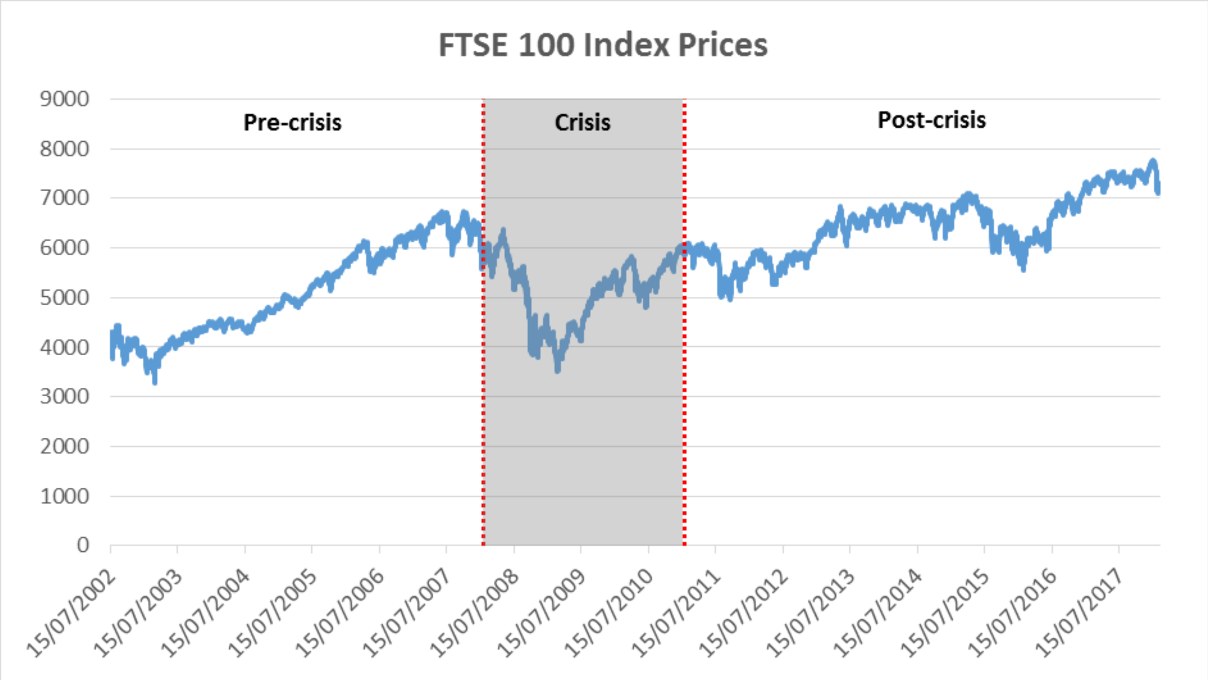
Figure 14: Histogram CAC 40 Index Prices



Source: Own elaboration

British index FTSE 100

Figure 15: Graph FTSE 100 Index Prices



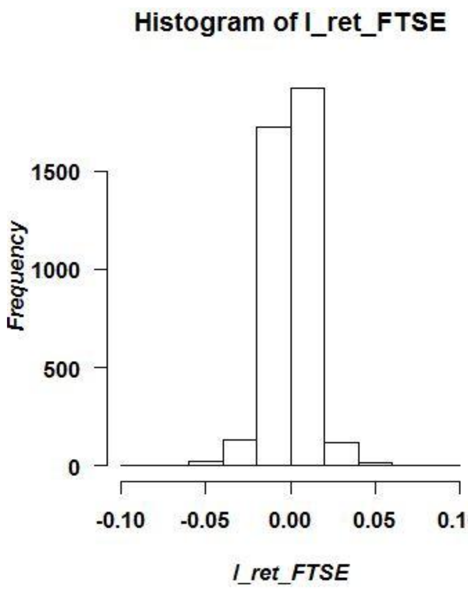
Source: Own elaboration

Table 10: Descriptive Statistics of the FTSE 100 Return Series

	l_ret_FTSE
nobs	3939.000000
NAs	0.000000
Minimum	-0.092656
Maximum	0.093843
1. Quartile	-0.005082
3. Quartile	0.005779
Mean	0.000152
Median	0.000483
Sum	0.599611
SE Mean	0.000187
LCL Mean	-0.000215
UCL Mean	0.000520
Variance	0.000138
Stdev	0.011759
Skewness	-0.110434
Kurtosis	7.323553

Source: Own elaboration

Figure 16: Histogram FTSE 100 Index Prices



Source: Own elaboration

Annex B – Code in R for the empirical study

Due to the extensiveness of the complete script linked to the amount of series studied, this annex contains fragments and examples of the code in R-Studio used for every step of the empirical study.

Packages

```
install.packages("fBasics")
library(fBasics)
install.packages("urca")
library(urca)
install.packages("tseries")
library(tseries)
install.packages("binaryLogic")
library(binaryLogic)
```

Database

```
data<-read.csv("DATA.csv")
COLCAP<-data[,2]
IPSA<-data[,3]
MEXBOL<-data[,4]
LIMA<-data[,5]
IBEX<-data[,6]
DAX<-data[,7]
CAC<-data[,8]
FTSE<-data[,9]
```

Logarithm returns series

```
l_ret_COLCAP0<-diff(log(COLCAP))
l_ret_COLCAP=l_ret_COLCAP0[l_ret_COLCAP0!=0]
basicStats(l_ret_COLCAP)
```

Histogram logarithm returns

```
win.graph(width=8,height=5)
par(mfrow=c(1,2),font=2,font.lab=4,font.axis=2,las=1)
hist(l_ret_COLCAP)
hist(COLCAP,nclass=50,col="steelblue", main = "Histogram log returns COLCAP")
```

Unit root tests

```
ret_COLCAP.df<-ur.df(l_ret_COLCAP, type = c("drift"), lags=20, selectlags = c("BIC"))
```

```
summary(ret_COLCAP.df)
plot(ret_COLCAP.df)
ret_COLCAP.pp<-ur.pp(l_ret_COLCAP, type = c("Z-tau"), model = c("constant"))
summary(ret_COLCAP.pp)
ret_COLCAP.kpss<-ur.kpss(l_ret_COLCAP, type = c("mu"), lags = c("short"))
summary(ret_COLCAP.kpss)
```

Autocorrelation test

```
Box.test(l_ret_COLCAP, lag = 20, type = c("Ljung-Box"))
win.graph(width=8,height=5)
par(mfrow=c(1,2),font=2,font.lab=4,font.axis=2,las=1)
acf(l_ret_COLCAP,ylim=c(-1,1),main="l_ret_COLCAP")
pacf(l_ret_COLCAP,ylim=c(-1,1),main="l_ret_COLCAP")
```

Runs test

```
bincol<-as.factor(l_ret_COLCAP>median(l_ret_COLCAP))
runs.test(bincol)
```

Alternative Runs test

```
bincol<-ifelse(l_ret_COLCAP-median(l_ret_COLCAP)<0,0,1)
n<-length(bincol)
n.ones<-sum(bincol);n.ones
n.zeros<-n-n.ones;n.zeros
mean<-((2*n.ones*n.zeros)/n)+1
variance<-(2*n.ones*n.zeros*(2*n.ones*n.zeros-n))/n^2*(n-1)
runs<-rle(bincol);runs
u.runs<-length(runs$lengths);u.runs
z.stat<-(n.runs-mean)/sqrt(variance);z.stat
p.value<-pnorm(z.stat);p.value
```

Pre-crisis, crisis, post-crisis time series

```
l_ret_COLCAP_pc<-l_ret_COLCAP0[1:1996]
l_ret_COLCAP_pc=l_ret_COLCAP_pc[l_ret_COLCAP_pc!=0]
l_ret_COLCAP_c<-l_ret_COLCAP0[1997:3092]
l_ret_COLCAP_c=l_ret_COLCAP_c[l_ret_COLCAP_c!=0]
l_ret_COLCAP_poc<-l_ret_COLCAP0[3093:5697]
l_ret_COLCAP_poc=l_ret_COLCAP_poc[l_ret_COLCAP_poc!=0]
```

Annex C – Overview Tests and Autocorrelation Tables of Return Series

IPSA index series - pre-crisis, crisis and post-crisis

Table 11: Overview of the IPSA Index weak form efficiency tests

		ADF Test	PP Test	KPSS Test	L-B Test	Runs Test
Null Hypothesis (H_0)		Non-stationarity	Non-stationarity	Stationarity	No serial correlation up to 20 lags	The return series behaves as a random walk
Pre- Crisis	Statistic	-24,205 ***	-30,9078 ***	0,0669	-	-
	P-value	-	-	-	2,031e^{-6} ***	7,099e^{-7} ***
	Conclusion	Reject the H_0	Reject the H_0	The H_0 is not rejected	Reject the H_0	Reject the H_0
Crisis	Statistic	-18,6243 ***	-24,1614 ***	0,2893	-	-
	P-value	-	-	-	0,0001512 ***	1,161e^{-5} ***
	Conclusion	Reject the H_0	Reject the H_0	The H_0 is not rejected	Reject the H_0	Reject the H_0
Post-Crisis	Statistic	-25,6563 ***	-35,0694 ***	0,4062 *	-	-
	P-value	-	-	-	3,331e^{-16} ***	3,722e^{-8} ***
	Conclusion	Reject the H_0	Reject the H_0	Reject the H_0	Reject the H_0	Reject the H_0
Note: * indicates significance level at 10%; ** indicates significance level at 5%; *** indicates significance level at 1%.						

Source: Own elaboration

S&P BMV IPC index series - pre-crisis, crisis and post-crisis

Table 12: Overview of the S&P BMV IPC Index weak form efficiency tests

		ADF Test	PP Test	KPSS Test	L-B Test	Runs Test
Null Hypothesis (H_0)		Non-stationarity	Non-stationarity	Stationarity	No serial correlation up to 20 lags	The return series behaves as a random walk
Pre- Crisis	Statistic	-26,3169 ***	-34,3456 ***	0,0745	-	-
	P-value	-	-	-	0,2282	0,1316
	Conclusion	Reject the H_0	Reject the H_0	The H_0 is not rejected	The H_0 is not rejected	The H_0 is not rejected
Crisis	Statistic	-19,4263 ***	-25,0173 ***	0.2721	-	-
	P-value	-	-	-	0,002099 ***	0,1778
	Conclusion	Reject the H_0	Reject the H_0	The H_0 is not rejected	Reject the H_0	The H_0 is not rejected
Post-Crisis	Statistic	-26,4545 ***	-40,2228 ***	0,0236	-	-
	P-value	-	-	-	0,0004448 ***	0,7588
	Conclusion	Reject the H_0	Reject the H_0	The H_0 is not rejected	Reject the H_0	The H_0 is not rejected
Note: *** indicates significance level at 1%.						

Source: Own elaboration

S&P Lima General index series - pre-crisis, crisis and post-crisis

Table 13: Overview of the S&P Lima General Index weak form efficiency tests

		ADF Test	PP Test	KPSS Test	L-B Test	Runs Test
Null Hypothesis (H_0)		Non-stationarity	Non-stationarity	Stationarity	No serial correlation up to 20 lags	The return series behaves as a random walk
Pre- Crisis	Statistic	-23,1579 ***	-29,2174 ***	0,1129	-	-
	P-value	-	-	-	2,598e^{-12} ***	0.0001477 ***
	Conclusion	Reject the H_0	Reject the H_0	The H_0 is not rejected	Reject the H_0	Reject the H_0
Crisis	Statistic	-11,3899 ***	-23,6612 ***	0,3407	-	-
	P-value	-	-	-	1,499e^{-14} ***	0,002698 ***
	Conclusion	Reject the H_0	Reject the H_0	The H_0 is not rejected	Reject the H_0	Reject the H_0
Post-Crisis	Statistic	-27,5493 ***	-36,3561 ***	0,3177	-	-
	P-value	-	-	-	5,604e^{-7} ***	1,36e^{-5} ***
	Conclusion	Reject the H_0	Reject the H_0	The H_0 is not rejected	Reject the H_0	Reject the H_0
Note: *** indicates significance level at 1%.						

Source: Own elaboration

IBEX 35 index series - pre-crisis, crisis and post-crisis

Table 14: Overview of the IBEX 35 Index weak form efficiency tests

		ADF Test	PP Test	KPSS Test	L-B Test	Runs Test
Null Hypothesis (H_0)		Non-stationarity	Non-stationarity	Stationarity	No serial correlation up to 20 lags	The return series behaves as a random walk
Pre- Crisis	Statistic	-27,0518 ***	-39,5453 ***	0,0422	-	-
	P-value	-	-	-	0,01936 **	0,002125 ***
	Conclusion	Reject the H_0	Reject the H_0	The H_0 is not rejected	Reject the H_0	Reject the H_0
Crisis	Statistic	-20,9536 ***	-28,301 ***	0,1802	-	-
	P-value	-	-	-	0,0939 *	0,664
	Conclusion	Reject the H_0	Reject the H_0	The H_0 is not rejected	Reject the H_0	The H_0 is not rejected
Post-Crisis	Statistic	-30,8052 ***	-40,2201 ***	0,0645	-	-
	P-value	-	-	-	0,0001587 ***	0,2322
	Conclusion	Reject the H_0	Reject the H_0	The H_0 is not rejected	Reject the H_0	The H_0 is not rejected
Note: * indicates significance level at 10%; ** indicates significance level at 5%; *** indicates significance level at 1%.						

Source: Own elaboration

DAX index series - pre-crisis, crisis and post-crisis

Table 15: Overview of the DAX Index weak form efficiency tests

		ADF Test	PP Test	KPSS Test	L-B Test	Runs Test
Null Hypothesis (H_0)		Non-stationarity	Non-stationarity	Stationarity	No serial correlation up to 20 lags	The return series behaves as a random walk
Pre- Crisis	Statistic	-26,4525 ***	-39,6998 ***	0,208	-	-
	P-value	-	-	-	$8{,}096e^{-5}$ ***	0,001172 ***
	Conclusion	Reject the H_0	Reject the H_0	The H_0 is not rejected	Reject the H_0	Reject the H_0
Crisis	Statistic	-21,2843 ***	-28,5317 ***	0,4281*	-	-
	P-value	-	-	-	0.04438 **	0,7721
	Conclusion	Reject the H_0	Reject the H_0	Reject the H_0	Reject the H_0	The H_0 is not rejected
Post-Crisis	Statistic	-29,8357 ***	-40,453 ***	0,0406	-	-
	P-value	-	-	-	0,01854 **	0,541
	Conclusion	Reject the H_0	Reject the H_0	The H_0 is not rejected	Reject the H_0	The H_0 is not rejected
Note: * indicates significance level at 10%; ** indicates significance level at 5%; *** indicates significance level at 1%.						

Source: Own elaboration

CAC 40 index series - pre-crisis, crisis and post-crisis

Table 16: Overview of the CAC 40 Index weak form efficiency tests

		ADF Test	PP Test	KPSS Test	L-B Test	Runs Test
Null Hypothesis (H_0)		Non-stationarity	Non-stationarity	Stationarity	No serial correlation up to 20 lags	The return series behaves as a random walk
Pre- Crisis	Statistic	-27,2994 ***	-39,2736 ***	0,0582	-	-
	P-value	-	-	-	$5,123e^{-5}$ ***	$5,99e^{-5}$ ***
	Conclusion	Reject the H_0	Reject the H_0	The H_0 is not rejected	Reject the H_0	Reject the H_0
Crisis	Statistic	-21,7326 ***	-30,1894 ***	0,3032	-	-
	P-value	-	-	-	0,001539 ***	0,9425
	Conclusion	Reject the H_0	Reject the H_0	The H_0 is not rejected	Reject the H_0	The H_0 is not rejected
Post-Crisis	Statistic	-30.8202 ***	-42,4436 ***	0,0563	-	-
	P-value	-	-	-	0,02832 **	0,05196*
	Conclusion	Reject the H_0	Reject the H_0	The H_0 is not rejected	Reject the H_0	Reject the H_0
Note: * indicates significance level at 10%; ** indicates significance level at 5%; *** indicates significance level at 1%.						

Source: Own elaboration

FTSE 100 index series - pre-crisis, crisis and post-crisis

Table 17: Overview of the FTSE 100 Index weak form efficiency tests

		ADF Test	PP Test	KPSS Test	L-B Test	Runs Test
Null Hypothesis (H_0)		Non-stationarity	Non-stationarity	Stationarity	No serial correlation up to 20 lags	The return series behaves as a random walk
Pre- Crisis	Statistic	-27,1765 ***	-41,8707 ***	0.029	-	-
	P-value	-	-	-	1,078e^{-8} ***	0,05943 *
	Conclusion	Reject the H_0	Reject the H_0	The H_0 is not rejected	Reject the H_0	Reject the H_0
Crisis	Statistic	-13,089 ***	-29,4728 ***	0.3277	-	-
	P-value	-	-	-	5,433e^{-5} ***	0,179
	Conclusion	Reject the H_0	Reject the H_0	The H_0 is not rejected	Reject the H_0	The H_0 is not rejected
Post-Crisis	Statistic	-23,2475 ***	-41,2758 ***	0.0284	-	-
	P-value	-	-	-	0,1753	0,4091
	Conclusion	Reject the H_0	Reject the H_0	The H_0 is not rejected	The H_0 is not rejected	The H_0 is not rejected
Note: * indicates significance level at 10%; *** indicates significance level at 1%.						

Source: Own elaboration

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