The efficient market hypothesis: problems with interpretations of empirical tests

DENIS ALAJBEG, PhD*

ZORAN BUBAŠ, PhD*

VELIMIR ŠONJE, MBA*

Preliminary communication**
JEL: G10, G14
UDC: 336.76
doi: 10.3326/fintp.36.1.3

* The authors would like to thank three anonymous referees for their useful comments and suggestions.

** Received: June 5, 2011
Accepted: September 26, 2011

Denis ALAJBEG
Zagreb School of Economics and Management, Jordanovac 110, 10000 Zagreb, Croatia
e-mail: dalajbeg@zsem.hr

Zoran BUBAŠ
Zagreb School of Economics and Management, Jordanovac 110, 10000 Zagreb, Croatia
e-mail: zbubas@zsem.hr

Velimir ŠONJE
Arhivanalitika, Ivana Kukuljevića 32, 10000 Zagreb, Croatia; and Zagreb School of Economics and Management, Jordanovac 110, 10000 Zagreb, Croatia
e-mail: vsonje@arhivanalitika.hr

Abstract

Despite many "refutations" in empirical tests, the efficient market hypothesis (EMH) remains the central concept of financial economics. The EMH's resistance to the results of empirical testing emerges from the fact that the EMH is not a falsifiable theory. Its axiomatic definition shows how asset prices would behave under assumed conditions. Testing for this price behavior does not make much sense as the conditions in the financial markets are much more complex than the simplified conditions of perfect competition, zero transaction costs and free information used in the formulation of the EMH. Some recent developments within the tradition of the adaptive market hypothesis are promising regarding development of a falsifiable theory of price formation in financial markets, but are far from giving assurance that we are approaching a new formulation. The most that can be done in the meantime is to be very cautious while interpreting the empirical evidence that is presented as "testing" the EMH.

Keywords: efficient market hypothesis, financial market effiency

1 INTRODUCTION

The efficient market hypothesis became one of the most influential concepts of modern economics and a cornerstone of financial economics. It was extended in many directions, and literally thousands of papers were written about it. Nevertheless, almost half a century after the original theoretical formulation (Samuelson, 1965), financial market efficiency is still a matter of dispute, a situation which provided the main motivation for this paper. The paper offers a discussion of fundamental concepts rather than an overview of the related literature.

We present the view that the EMH is not a "falsifiable" theory[1], which is a consequence of the axiomatic approach to the definition of an informationally efficient market. An axiomatic approach provides theoretical predictions about the behavior of asset prices under assumptions that do not attempt to reflect actual market conditions. It does not provide criteria about what is an efficient and what is not an efficient actual market. For that reason, the concept of market efficiency needs substantial extension in order to become a falsifiable empirical theory. In the absence of such a theory for the time being, the so-called empirical tests of the EMH are nothingmore but valuable descriptions of statistical facts representing the behavior of actual markets.[2]

---

[1] Falsifiability is usually interpreted as the ability to expose a theory to criticism and empirical testing (see e.g. Polšek, 1996). Karl Popper (1959) introduced the concept into epistemology. David Deutsch (1997, 2001) stated that criticism is far more important than empirical testing. According to Deutsch, a falsifiable theory is a theory that can be criticised easily. In order to meet this condition, theory needs to be based on a robust conjecture – it has to contain comprehensive explanations about real phenomena. A robust explanation is based on many details that are strongly linked to the phenomena explained (thus avoiding the trap of Occam's razor). Only robust explanations are worth criticism and testing.

[2] A reader should not confuse this statement with the statement that the theory is useless. Non-empirical theories that cannot be falsified can be very useful (e.g. Euclidean geometry).

FINANCIAL THEORY AND PRACTICE
36 (1) 53-72 (2012)

The paper is divided into five sections. After the introduction, the second part gives an overview of the EMH groundwork. In the third section, the financial market efficiency concept is interpreted from the viewpoints of statisticians and market participants. The fourth section presents the most widely-used groups of EMH tests and acquaints the reader with behavioural criticism. The fifth section briefly discusses the adaptive market hypothesis (AMH). Concluding remarks are to be found in the final section.

2 THE BEGINNINGS: AXIOMATIC AND EMPIRICAL APPROACH TO INFORMATIONALLY EFFICIENT MARKETS

We owe to Paul Samuelson (1965) the first theoretically rigorous formulation of the EMH.[3] However Samuelson argued that the unpredictability of successive price changes does not represent a valid basis for empirical tests of informational market efficiency. Samuelson was fully aware that the definition of market efficiency is comparable to the Pythagorean Theorem: the market is efficient and prices equal to fundamental values if there is perfect competition in the market under conditions where all participants have free access to the information essential for trading. In such circumstances all relevant information is incorporated into prices. Samuelson was explicit that actual markets may have such characteristics only by chance[4].

From Samuelson's "general stochastic model of price changes" followed the *fair game theorem* of determining future prices. The theorem shows that the expected price change based on available price information is equal to zero or the market average. In this case, each spot market price will completely reflect all available information on fundamental factors affecting it: prices equal fundamental values (LeRoy, 1989). In such circumstances one should not expect profit if any of statistical or chart analysis is adjusted to past information on prices – all relevant information is already incorporated in security prices. This follows directly from assumptions – axioms, and is not subject to empirical tests.[5]

Seminal works of Mandelbrot (1963) and Fama (1965) were inspired by the fact that actual distributions of financial asset price changes do not conform to the normal distribution. They are better described by the Paretian family of distributions that allow for "fat tails". Accordingly, in his early works, inspired by the earlier random walk tradition, Fama (1965) strove to interpret the EMH as an empirically-based, falsifiable theory that could explain the actual behaviour of stock market prices. His empirical motivation was very different from Samuelson's.

[3] The ancestor is found in the work of Bachelier (1900).
[4] In an article entitled "Proof That Properly Anticipated Prices Fluctuate Randomly", Paul Samuelson (1965:42) stated that: "...I think we can suspect that there is no a priori necessity for actual Board of Trade grain prices to act in accordance with specific probability models. Perhaps it is a lucky accident, a boon from Mother Nature so to speak, that so many actual price time series do behave like uncorrelated or quasi-random walks."
[5] Samuelson (1965:42) writes: "From a nonempirical base of axioms you never get empirical results."

Under Samuelson's assumption, prices at which individual transactions are made are elements of the distribution whose individual "drawings", i.e. individual price changes should be independent and identically distributed. Hence zero expected price change and strong limits on its variability. Fama (1965:37) on the other hand sought for characteristics of actual markets to support Samuelson's assumptions. He was aware of two characteristics which, at a first glance, oppose the assumptions: (a) there are opinion leaders who act through the media and are followed by other market participants; and (b) there is inertia in the process of news creation: good news tends to be followed more often by good news than by bad news, and bad news tends to be followed by bad news. To eliminate the possibility that such market characteristics cause inefficiency, Fama (1965) used the concept of a *sophisticated trader*[6]. Under Fama's interpretation of the EMH, the impact of sophisticated traders on the market is so strong that they reduce the dispersion of the distribution of actual prices close to their expected value, which is equal to the fundamental (intrinsic) value. It follows that market prices visible on the screen, though they need not always be equal to fundamental values, are a good approximation of them. As the number of sophisticated traders and their level of expertise and access to information grow, the approximation gets better, in limit converging to Samuelson's case. Noting the possibility that sophisticated traders' actions produce market efficiency, Fama did no further research into the actual behavior of market agents and processes but rather assumed that ingenious traders are sufficient to ensure market efficiency and looked for confirmation of this hypothesis in price data observed at actual markets.

From the works of Samuelson and Fama we can distinguish two various aspects of market efficiency – efficiency as a state (axiomatic approach) and as a process (empirical approach). Samuelson (1965) defined efficiency as a state which is reached in conditions of perfect competition, zero transaction costs and complete and freely available information. He did not look into how assumptions correspond with the reality of particular markets. Fama's perspective was different. Fama (1965) saw efficiency as an actual outcome produced by sophisticated traders. However he failed to analyse these market processes believing that sophisticated traders should always be there to ensure market efficiency. By using an assumption instead of doing analysis if this assumption holds, Fama paved the way for conflicting interpretations and variable definitions of efficient markets (LeRoy, 1989).

[6] The astute and competent sophisticated trader knows how to use market anomalies for her own benefit (profit). She eliminates the key market anomaly – the appearance of dependent (serially correlated) stock price changes. Serial correlation may tend to produce bubbles in the price series or a long-term price slump if the current change depends on some past price change. In the creation of such potential anomalies, Fama's sophisticated traders see opportunities for profits. Since they know how to assess fundamentals – intrinsic stock values, they sell stocks when prices are soaring (above the fundamental value) and buy stocks when prices are plummeting (below the fundamental value). Thus they prevent the bubbles from ever occurring and keep the market close to the state of efficiency.

On top of this, economists at that time did not fully understand the implications of the martingale model introduced by Samuelson. They still thought that the random walk model is the best description of price behavior in an informationally efficient market. Even Fama (1970) used the random walk as a synonym for so-called "weak-form" market efficiency – a condition in which market prices cannot be predicted at the basis of past prices alone. "Semi-strong" efficiency implied that a market is efficient given a much wider set of all publicly available information, while "strong-form" efficiency implied that a market is efficient even when inside information is taken into account.[7] These definitions are still very popular among financial economists, but they have little if any theoretical importance. Martingale models hold much firmer theoretical footing in comparison with classical random walk as an equilibrium theory of asset price determination.[8] However martingales cannot account for variability of price changes observed in actual markets (Mandelbrot, 1997). This is a point we shall refer to later in the text.

3 STATISTICIANS' AND MARKET PARTICIPANTS' VIEWS ON MARKET (IN)EFFICIENCY

Problems with finding a proper statistical model of price changes were not the only problems with the EMH. Difficulties with early interpretations of market efficiency theory were revealed by Grossman and Stiglitz (1980). They pointed out that Fama's efficient market must "implode" as it cannot exist without sophisticated traders. And they may disappear from an efficient market, making it inefficient. This is a kind of a paradox if one thinks about the processes of emergence of sophisticated traders which occur in historical time. In particular, sophisticated traders cannot earn above-average profit in an efficient market – in such a market, prices would become equal to fundamental values, which means that sophisticated traders would have no incentive to invest in the acquisition of knowledge, skills and information. Then, in the long run, it is more profitable to hold a representative market portfolio of securities, which may be acquired without information costs and at minimum transaction costs. But in this case there are no sophisticated traders. Market efficiency is hence an unattainable fiction as there is no sufficient incentive for the emergence and operation of agents that should produce and

---

[7] According to Campbell, Lo and MacKinlay (1997) the original distinction of three types of efficiency conditional on information sets is due to Roberts (1967).

[8] At the end of his 1965 paper Fama did not distinguish between the concepts of market efficiency, unpredictability of market prices, and the stochastic random walk process: $P_{t+1} = P_t + u_{t+1}$. However, it is well established today that random walk is part of a broader class of processes known as *martingales* that comply with the efficiency condition (unpredictability of price changes) if $E(P_{t+1} | \Omega_t) = P_t(1+r)$ holds for information set Ω_t, where r is the normal measure of time preference of money or, in the case of stocks, represents the constant rate of growth of dividend. LeRoy (1989) noted that this is a generally accepted interpretation that implicitly assumes that P_{t+1} include the effect of capital appreciation and dividends. Excluding that effect, this is a traditional martingale: $E(P_{t+1} | \Omega_t) = P_t$ which shows that expected price equals current price as it already incorporates all relevant information contained in the information set Ω. One should notice the relation between this formulation of the martingale and Samuelson's definition given at the beginning. Therefore martingales are a theory of price determination while random walk is just a statistical description without a firm theoretical footing.

maintain it[9]. If markets were in a state of efficient equilibrium, the end of information acquisition investment would push the market out of that state immediately. The Grossman-Stiglitz contribution helped financial economists to understand that Fama's assumption hides complex issues of the functioning of actual markets related to the number, motives and behaviour of sophisticated traders.[10] Furthermore, it raises the issue of distinction between a statistical (or academic) and practical (or market participant's) view of financial market (in)efficiency.

3.1 STATISTICAL VIEW ON MARKET EFFICIENCY

The statistical view on financial market (in)efficiency represents the mainstream in empirical financial economics literature. In early applications which started in the 1950s[11] – based on the re-discovery of work by Bachelier (1900) – it was considered that prices in efficient markets follow a random walk with price innovations that obey the normality condition. The implication was that successive price changes should not be serially correlated. Thousands of "tests" were based on this prediction although Samuelson's (1965) was explicit that unpredictability of price changes is not a good basis for testing the theory. Also, his work showed that random walk belongs to a wider class of martingale models that impose smaller restrictions on the probability distribution of price changes although, according to Mandelbrot (1997), smaller restrictions implied by martingales (allowing for heteroscedasticity) were still far too rigid to account for actual price behavior. A test of variance bounds (Lo and MacKinlay, 1988) appropriate for martingales with heteroscedastic errors was developed more than 20 years after Samuelson's article, illustrating the slow evolution of empirical efforts in the EMH tradition. However, as we shall see in detail in the next section, even variance bounds tests leave a number of interpretational issues open.

In addition, models of rational expectations (LeRoy, 1973; Lucas, 1978) allowed for serial correlations of price changes in informationally efficient markets when risk preferences shift, implying that it is perfectly normal to record autocorrelation of successive price changes in an informationally efficient market. Hence serial correlation can not refute EMH.

---

[9] Some earlier empirical studies also suggested that it would be useful to make a distinction between efficiency as a state and as a process. Watts (1978), for example, finds small market inefficiency, showing that no one but brokers themselves, who do not pay brokerage fees, can earn above-average returns. In other words, a market is efficient for almost all participants, apart from those who make it and enjoy a slight cost and informational advantage. It should be noted that informational advantages are probably gradually lost with the spread of new technologies.

[10] In this, the information and knowledge market (which operates as any other market) has an important role – its participants invest in information acquisition as long as the marginal return on information acquisition exceeds its marginal costs, i.e. as long as investment in information and knowledge generates profit. This thesis may be correlated to the EMH definition as given by Jensen (1978), which stresses the necessity to compare risk adjusted returns net of all costs. Costs of information acquisition and processing, including learning costs, could be included into transaction costs, which fit into a broader definition by Jensen.

[11] The first attempts were Cowles (1933) and Cowles and Jones (1937) but literature was sparse in the two decades following Cowles and Jones. See Fama (1965) for a survey of early empirical work.

Finally Fama himself in 1976 stated that the EMH is not an empirically testable proposition because any test showing that the market is (in)efficient may show either that the EMH does not hold or that the equilibrium model of price determination implicit in the strategy of the empirical test is wrong. This is known as the joint hypothesis problem.

So there are four critical problems that hamper the validity of empirical testing of the EMH: (a) inappropriate statistical models of price changes (the price variability problem); (b) joint hypothesis problem; (c) theoretical possibility of autocorrelation of successive price changes in an informationally efficient market; (d) possibility of implosion of an efficient market due to weak incentives for investment in the acquisition of information.

These problems arose due to the fact that although Fama (1965) was primarily interested in the world of actual financial markets he did not fully diverge from Samuelson's Pythagorean (axiomatic) tradition which, according to Samuelson himself, was not meant to produce a falsifiable theory. It is easy to think of an ideal world without extreme price changes which works under Samuelson's conditions, in which the Grossman-Stiglitz problem can be overcome by assuming that sophisticated traders react instantaneously by investing in information at a slight signal of departure from equilibrium. However such a world is a mental construct. Despite this, Fama tried to find proofs that the main predictions of Samuelson's model could be found in the actual markets. It was like trying to find proofs for the theory of free fall near the surface of the Earth. One has to ignore additional variables such as air friction and body mass in order to try to make an empirical test. Once these variables are taken into account, the test makes no sense. In general, ignoring characteristics of experimental environment leads either to wrong refutations or inconclusive results, which was an important part of the history of EMH statistical "tests".

3.2 MARKET PARTICIPANTS' VIEW ON MARKET EFFICIENCY

On the other hand, the potential for above-average earnings per unit of risk taken is the relevant (in)efficiency criterion for stock traders.[12] This perspective led scholars before Fama (e.g. Alexander, 1961) to test the efficiency of actual trading (filter) rules rather than statistical characteristics of price changes. Fama (1965) also followed this approach in his early work: if it could be demonstrated that no trading rule can beat the market in the long run, the market would be proved to be efficient.

There is a fundamental problem with this view. Finding or not finding a trading rule which beats the market in the long run is impossible to interpret in a theoretically rigorous way. Being aware of this problem, Campbell, Lo and MacKinlay

[12] The market average may always be earned by using the naive "buy and hold" strategy of buying a representative stock market portfolio. In most studies, a representative portfolio is approximated by the stock exchange index.

(1997:42) called empirical "tests" based on filter rules "…kind of 'economic' tests … (that) have captured the interest of the financial community for practical reasons." [13]

One expects to find many trading rules (and many investment funds) that beat the market in the short run by pure chance. In a sufficiently short run there are always funds and rules that yield above-average, as well as those that earn below-average returns. However, as the time period under investigation is extended, one expects to find fewer trading rules or funds that *consistently* outperform the market average per unit of risk taken net of transaction costs.[14] So, what does it mean if one can find a trading rule or a mutual fund that consistently beats the market after N years? Following Alexander (1961) and Fama (1965), picking a rule and showing that it cannot beat the market speaks in favor of the EMH (and vice versa).

It is not possible to provide a meaningful answer to the question "what does it mean to beat the market in the long run after N years?" No one can know the whole set of possible trading rules in a particular period, so it is impossible to calculate the statistical significance of finding a rule that beats the market in the period of N years. Perhaps it is a matter of pure chance irrespective of the size of N. Also, if N is very large, it may be larger than any relevant investment horizon. For example, if there is a rule that beats the market after 60 years, it may be irrelevant for any actual investor unless we assume extremely low discount factors and unlimited intergenerational altruism, which is not realistic.

Finally, any winning trading rule which is "discovered" using past data is discovered with the benefit of hindsight. In other words, "discovering" winning rules backwards in time is very different from discovering winning rules forward in time. Savage (2009) calls this the Pearl Harbour effect. When investigators looked at bits of information revealed prior to the Japanese attack on Pearl Harbour (strange behavior of Japanese messengers, etc.), now knowing that the attack actually did happen, they concluded that the bits of information did point to the non-negligible probability of an attack on Pearl Harbour. This argument is notoriously flawed because it rests on the benefit of hindsight. Prior to the attack there was a chaos of information that looked random, i.e. pointed to the equal probability of attacks in many different places. After the attack has happened, one can easily take the pieces of formerly random information and point out their "meaning", forgetting that meaning was produced only later, by the attack itself, which represents additional information.[15] So, it is our opinion that trading rule tests that are performed with the benefit of hindsight do not have firm theoretical founda-

[13] Campbell, Lo and MacKinlay (1997) in Chapter 2 of their book distinguish between filter rules and charting techniques of technical analysis. For any practical purpose these are the same methods.
[14] Jensen's (1978) definition of market efficiency is most appropriate here because it defines effiency in relation to both risks and transaction costs. Beating the market with a trading rule means that the rule's risk adjusted return net of transaction costs is higher than average market return adjusted for risk net of transaction cost.
[15] Conceptually this is similar to the "Monty Hall problem", famous from the theory of probability. The same argument has been pointed out by Mandelbrot (1997).

tions and cannot be interpreted as tests of the EMH, even in a loose sense suggested by Campbell, Lo and MacKinlay (1997).

4 OTHER MAJOR EMPIRICAL EFFICIENT MARKET HYPOTHESIS CHALLENGES AND BEHAVIORAL FINANCE

Additional types of empirical "tests" beyond trading rules and tests of randomness have been employed since the inception of the EMH debate. Their contribution to the understanding of the actual functioning of financial markets at a descriptive level has been immense. However, their contribution to "empirical testing" of the EMH has been negligible, if any. We do not provide a survey of the literature here, as there many have been published already[16], but we will discuss the deeper implications of some of the more interesting results.

The most widely quoted groups of other major empirical challenges are the following: (a) tests of the speed of adjustment of prices to new information; (b) consistency tests of prices and fundamental values (variation tests); and (c) case studies within the tradition of behavioural finance.

4.1 SPEED OF THE ADJUSTMENT OF PRICES TO NEW INFORMATION

Market anomalies, such as the January effect, the weekend effect and the momentum effect have been widely quoted as evidence against the EMH.[17] Proponents of the EMH believed them mere artifacts that are in the focus of researchers and financial experts due to the selection bias (desire to see only what is interesting), in contrast with other parts of the random variable distribution that always remain in the media shadow (Merton, 1987). Malkiel (2003) showed that these anomalies vanish when they become widely known which can be interpreted as evidence in favor of the EMH if learning of sophisticated traders is the driving force behind the elimination of anomalies.

Within the same group of challenges, attempts to refute the EMH were made based on the thesis that low-value stocks (and markets) as well as stocks (and markets) with below-average capitalisation generate above-average market returns over an extended period of time (Shiller, 2005).[18] However, bearing in mind

[16] An exhaustive illustration of EMH tests is beyond the scope of this paper. For that purpose, see for example LeRoy (1989), Beechey, Gruehn and Vickery (2000) and Barbić (2010).

[17] See Malkiel (2003) for references. These are not the only empirically captured anomalies, but these three serve as an illustration. It was empirically recorded that returns on stocks are unusually high early in the year (which, for example, creates an opportunity to profit from purchasing stocks in December of the preceding year and selling them in January of the current year). Also, observed over a long run, it has been established that weekends (Friday's closing prices vs. Monday's closing prices) are not beneficial for stocks – Monday is the only day of the week with an average negative rate of return. The existence of "momentum" in price movements has also been proved; the basis of this strategy is to purchase stocks with high returns over the previous period and sell stocks with low returns in the same period.

[18] See also section on the EMH on Wikipedia. Shiller dealt with market level data. For variance bounds tests which refute serial independence for low-value stocks see Campbell, Lo and MacKinlay (1997). Although not directly related to this stream of literature, literature on "Samuelson's dictum" – a phenomenon implying that individual shares behave closer to predictions of the EMH in comparison to market aggregates, is worth careful reading (Jung and Shiller, 2005).

Jensen's (1978) definition of the EMH under which one should prove a higher risk adjusted return net of all costs, it is very likely that the stated value effects arise in more risky stocks (e.g. less liquid stocks and markets) and/or stocks (and markets) involving higher transaction costs of information acquisition.[19] This is a clear example of a case where negative results are more likely due to a faulty empirical strategy rather than to market inefficiency itself.

These are good examples of how much caution is necessary in interpreting whether a result provides evidence against or in favour of the EMH, or is irrelevant for EMH.[20] In this context one should again bear in mind that the EMH is like a theory of free fall which cannot be tested near the surface of the Earth. So, using real data from actual markets under overly restrictive theoretical and statistical assumptions involves a testing environment bias that one has to take into account.

4.2 DISCREPANCIES BETWEEN PRICES AND FUNDAMENTAL VALUES

These tests, popular in the 1980s, were presented in LeRoy (1989) and Shiller (2003). Their results are inconclusive, too. One may ask how large fluctuations an efficient market will allow around the hypothetical fundamental. In other words, if ever since Fama (1965) it has been understood that actual prices fluctuate around fundamental values and that their distribution is not necessarily Gaussian, why is it still not known how far and how long prices may depart from fundamentals for the market to still be called "efficient"?

Variance bounds tests provide an answer in terms of the theory of martingales but this theory suffers from two drawbacks. First, martingales do not allow for high variability observed in actual stock price changes. Second, martingales tell nothing about the processes that produce convergence of prices towards fundamentals (as well as divergence from fundamentals). Without knowing which processes are critical for convergence and without actually observing them, one observer may see the divergence as evidence of market inefficiency or a bubble, while another observer may see it as an evidence of efficiency if the market successfully adjusted after e.g. two years, without allowing larger discrepancy between market prices and fundamental values. Observers may hold their views irrespective of the result of the variance bound test. So, any test of this type faces an insurmountable problem of isolating the part of variance due to changed fundamentals from the part of variance due to excess volatility. Campbell (1991) indicated that excess volatility dominated over variability of fundamental values. However, this issue remains unresolved as there is always a degree of arbitrariness in the calculation due to the choice of the discount rate.[21]

[19] Again, these are (as a rule) more risky and/or less liquid stocks (and markets).
[20] The most significant studies following this tradition relate to the observation that announcements of unexpected earnings have a relatively long and positive impact on stock prices. To many market participants, this gives sufficient time to profit from information on past price growth. Following Fama's (1976) joint hypothesis problem, Ball (1978) argued that this effect does not prove market inefficiency but the inappropriateness of the model used to describe efficiency.
[21] If the discount rate in the model is linked with the interest rate (as in Shiller, 2003), calculations will show prices below fundamentals in depressions when interest rates are low. In order to illustrate the problem, assume

In one of the most influential papers in the history of financial economics ("Noise"), Fischer Black (1986) argued that an efficient market is the one where prices never fall to below 50% or rise above 200% of the fundamental value: "Still, the farther the price of a stock moves away from value, the faster it will tend to move back. This limits the degree to which it is likely to move away from value. All estimates of value are noisy, so we can never know how far away price is from value. However, we might define an efficient market as one in which price is within a factor of 2 of value, i.e. the price is more than half of value and less than twice value. The factor of 2 is arbitrary, of course. Intuitively, though, it seems reasonable to me, in the light of sources of uncertainty about value and the strength of the forces tending to cause price to return to value. By this definition, I think almost all markets are efficient almost all of the time. Almost all means at least 90%." (Black, 1986:533).

Black never offered anything similar to a theoretical explanation of this choice of particular interval, although in other fields of finance he was one of the most rigorous scholars, with a rich practical experience. He thought this kind of reasoning put him between Merton's belief in efficiency and Shiller's suspicion about efficiency (Black, 1986:533). Black's arbitrary efficiency interval (-50%; +200%) and the logic behind it is a beautiful illustration of an intellectual gap that financial economics still has to close. On top of it, while Black's argumentation can offer some broad-brush idea of how to approach a process based efficiency of actual markets, it is overly simplified because it focused on variance only without mentioning the historical time interval of variation. Financial economists need criteria to determine the time and variability intervals inside which the fluctuation has to occur (the market cycle needs to be completed) in order to claim the market is efficient.[22]

The problem is closely linked to Mandelbrot's (1997) observation that widespread statistical models of price changes do not allow for the variability, discontinuity and concentration of price changes observed in actual markets. There are two implications of his observation. First, as actual markets are usually not able to respond instantly to the flow of news due to trading limits, liquidity problems, regulation and other market peculiarities, one needs a model of price determina-

a perpetual dividend model (which is the same as the model in Jung and Shiller (2005) under the assumption of no dividend growth), where stock price equals dividend divided by the discount rate k: P=D/k. Assume three states of the market: bad (discount rate 300 basis points above normal), normal (normal discount rate for equities of 8%) and good (discount rate 300 basis points below normal). In this case, ratio of price (good) to price (bad) would be 3.4 and price-earnings ratio would fluctuate between 9 and 20 which is smaller variability than actually observed: from 1881:1 to 2011:8 P/E ranged between 4.8 and 44.2 in US. However, with variations in the discount rate of +/- 570 bps P/E interval is widened to (7.2 ; 45.5) which describes total range of observations except Great Depresssion and 1982 when the interest rates were much higher anyway (10y treasuries yield reached 14.6% in January 1982). This calculation does not explain anything; it just shows how hard it is to attribute variance to particular causes.

[22] This is analogous to the problem of speed of adjustment of prices to new information. Summing it up, financial economists do not know how wide and how fast prices can fluctuate in order to preserve the claim of market efficiency. Classical definitions do not tackle this problem at all. They usually refer to the very general efficiency conditions, such as "prices reflect all available information".

tion with serial dependence (Mandelbrot, 1997:55). Second, Mandelbrot (1997:58) pointed out the possibility of order in randomness: "...a sample from a suitable fractal random process can exhibit features on which a technical analyst would base by or sell recommendations."

As far as the second observation on fractal geometry is concerned, we are still not able to fully understand all the consequences it may have regarding the EMH and its tests. [23] Regarding the first observation on serial correlation under realistic market conditions, it calls for redefinition of the concept of market efficiency in order to incorporate statistical and other characteristics of actual markets (such as discontinuities and concentrations in price changes).

In the absence of such a redefinition, the concept of market (in)efficiency has so far failed to include criteria for its gradation given price data from actual markets. Inefficiency is not a binary concept in the world of actual markets: markets can be closer to or further from the state of efficiency. The absence of a standard and continuous measure of (in)efficiency is the logical consequence of Samuelson's (1965) deduction of the concept of efficiency as unpredictability, which led financial economists to understand efficiency as a state (in which it is impossible to predict future prices), and neglect the efficiency of actual market processes of learning and discovering information. Obviously, these actual processes can lead the market closer to or farther from some yet unknown process efficiency standard needed in order to pave the way for a falsifiable theory of informational efficiency in financial markets.[24]

4.3 BEHAVIORAL FINANCE AND EFFICIENCY AS A PROCESS

Every market practitioner knows that psychology heavily affects decision-making in financial markets. Overconfidence, imitation (herd behavior), hope, fear and other psychological phenomena may explain some "market anomalies". An example of such an anomaly is the well documented increased frequency of purchasing individual stocks following media reports on their issuers (Shefrin, 2002). Studies in behavioral finance documented dozens of such "anomalies".[25] Such phenomena

[23] Implications of fractal geometry for the EMH are not straightforward because, according to Mandelbrot (1997), patterns in the randomness do not affect predictability. Nevertheless the implications are not clear because mainstream economists ignored Mandelbrot's work for years. For example, Robert Shiller in his 2003 review of the subject published in the Journal of Economic Perspectives does not report any reference of Mandelbrot. Rather, he attributes the beginnings of the extensive discussion on excess volatility of stock prices to his own work in 1981 and Le Roy and Porter (1981).

[24] Scholars tried to avoid this fundamental problem. Lo (2004) interprets degrees of (in)efficiency in terms of standard statistical measures i.e. size of autocorrelation coefficient of price changes. In a similar vein, Campbell, Lo and MacKinlay (1997) substitute absolute Samuelson-type efficiency for relative efficiency which is obtained by performing traditional statistical tests in different markets. Their claim is that even within the existing EMH testing paradigm it is possible to measure degrees of (in)efficiency in individual markets. They see standard statistical measures as an analogue to efficiency measures in physical systems – physical efficiency is a matter of degree. It cannot be firmly established that such approach makes theoretical sense and that the analogue to physics is permissible as EMH is more similar to abstract theoretical constructs like an Euclidean triangle rather than to the efficiency concept of classical physics.

[25] Shefrin (2002) provides a valuable survey.

suggest that actual markets are not efficient markets as defined by Samuelson (1965). While this is sometimes interpreted as a "proof" against the EMH, it is nothing more than a very useful description of how actual financial markets really work.

Scholars have rightly emphasized that profit opportunities associated with market anomalies usually go hand in hand with higher risks (Shefrin, 2002). This means that it is not easy to interpret what market anomaly means in terms of the EMH, i.e. what part of excess reward represents a compensation for risk and/or transaction costs and what part is "excess".

For example, think deeper about Grossman's and Stiglitz's (1980) focus on the role of sophisticated traders and their incentives for investment in knowledge and information, which is a process of critical importance for market efficiency. In the subsequent literature there were not many attempts to develop their model of investment in knowledge and information further. However Litvinova and Ou-Yang (2003) expanded the Grossman-Stiglitz model by introducing assumptions on agents' strategic behavior regarding investments in the acquisition of information and knowledge. They linked agents' information acquisition efforts and costs with information quality and introduced the assumption that (in choosing an optimal effort level in acquiring information) agents bear in mind the fact that there are other informed agents in the market. This assumption spurs competition, i.e. strategic interaction among sophisticated traders in the initial step, when agents decide on investing in information and knowledge. In the Litvinova and Ou-Yang model, when more agents acquire information, the marginal benefit of each agent's information decreases. Marginal benefit may thus fall to a level at which investment in information acquisition is no longer effective. This implies both higher risk and higher cost for sophisticated traders. Thus the increase in the number of agents considering investment in information acquisition does not necessarily lead to higher market efficiency. This is why there is no equilibrium in their model.

Therefore the critical processes that have to be taken into account in the improved explanation of market efficiency are changes in the shares of populations of traders classified according to their psychological characteristics, speed and costs of their learning, and costs of information acquisition. These variables are in the focus of the adaptive market hypothesis (AMH).

5 ADAPTIVE MARKET HYPOTHESIS

The AMH is focused on capturing characteristics of the changing psychology of different investor groups and their balance in actual markets. It rests on the application of evolutionary principles to financial markets, amalgamating the behavioural alternatives with the EMH by explaining the so-called irrationalities as a rational reaction to a change in environmental conditions of the market(s). The AMH implies that the degree of market efficiency is related to environmental factors characterizing market ecology (e.g. number of competitors, magnitude of available profit opportunities, adaptability of the market participants, etc.).

Lo's (2004, 2005) breakthrough work on the AMH is an eclectic collection of criticism against the EMH from the camp of behavioural economists coupled with the assumption of asymmetric information introduced by Grossman and Stiglitz (1980) and the assumption by Black (1986) on the existence of "noise" traders. "Noise" traders or emotional traders are the main losers or sources of profit for sophisticated traders. Put colloquially, they are small fish at the end of the market "food chain" that make profits only accidentally – for them the market is a gambling house. They suffer from psychological "unfunctionalities" described within the framework of the behavioural finance tradition. This means that their behaviour may cause a serial dependence in price changes unless sophisticated traders find ways to eliminate it quickly by making money out of their ignorance and emotional drive.

Not only are there sophisticated and emotional traders in the market, but there is also a feedback loop between various investor groups. Shefrin (2002) stresses that sophisticated traders may feel the presence of an increased number of noise traders through larger swings in prices. This is the reason why their assessment of risk may increase and their desire for transactions decrease (recall that risk may be endogenous), which eventually, due to the diminished role of sophisticated traders, leads to larger price fluctuations. Accordingly, the balance of power between sophisticated traders and "noise" traders changes over an extended period of time, which in turn changes the structural characteristics of stock price time series – one may expect larger price fluctuations during periods dominated by noise traders.[26]

Markets are even richer in various types of participants. A more precise description of their number and behaviour would enable the modelling of an "ecological environment" and the complexity of competition for limited resources in that market. This would illustrate how the number of certain types of players changes, and how some of them are made extinct while new ones are being born (Farmer and Lo, 1999). Heterogeneous beliefs and adaptive learning models are particularly powerful in depicting financial market dynamics which produces price series that have observed characteristics (high kurtosis, fat tails, occasional periods of autocorrelation, much higher autocorrelations on monthly than on daily data, etc.) (Verbič, 2008). This is why Lo believes that an analysis of the psycho-evolutionary dynamics in a changing social environment (potentially) provides an opportunity to: (a) explain changes in stock risk premiums; (b) explain changes in risk attitudes; and (c) explain changes in the winning investment strategy[27]. Hence modeling learning and psycho-social dynamics in the complex market environ-

[26] De Long et al. (1990) assume that sophisticated traders buy in anticipation of noise traders' frenzy but they do not offset the whole expected effect due to increased perception of risk.
[27] Under the Farmer-Lo model, over the long-run, winners are those that adapt most quickly to the changing environment, just like in Darwin's model of evolution.

ment can be very useful for deeper understanding of process efficiency, as the speed of learning, the speed of elimination of agents with systematically wrong forecasts and the investment in acquisition of information and knowledge are elements of process efficiency. While undoubtedly very useful as descriptive tools, these models will have to develop further in order to provide some clues regarding a useful definition of efficiency in the actual financial markets.

Psychological "anomalies" (e.g. herd behavior, sensitivity to framing, etc.) and risk aversion leave open the question about how real psychological processes of financial decision-makers fit into the efficient market concept. Models in the tradition of AMH will probably provide some insight about the way psychological anomalies fade out over time in efficient markets – thus having the character of temporariness. However the question of whether there are some deeper "irrationalities" which make financial markets predominantly inefficient will remain controversial without a firmer theoretical frame for process-based definition of efficiency in financial markets.

6 CONCLUDING REMARKS

The dilemma on how to define and measure the informational efficiency of actual markets presented in this paper is much wider as parallels to it can be found outside financial economics. For example, an optimistic view of market behavior similar to the EMH is supported by Surowiecki (2005), who claims that crowds (especially when organized in markets and/or democratic institutions) know more than individuals ("Wisdom of the crowds"). According to this view, markets and democratic institutions produce the best outcomes one can expect near the surface of the Earth. Surowiecki's vision of efficiency is reflected in the higher predictive powers of large groups than of individuals and smaller groups when groups have some knowledge of the matter. The opposing view, which is similar to the behavioral finance view on financial markets, is provided by a long stream of literature which started with Mackay's (1841) account of history of financial follies ("Madness of the crowds").

There is evidence supporting both views, so it is not possible to conclude whether markets are efficient in the long run only on the basis of inconclusive empirical evidence. Accordingly, empirical "testing" cannot reject or confirm EMH. There is a need for additional theoretical framing regarding information structures and learning environments that give support to collective choices in the markets. Most probably, financial economics would need a step further, most probably beyond the AMH complexity models, further integrating the findings of psychology, sociology, behavioral finance and statistics in order to come to a workable definition of process efficiency in financial markets, hopefully rationalizing Fischer Black's price interval.

For the time being one should bear in mind that actual markets are not Samuelson-type markets as there are transaction costs, investments in acquisition of information and learning, shifts in risk preferences, technologies and regulation, market discontinuities, concentrations of price changes in tails, and different types of investors whose shares and behaviors change in time. So, the behavior of actual time series of asset prices usually exhibits departures from the predictions of the Samuelson model. But this is not sufficient to conclude that markets are informationally inefficient because attempts to explore Samuelson-type informational efficiency in the actual markets are limited due to the axiomatic introduction of the sophisticated trader, whose actions are meant to produce market efficiency in Samuelson's sense. By using this approach, Fama paved the way for decades of efforts which were channeled towards empirical "testing" of the EMH. However, these tests were like testing free fall near the surface of the Earth. Neither Fama nor empirical financial economists (at least initially) were aware that they were "testing" a theory which is not falsifiable. Nevertheless, "tests" provided plenty of descriptive statistical evidence about actual markets.

Behavioral finance at the outset was a sum of market anecdotes. However, the emergence of computing powers which allowed complex simulations on personal computers opened the doors to the adaptive market hypothesis, which defines efficiency from an evolutionary perspective. Models in this tradition are descriptive and promising, especially in their revelation of the role of the changing nature of market psychology. Nevertheless it is still not clear how they can contribute to a process-based understanding of market efficiency. We are still missing a workable definition.

In addition it should be noted that the emergence of new democracies and the development of market economies and capital markets after the fall of the Berlin Wall provided valuable practical experience regarding the development of a process-based theory of efficient markets. This experience has shown that efficient markets do not develop spontaneously – they are not "rooted" in some mystical characteristic of human nature which, after being freed up, "produces" efficient markets. Rather, it has shown that the problems involved in information acquisition, transaction costs and the time required for learning may prove to be insourmountable obstaclesto the efficient functioning of financial markets, especially when ownership rights are weakly defined and badly protected.
The lesson to be learned is that the institutions (including markets themselves) are costly and sometimes evolve in unpredictable ways. It was naïve to think that a Samuelson-type efficient market will spontaneously emerge on Earth in a place where nothing similar ever existed. A wider implication is that the impossibility to replicate free fall near the surface of the Earth tells nothing about free fall itself. Instead, it tells about a futile experiment.

A process-based (empirical and falsifiable) theory of efficient markets may be built along some promising avenues of research which, if they become convergent, may offer us deeper theoretical insights in the years to come. In the meantime, the best we can do is to interpret empirical results about the actual behavior of asset prices with a high dose of caution, because EMH is not a falsifiable theory.

LITERATURE

Bachelier, L., 1900. *Theorie de la speculation* [online]. Paris: Gauthier-Villars. Available from: [http://archive.numdam.org/ARCHIVE/ASENS/ASENS_1900_3_17_/ASENS_1900_3_17__21_0/ASENS_1900_3_17__21_0.pdf].

Ball, R., 1978. "Anomalies in Relationship between Securities' Yields and Yield-Surrogates". *Journal of Financial Economics*, 6, 103-126. doi: 10.1016/0304-405X(78)90026-0

Barbić, T., 2010. "Testiranje slabog oblika hipoteze efikasnog tržišta na hrvatskom tržištu kapitala". *Zbornik Ekonomskog fakulteta u Zagrebu*, 8 (1), 155-172.

Beechey, M., Gruen, D. and Vickery, J., 2000. "The Efficient Market Hypothesis: A Survey". *Research Discussion Paper*, 2000-01. Sydney: Reserve Bank of Australia.

Black, F., 1986. "Noise". *Journal of Finance*, 41, 529-543. doi: 10.2307/2328481

Campbell, J. Y., 1991. "A Variance Decomposition of Stock Returns." *Economic Journal*, 101 (405), 157-179. doi: 10.2307/2233809

Campbell, J. Y., Lo, A. W. and MacKinlay, A. C., 1997. *The Econometrics of Financial Markets*. Princeton: Princeton University Press.

Cowles, A. and Jones, K., 1937. "Some A Posteriori Probabilities in Stock Market Action". *Econometica*, 5, 280-294. doi: 10.2307/1905515

Cowles, A., 1933. "Can Stock Market Forecasters Forecast?" *Econometrica*, 1, 309-324. doi: 10.2307/1907042

De Long, J. B. [et al.], 1990. "Positive Feedback Investment Strategies and Destabilizing Rational Speculations". *Journal of Finance*, 45 (2), 379-395. doi: 10.2307/2328662

Deutsch, D., 1997. *Fabric of Reality*. New York: Penguine Books.

Deutsch, D., 2011. *The Beginning of Infinity*. New York: Penguine Books : Viking.

Fama, E. F., 1965. "The Behavior of Stock-Market Prices". *The Journal of Business*, 38 (1), 34-105. doi: 10.1086/294743

Fama, E. F., 1970. "Efficient Capital Markets: A Review of Theory and Empirical Work". *The Journal of Finance*, 25, 383-417. doi: 10.2307/2325486

Fama, E. F., 1976. *Foundations of Finance*. New York: Basic Books.

Fama, E. F., 1991. "Efficient Capital Markets II". *Journal of Finance*, 46, 1575-1617. doi: 10.2307/2328565

Fama, E. F., 2010. Interview. "Rational Irrationality" in: *New Yorker*, 13th January 2010 [online]. Available from: [http://www.newyorker.com/online/blogs/johncassidy/2010/01/interview-with-eugene-fama.html].

Farmer, A. and Lo, A., 1999. "Frontiers of Finance: Evolution and Efficient Markets". *Proceedings of the National Academy of Sciences*, 96, 9991-9992. doi: 10.1073/pnas.96.18.9991

Grossman, S. and Stiglitz, J., 1980. "On the Impossibility of Informationally Efficient Markets". *American Economic Review*, 70, 393-408.

Jensen, M. C., 1978. "Some Anomalous Evidence Regarding Market Efficiency". *Journal of Financial Economics*, 6 (2-3), 95-101. url: 10.1016/0304-405X(78)90025-9

Jung, J. and Shiller, R. J., 2005. "Samuelson's Dictum and the Stock Market". *Economic Inquiry*, 43 (2), 221-228. doi: 10.1093/ei/cbi015

Le Roy, S. F. and Porter, R. D., 1981. "The Present-Value Relation: Test Based on Implied Variance Bounds". *Econometrica*, 46 (6), 1429-1445.

LeRoy, S. F., 1973. "Risk Aversion and the Martingale Property of Stock Returns". *International Economic Review*, 14, 436-446. doi: 10.2307/2525932

LeRoy, S. F., 1989. "Efficient Capital Markets and Martingales". *Journal of Economic Literature*, 27 (4), 1583-1621.

Litvinova, J. and Ou-Yang, H., 2003. *Endogenous Information Acquisition: A Revisit of the Grossman-Stiglitz Model*. Mimeo. Duke University.

Lo, A. W. and MacKinlay, C., 1988. "Stock Market Prices Do Not Follow Random Walks: Evidence from a Simple Specification Test". *Review of Financial Studies* (1), 41-66. doi: 10.1093/rfs/1.1.41

Lo, A. W., 2004. "The Adaptive Market Hypothesis: Market Efficiency From an Evolutionary Perspective". *Journal of Portfolio Management*, 30, 15-29. doi: 10.3905/jpm.2004.442611

Lo, A. W., 2005. "Reconciling Efficient Markets with Behavioral Finance: The Adaptive Markets Hypothesis". *Journal of Investment Consulting*, 7, 21-44.

Lo, A. W., 2007. "Efficient Market Hypothesis" in: L. Blume and S. Durlauf, eds. *The New Palgrave: Dictionary of Economics*. New York: Palgrave McMillan.

Lucas, R. E., 1978. "Asset Prices in an Exchange Economy". *Econometrica*, 46, 1429-1446. doi: 10.2307/1913837

Mackay, C., 1841. *Extraordinary Popular Delusions and the Madness of Crowds*. New York: Wiley Investment Classic, 1996.

Malkiel, B. G., 2003. "The Efficient Market Hypothesis and Its Critics". *Journal of Economic Perspectives*, 17, 59-82. doi: 10.1257/089533003321164958

Mandelbrot, B. B., 1963. "New Methods in Statistical Economics". *Journal of Political Economy*, 71, 421-440. doi: 10.1086/258792

Mandelbrot, B. B., 1997. *Fractals and Scaling in Finance: Discontinuity, Concentration and Risk*, New York: Springer.

Merton, R., 1987. "A Simple Model of Capital Market Equilibrium with Incomplete Information". *Journal of Finance*, 42, 483-510. doi: 10.2307/2328367

Pesaran, M. H., 2010. *Predictability of Asset Returns and the Efficient Market Hypothesis* [online]. Available from: [http://www.econ.cam.ac.uk/dae/repec/cam/pdf/cwpe1033.pdf].

Polšek, D., 1996. *Pokušaji i pogreške: Filozofija Karla Poppera*. Zagreb: Filozofska istraživanja.

Popper, K., 1959. *The Logic of Scientific Discovery.* London: Routledge.

Roberts, H., 1967. *Statistical versus Clinical Prediction of the Stock Market*. Manuscript. University of Chicago: Center for Research in Security Prices.

Samuelson, P., 1965. "Proof that Properly Anticipated Prices Fluctuate Randomly". *Industrial Management Review*, Spring 6, 41-49.

Savage, S. L., 2009. *The Flaw of Averages: Why We Underestimate Risk in the Face of Uncertainity.* New Jersey: John Wiley & Sons.

Schiller, R. J., 2005. *Irrational Exuberance*. Princeton: Princeton University Press.

Shefrin, H., 2002. *Beyond Greed and Fear: Understanding Behavioral Finance and the Psychology of Investing*. Oxford: Oxford University Press.

Shiller, R. J., 1981. "The Use of Volatility Measures in Assessing Market Efficiency". *Journal of Finance*, 36, 291-304. doi: 10.2307/2327010

Shiller, R. J., 2003. "From Efficient Markets Theory to Behavioral Finance". *Journal of Economic Perspectives*, 17 (1), 83-104. doi: 10.1257/08953300332 1164967

Surowiecki, J., 2005. *The Wisdom of Crowds.* New York: Anchorbooks.

Watts, R. L., 1978. "Systematic Abnormal Returns after Quarterly Earnings Announcements". *Journal of Financial Economics*, 6, 127-150. doi: 10.1016/0304-405X(78)90027- 2