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Predicting Stock Returns: Random Walk or Herding Behaviour?

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Abstract.

The analysis is based on Efficient Market Hypothesis and predictability of stock returns. Both concepts will be theoretically showed and demonstrated following the most known asset pricing theories and studying the bid/ask spreads. The 3 Efficient Market Hypotheses will be empirically tested through the Technical Analysis and the Fundamental Analysis. The aim of the model is to highlight the Efficient Market Hypothesis' limits by instructing several tests related to the irrationality of investors, such as the analysis of the noise trading and the respectively effects on volatility, the empirical test of hedging, arbitrage and speculation concepts, the demonstration of the divergence between behavioural finance and expected returns, to conclude with the comparison between random walk and herding behaviour.

Keywords: **C32** Time Series Models, **D84** Expectations and Speculations, **G02** Behavioural Finance, **G12** Asset Pricing and Trading Volume, **G14** Information and Market Efficiency

Scientific areas: **C** Mathematical and Quantitative Methods, **D** Microeconomics, **G** Financial Economics

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Introduction.

At the bottom of the analysis there are the concepts of Efficient Market Hypothesis and predictability of stock returns. Both concepts will be tested and demonstrated after an analysis of the most spread asset pricing theories. Starting from P. A. Samuelson results (Samuelson, 1965), integrated with E. F. Fama, L. Fisher, M. C. Jensen and R. Roll conclusions (Fama, Fisher, Jensen and Roll, 1969), coordinated with K. R. French and R. Roll assumptions (French and Roll, 1986) and considering R. Roll outputs (Roll, 1984), the Efficient Market Hypothesis is tested and demonstrated.

1. Efficient Market Hypothesis.

Asset pricing is based on Efficient Market Hypothesis (Samuelson, 1965) (Fama, 1970), which replaced the Modern Portfolio Theory (Markowitz, 1952) and its efficient frontier (see Tab 1).

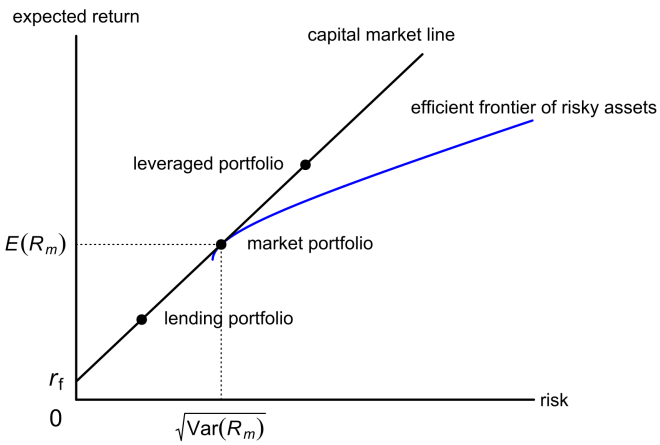

Chart 1 - Markowitz Efficient Frontier and Capital Market Line

Source: Datastream

Tab 1 - Efficient Frontier
The efficient frontier was introduced by H. Markowitz in 1952 and it represents the set of optimal portfolios offering the highest expected return for a chosen level of risk or the lowest risk for a chosen level of expected return. Portfolios below the efficient frontier are sub-optimal, because they do not provide enough return for the chosen level of risk. Portfolios that lie to the right of the

efficient frontier are sub-optimal as well, because they have a higher level of risk for the chosen rate of return. Since the efficient frontier is not linear but curved, the benefit of diversification is a closely related concept. Optimal portfolios on the efficient frontier offer a higher diversification than the sub-optimal ones, which are typically less diversified.

Following the Efficient Market Hypothesis, efficiency in stock markets will be intended in terms of allocation, evaluation, operation and information. E. F. Fama was able to quantify the correlation between the spreading of information and how asset prices include and reflect it (it will be treated as an input variable) (Fama, 1970).

The literature is plenty of Asset Pricing and Market Microstructure publications trying to explain predictability of stock returns. E. F. Fama introduced the model characterized by no free lunch (Fama, 1970) (see Tab 2): stock prices incorporate relevant public information so there is no way to arbitrage. In an efficient and competitive market returns are in equilibrium (supply equals demand, so there is no bid/ask spread), so neither technical analysis nor fundamental analysis is able to generate extra returns.

It means both approaches are not able to construct an efficient portfolio, which generates higher return than a portfolio constructed on a random basis (given the same risk level).

Tab 2 - Free Lunch
A free lunch happens when a good or service is received without bearing a cost, with the true fee of the good or service borne by some agents, which may even include the recipient. A "free lunch" was often offered during the 1800s to bar patrons who ordered drinks as a way of bringing in more business, though in modern times the term is used to describe anything purportedly received for free. Free lunch became an investment slang term referring to unlimited riskless profits. The phrase "there's no such thing as a free lunch" is commonly used to describe situations in which investors are not able to consistently make large profits without bearing the risk of a potential loss.

The analysis considers the CCAPM (Campbell and Cochrane, 1995) (Consumption-based Capital Asset Pricing Model - see Tab 3), stating that stock prices and returns already include the expected value of future variables (such as dividends or other discounted factors), where the expected value is affected by spot public information.

As demonstrated below:

$$\tilde{r} = r_f + \beta_c(r_m - r_f) \quad (1)$$

Where:

$\tilde{r} = Expected\ return\ on\ security;$

$r_f = Risk\ free\ rate;$

$\beta_c = Consumption\ beta;$

$r_m = Return\ from\ market.$

Tab 3 – Consumption-based Capital Asset Pricing Model (CCAPM)
It is a financial model that extends the concepts of the Capital Asset Pricing Model (CAPM) to include the amount that an individual or firm wishes to consume in the future. The CCAPM uses consumption measures, in terms of a consumption *Beta*, in its calculation of a given investment's expected return. The CCAPM differs from the CAPM by only the Beta, it attempts to measure the covariance between investor's ability to consume goods and services from investments versus the return from a market index.

Then, it is also analysed the random walk model (Fama, 1965), stating that stock extra-returns should not be able to being produced by using any available public information. At this time, the finance 2.0 (behavioural finance) starts to become relevant.

The effective value of a variable equals the conditional expectation of the same variable adjusted by the forecasting error. So the effective return of a security in $t + 1$ equals:

$$r_{i\,t+1} = E_t(r_{i\,t+1}) + \varepsilon_{t+1} \quad (2)$$

Where the forecasting error (white noise) ε_{t+1} is not correlated with respect to the conditional expectation. If the operator is rational, thus he correctly uses the public information Ω_t available at time t, then the forecasting error is not correlated to any variable included in the sample of information Ω_t because it is used to obtain the expectation $E_t(r_{i\,t+1})$ as well.

In other terms, if expectations are rationally then the conditional expectation of the forecasting error ε_{t+1} is null.

Thus, now, the E. F. Fama 3 market efficiencies will be tested as:

- Weak;
- Semi-strong;
- Strong.

Statistics, and in particular the stochastic approach, states that any investor is able to get advantage from any of the market efficiencies. It is due to the fact that stock prices change following a random walk without drift, whose distribution function has null average. Moreover, the analysed fluctuation has the characteristic of not being stationary in covariance and so the expected price in $t + 1$ equals the actual price at any time. Market is a fair game and the only way to beat the market is via fortuity.

2. Technical Analysis.

The technical analysis tries to gain extra returns using time series and trading volumes. However it has been empirically demonstrated that technical analysis does not produce extra returns, even if it has been shown to have success in emerging markets (since the high illiquidity level characterizing these markets), and there are so many possible technical analysis trading strategies that they cannot all be tested. Then, the efficiency technical analysis strategies should be evaluated considering all costs (information, analysis and trading).

2.1. Empirical Technical Analysis and Limits.

An empirical application of the technical analysis' limits is conducted to Lehman Brothers event. In particular, analysing and comparing 5 day moving average, 10 day moving average and 20 day moving average with respect to the stock price, it is highlighted the main limit of the technical analysis. The test is conducted from December the 31st, 2007, to January the 5th, 2009. Several variables are considered, such as the open and close price, the intraday maximum and minimum price, the intraday delta and the daily trading volume. The technical analysis is applied normalizing data with respect to the variables above. Next table shows the strong buy stance, supported by the concept of persistency, suggested using the technical analysis in each of the 5 days preceding the Lehman Brothers' collapse.

LEHMQ US Equity	OPEN	HIGH	LOW	PX LAST	Intraday Delta	PX VOLUME						
Data	Open	Max	Min	Close		Volume	MA5g	Action	MA10g	Action	MA20g	Action
09/09/08	12.92	13.1	7.64	7.79	65.85%	383,517,812.00	14.05	Buy	14.92	Buy	14.73	Buy
09/10/08	9.15	9.25	6.93	7.25	26.21%	256,537,502.00	12.11	Buy	14.17	Buy	14.31	Buy
09/11/08	4.47	5.3	3.79	4.22	5.92%	473,167,240.00	9.92	Buy	13.00	Buy	13.71	Buy
09/12/08	3.84	4.05	3.17	3.65	5.21%	307,134,290.00	7.41	Buy	11.76	Buy	13.09	Buy
09/15/08	0.26	0.34	0.15	0.21	23.81%	467,808,827.00	4.62	Buy	10.17	Buy	12.35	Buy
09/16/08	0.2169	0.3	0.15	0.3	-27.70%	141,624,983.00	3.13	Buy	8.59	Buy	11.71	Buy
09/17/08	0.22	0.23	0.1	0.13	69.23%	215,333,094.00	1.70	Buy	6.91	Buy	11.03	Buy
09/18/08	0.13	0.145	0.05	0.052	150.00%	173,127,532.00	0.87	Buy	5.40	Buy	10.35	Buy

Table 1 - Lehman Brothers technical analysis

Source: attached file Excel

The analysis is also confirmed by the moving average persistency concept highlighted in next chart.

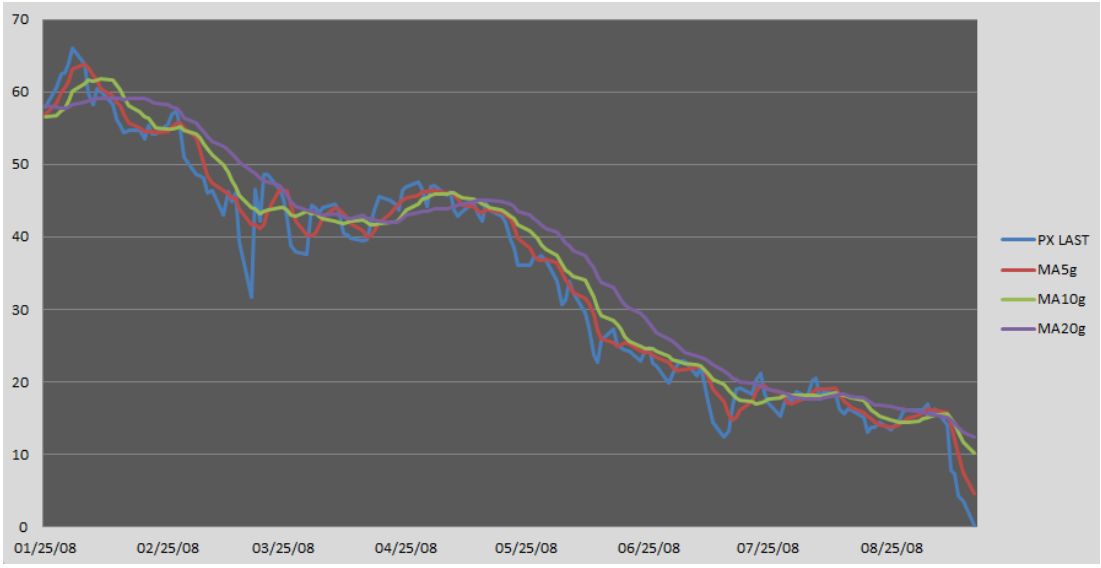

Chart 2 - LEH moving averages persistency

Source: attached file Excel

Next chart shows the intraday trading degenerating in September 2008 conducting the stock price to the minimum since inception.

Chart 3 - Lehman Brothers Intraday Scatter Plot

Source: attached file Excel

While the following chart is a composite chart composed by the Lehman Brothers security price and its trading volume, highlighting how markets discounted news at the beginning of September and how the concept of noise trading is empirically verified.

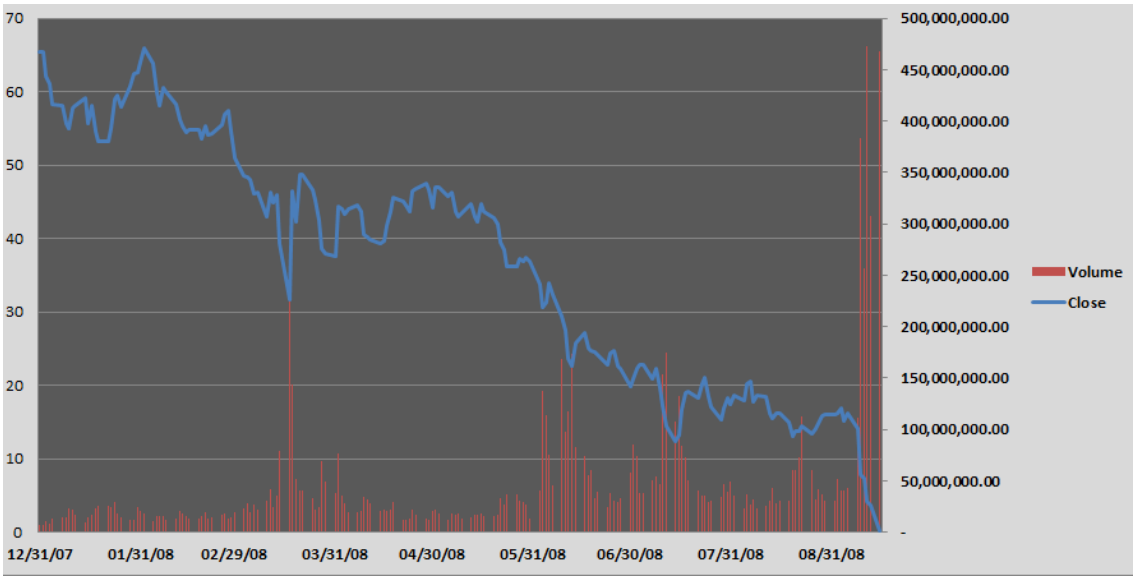

Chart 4 - Lehman Brothers Price/Volume Index

Source: attached file Excel

Still, the following three charts show the analysis of single moving average (5 day, 10 day and 20 day), all above the spot stock price in September 2008.

Chart 5 - Lehman Brothers 5 day moving average

Source: attached file Excel

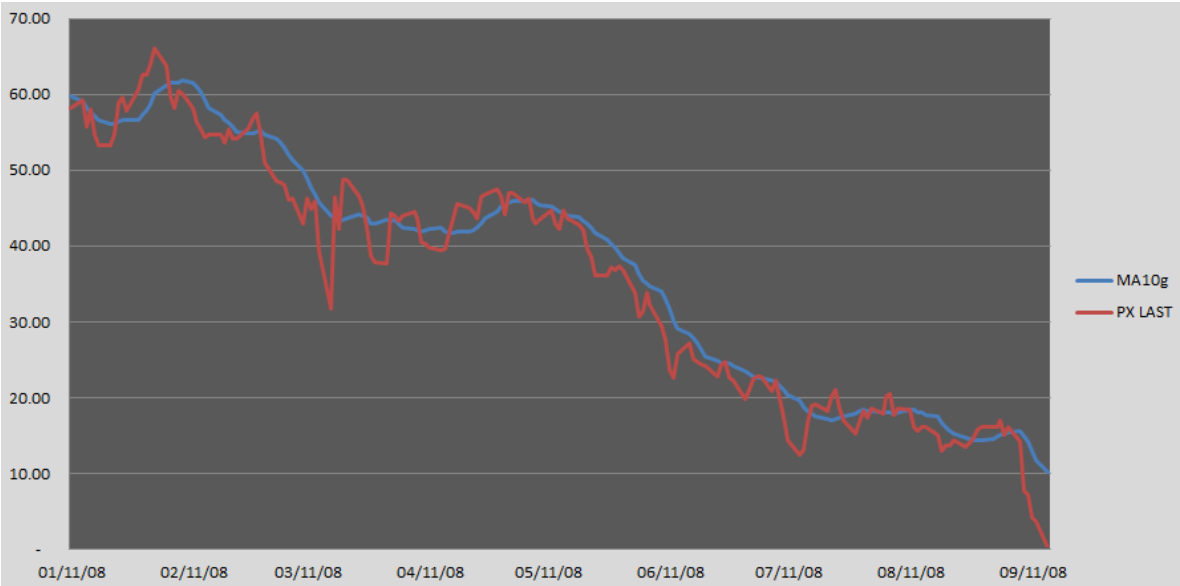

Chart 6 - Lehman Brothers 10 day moving average

Source: attached file Excel

Chart 7 - Lehman Brothers 20 day moving average

Source: attached file Excel

The main limit of the empirical technical analysis is highlighted by the fact that following this approach the first sell stance, supported by the concept of persistency, is suggested in January, the 5th, 2009, so 4 months after the collapse.

LEHMQ US Equity	OPEN	HIGH	LOW	PX LAST	Intraday Delta	PX VOLUME						
Data	Open	Max	Min	Close		Volume	MA5g	Action	MA10g	Action	MA20g	Action
12/25/08	0.027	0.0275	0.025	0.025	8.00%	2,715,504.00	0.03	Buy	0.03	Buy	0.04	Buy
12/26/08	0.025	0.028	0.025	0.0265	-5.66%	3,214,580.00	0.03	Stand-by	0.03	Buy	0.03	Buy
12/29/08	0.027	0.031	0.027	0.0295	-8.47%	7,046,232.00	0.03	Sell	0.03	Stand-by	0.03	Buy
12/30/08	0.029	0.033	0.028	0.0305	-4.92%	6,657,926.00	0.03	Sell	0.03	Sell	0.03	Buy
12/31/08	0.0295	0.0305	0.0258	0.0285	3.51%	6,556,960.00	0.03	Sell	0.03	Sell	0.03	Buy
01/01/09	0.0295	0.0305	0.0258	0.0285	3.51%	6,556,960.00	0.03	Stand-by	0.03	Sell	0.03	Buy
01/02/09	0.0295	0.033	0.029	0.033	-10.61%	6,039,554.00	0.03	Stand-by	0.03	Sell	0.03	Stand-by
01/05/09	0.036	0.044	0.036	0.044	-18.18%	15,517,243.00	0.03	Sell	0.03	Sell	0.03	Sell

Table 2 - Lehman Brothers technical analysis

Source: attached file Excel

The completed output of the Lehman Brothers technical analysis is showed in the attached file Excel.

3. Fundamental Analysis.

The fundamental analysis is based on taking decisions based on public financial statements and derived ratios. However, several theories support the reflection of all public available information already reflected in stock prices, highlighting a limit in producing extra returns using fundamentals.

4. Critics to Efficient Market Hypothesis.

"Give a monkey enough darts and they'll beat the market"

So says a draft article by Research Affiliates highlighting the simulated results of 100 monkeys throwing darts at the stock pages in a newspaper. The average monkey outperformed the index by an average of 1.7% per year since 1964. What is all this monkey business? It started in 1973 when Princeton University professor B. Malkiel claimed in his bestselling book, A Random Walk Down Wall Street, that *"A blindfolded monkey throwing darts at a newspaper's financial pages could select a portfolio that would do just as well as one carefully selected by experts"* (Malkiel, 1973). From the beginning of 2000 psychology and behaviour started to being taken seriously into account in pricing mechanisms, since past and recent happenings (such as the Dotcom bubble, the US mortgage crash and the August 2015 dropdown) showed that it is not reasonable to state that markets are efficient and stock prices reflect always the underlying fundamental value. Market evaluations can be significantly different and persistently different from investors' rational expectations (Summers, 1986) (still based on discounted expected cash flows). Going ahead the systematic patterns, it is shown the persistency of several anomalies:

- Friday bias;
- Weekend bias;
- End of month effect;
- Beginning and end of the year effects;
- "Sell in May and go away" bias;
- Holidays bias;

Together with these anomalies, called calendar anomalies, there are several anomalies that are not correlated with days, such as:

- T. Shumway and D. Hirshleifer (Shumway and Hirshleifer, 2003) studied the correlation between stock prices, trading volume and weather on 26 stock exchanges. The chart

below shows that average annual temperatures are increasing, could it affect markets?

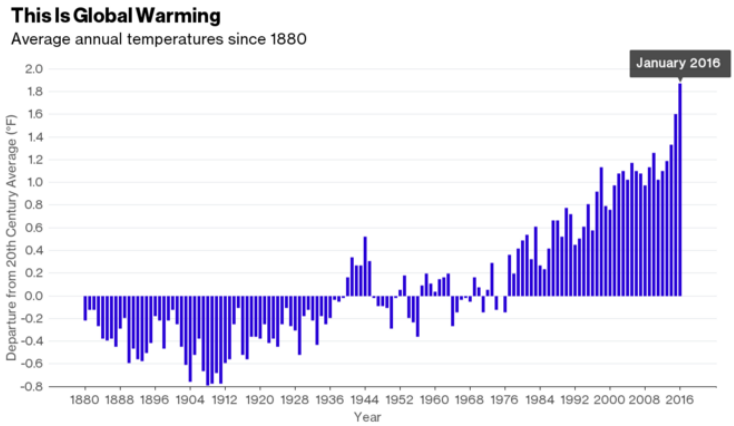

Chart 8 – Global warming and stock prices

Source: Bloomberg

- L. Harris and E. Gurel (Harris and Gurel, 1986), and A. Shleifer (Shleifer, 1986) demonstrated that when a security is included in an index, then the stock price will rally of an average of 3.5% and the increase is demonstrated to being permanent. The inclusion in an index has no new information spread in the market and no new variables that could affect the security, it is commonly called the S&P 500 Effect.

4.1. Expected Returns and Behavioural Finance.

The so-called finance 2.0, relatively to the predictability of expected extra-returns includes concepts such as noise trading, herding behaviour and investor sentiment. Traditional theories are based on EMH and rationality, while, according to the finance 2.0, agents act on emotion and instinct, which do not mandatorily satisfy the expected utility function's optimization. J. M. Keynes (Keynes, 1936) explained these actions through the animal spirits (see Tab 4).

Tab 4 - Animal Spirits
J. M. Keynes described human emotion driving consumer confidence through animal spirits. According to J. M. Keynes, they also generate human trust and are necessary to motivate people in taking positive action.

So behavioural finance can be classified as a multidisciplinary approach which mixes and coordinates economics, finance, psychology and sociology elements to better understand the real functioning of financial markets and the human mechanisms at the bottom of individual and group choices made by investors in a high uncertainty situations via robotic mechanisms. According to the first of the 3 E. F. Fama market efficiencies investors are fully aware and rational in their choices, they have unlimited data access, collection and analysis and so far they maximize their expected utility function. Empirically it is invalid, since investors usually act in a fully irrational way, going against Bayesian probabilities (see Tab 5) and risks.

Tab 5 - Bayesian probabilities
Instead of interpreting probability as frequency or propensity of an event, Bayesian probability is a quantity assigned to represent a state of knowledge or belief. This interpretation is an extension of propositional logic, enabling reasoning with hypotheses. Here, a probability is assigned to a hypothesis, while following frequentist inference, the hypothesis is typically tested without a probability.

Human mind is not able to respect the concept of full rationality: it is subject to physiological limits and it performs processes to continuously analyse, summarize and collect important data, leaving non-significant data. The above elaboration is a process full of evaluation errors, due to personal preferences, memory limits and emotions. The psychologists D. Kahneman and A. Tversky (Kahneman and Tversky, 1974) performed several experiments in order to investigate agents' mental processes in their valuations under uncertainty. They demonstrated that individuals act following heuristic rules (see Tab 6), which are processes to simplify information in order to better act, but these processes can lead to errors and biases. Through the heuristic process, the problem complexity is reduced so it is made easier to take quick, direct, rational and optimal decisions. The simplification of the decision making problem and decision driven by intuition can lead to a possible violation of the traditional theory of expectations and probability formulation.

Tab 6 - Heuristic process
This process is an approach to problem solving, learning, or discovery employing a practical method not guaranteed to be optimal or perfect, but sufficient for the immediate goals. If finding an

optimal solution is not possible, this method is used to speed up the process of finding a satisfactory solution. Heuristics could also be mental shortcuts easing the decision making.

4.2. Irrational Investors: Hedging, Arbitrage and Speculation.

The EMH's 3rd bullet point states that if investors act irrationally (as demonstrated by the above market anomalies), so not being followers of a stochastic and predictable trend, then arbitrageurs intervention should bring back stock prices to fundamentals. Arbitrageurs act to get free lunches by instructing buying and/or selling orders to gain from an eventual mispricing and to take back the market to the equilibrium. To hedge, arbitrageurs operate on perfect substitutes securities (see Tab 7).

Tab 7 - Microeconomic Perfect Substitutes
A substitute or a substitute good in consumer theory is a product or service that a consumer sees as the same or similar to another product. In microeconomics, X and Y are substitutes if the demand for X increases when the price of Y increases, or there is a positive cross elasticity of demand. The perfect substitutes utility function is the following: $$U(x, y) = ax + by \quad (3)$$

So it is reasonable that the markets' complexity and the hard-to-predict stock prices make any security a perfect substitute. Arbitrage limits make the process to try to arbitrage very risky, since it may cause a short run, a long run or a permanent mispricing.

S. F. Richard and R. Roll (Richard and Roll, 1989), and R. Roll (Roll, 1989) tried to compare stocks extra-returns and company earnings operating in the same sector. Peers are usually divided in the following sectors:

- Consumer Staples;
- Materials,
- Industrials;
- Financials;
- Information Technology;

- Healthcare;
- Consumer Discretionary;
- Telecommunication Services;
- Utilities;
- Energy.

They tried to explain the extra-returns generated by public data or by the concept of perfect substitutes securities. The evidence demonstrated that the Roll's indicator got a value of 0.35 (where 0 represents an event impossible to explain and 1 represents an event fully explained by the analysed variables), thus results showed that any public data is already incorporated and discounted by asset pricing, and perfect substitutes securities are quite unrealistic. So arbitrage becomes an action not empirically demonstrated.

J. B. De Long, A. Shleifer, H. Summers and R. J. Waldmann (De Long, Shleifer and Summers, 1990), and A. Shleifer and R. W. Vishny (Shleifer and Vishny, 1997) theoretically demonstrated and empirically verified that arbitrage is a risky strategy and it can often lead to greater disequilibria and higher gaps in stock prices. Arbitrageurs quite rarely make a free lunch, since they need huge financial sources to accomplish the strategy and to cover temporary losses. Moreover, usually professionals (informed traders) manage third party capital, so, since they have to comply with clients' policies and directives, they can be limited in their strategies. Since irrational choices made by noise trading agents can persist longer than rational agents' expectations, mispricing can persist in markets, generating a spiral. A loss for an arbitrageur is not only a wrong long stance on assets, like buying when the spike already happened, but is it also a short stance before the end of the rally. It is caused by different expectations among professionals and noise traders. The event can lead to higher and higher stock prices generating bubbles, since market sentiment will tend to increase the mispricing among asset prices and fundamentals. Since noise traders (irrational investors) are assumed risk averse, while professionals are assumed rational (so risk averse or risk loving depending on the case), the losses' fear will lead to a more prudential management than the EMH would require, generating a higher diversification than necessary, thus missing the maximum efficiency of their strategies and then of the market.

E. F. Fama (Fama, 1998) states that prices are not affected in a correctly way by new public data, but they are correctly affected by the missing data, making the market inefficient. So, behavioural finance becomes significant in explaining the inefficiency.

5. Conclusions: Random Walk versus Herding Behaviour.

In uncertainty conditions the individual's behaviour is widely affected by the rest of the agents, it is the traditional animal behaviour, so the basics of herding behaviour.

Even if investors build their own asset evaluation and strategies, they will tend to match their decisions with other agents. The theory denies the classical theory that states that investors are independent in their choices and evaluation errors (thus wrong decisions) are due to random walk, so these are not part of the process but una tantum events. Empirically it is demonstrated that it exists an aggregate behaviour of investors, influenced by the membership in social network that generates a system of communications and shared evaluations. So investment decisions can often be classified as group decisions. In case of losses, investors can find comfort in knowing that they are not the only losers. So, social, emotive, psychological and relational variables can lead to market inefficiency. Typical examples of herding behaviour are "investment clubs": small private group of individuals (often professionals) that plan their investments by dress risk-return expectations each other.

Herding behaviour is generated by the agents' common factor: greed. So, the best way to describe herding behaviour is the following quote.

"Understand that if you are speculating, whether it be in stocks, bonds, commodities, or currencies, there is an army of highly trained, educated, and experienced CFAs and PhDs trying to make money in the market. They are the sharks, you are the guppies."

(The Irrelevant Investor, M. Batnick)

S. Mullainathan and A. Shleifer (Mullainathan and Shleifer, 2005) also introduced the mass media effects on financial markets. Biases, which generate inefficiencies, are classified in 2 categories:

1. Ideology bias;
2. Spin bias.

First class derives from the editor's desire to affect readers, while the second one depends on tendency of exaggerating events, due to the constant research of scoops. These behaviours can affect stock market equilibria, widely affecting expectations and thus allocations. So, herding behaviour, supported by irrational behaviour and emotional behaviour boost, can incentive momentum-based strategies (see Tab 8) and it can lead to bubbles or stock prices crash, not justified by EMH.

Tab 8 - Foundations of Factor Investing
A factor can be thought of as any characteristic relating a group of securities that is important in explaining their return and risk. A large body of academic research highlights that long-term equity portfolio performance can be explained by factors. Certain factors have historically earned a long-term risk premium and represent exposure to systematic sources of risk. Factor investing is the investment process that aims to harvest these risk premia through exposure to factors. MSCI currently identifies 6 equity risk premia factors: Value, Low Size, Low Volatility, High Yield, Quality and Momentum (Bender, Briand, Melas, Subramanian, 2013).

It is verified the positive correlation of short-term stock extra-returns (not based on fundamentals) with respect to a long-term turnaround. Long-term mispricing may be caused by several factors, such as instructed stop loss, useful for investors to short stances in case of dropdown, but at the same time useless in strong spikes. In this case, noise traders that follow momentum-based strategies will prefer a long stance on securities under analysis, giving a higher boost to the growth and leading the market to overvaluation with respect to fundamentals.
C. P. Kindleberger (Kindleberger, 1978) analysed the bubble process and demonstrated that it is not instantaneous but it is divided in 3 phases:

1. Accumulation; it is characterized by strong long trades on assets, increasing the stock prices and trading volume.
2. Distribution; it is characterized by first short stances from professionals and continuing long stances from noise traders (until stock prices get the maturity point).
3. Liquidation; it is characterized by first and continuing short stances from noise traders, leading stock prices down to fundamentals.

A cycle that seems unbreakable and should persist at least as long as information inefficiency will exist between informed and noise traders.

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