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TESTING MARKET EFFICIENCY:
THE ROAD TO INTRINSIC VALUATION

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Abstract. *The paradigm of market equilibrium and the "efficient-market hypothesis" tied to it, dealing specifically with the behavior of capital markets, has no explanation for financial bubbles and their bursting that is leading to stock market crashes. Accordingly, the main goal of this paper is to discuss the inefficiency of markets, with examples of corporate decisions that directly abuse such inefficiency to psychologically motivate desired behavior of potential customers. To test the efficiency market hypothesis, we have used Stoxx Europe 600 index historical closing daily prices, for the period from 2012–2022. Using both non-parametric and parametric tests, such as the Kolmogorov–Smirnov test, run–test for random order, and ARIMA regression, we reject the hypothesis that the market is efficient in a weak form because it doesn't follow a random walk. Also, basic-level problems of economic theory were analyzed, emphasizing the view that perhaps the time has come to align the fundamentals of economic theory with basic concepts that have been used in practice for years.*

Key words: *market, efficiency, stock, price, prediction.*

JEL Classification: G14, G41, C22

1. INTRODUCTION

Let's forget, just for a while, the old economic textbooks and all that generations of economists have learned in school. The market is, if we look at the reality on the "ground level", a pretty chaotic system that weighs to extremes, as indicated by crisis and financial bubbles and stock market crashes, while the behaviors of individuals (agents or participants) are unpredictable and psychologically motivated. This is known and used in practice for years now. One of the main motivations that are "opposing" rational behavior is the desire for quick enrichment, or to say it more simply: greed. Although a lot of literature ties "greed and fear" or later "hope and fear" as primary emotions in market psychology (Hersh Shefrin, 2002), simple greed will suffice in this paper. It is now, and it has always been, one of the fundamental parameters of human behavior and a strong motivation for speculative behavior that is undermining the rationality concepts of the market equilibrium paradigm, constantly leading to market crashes. If something is profitable, people will buy it – many because they believe it will continue to be profitable, but some ("smart money") because they hope the market won't crush until they re-sell with the profit and exit – and if the feedback on profitability is not interrupted somehow, this self-fulfilling prophecy creates an endless loop of repeating behaviors which are fuelling the unsustainable speculative bubble that will eventually burst. Likewise, if something stops being profitable, generally everybody sells it, pushing the market downwards to irrationally low prices. We will showcase here how this greed of men is being used and abused by the big companies, and this is one of the reasons why Economics needs to embrace reality and let go of some disproven postulates that are now only "dead meat" on the body of science. In this paper, we are not yet trying to give definite answers, but rather simple guidelines – demonstrating what are the real problems and why we need the solutions, and pinpointing the right direction for search, all in hope of stimulating future efforts from fellow researchers, what is needed to return the economics on track scientifically.

2. THE GAP BETWEEN THEORY AND REAL-LIFE PRACTICES

If we believe in the paradigm of market equilibrium, we generally also believe in "efficient" markets. This was vaguely explained in the most important paper mentioning the term (Fama, 1970), which is also surprisingly the most quoted article in financial economics (Guerrien and Gun, 2011). The term was first used by the same author much earlier, in his published Ph.D. dissertation (Fama, 1965) and the article that followed (Fama, 1965), but this is how the most important explanation looks like: 'A market in which prices always "fully reflect" available information is called "efficient".' This means that all speculative assets (assets with uncertain returns, like stocks) will always incorporate the best information in their prices. This is the statement around which the whole investment theory revolves for almost half a century: we are led to believe for so long that it is, actually, impossible to beat the market, as the prices change only because of the relevant information. Also, the first fundamental theorem of welfare economics of general equilibrium theory states that every competitive equilibrium is Pareto efficient, meaning that no one can be made better off without someone being worse off. Malkiel (2003) similarly explains in another paper that he "will use as a definition of efficient financial markets that such markets do not allow investors to earn above-average returns without accepting above-average risks". The central paradigm in finance is still the "efficient market hypothesis" which is tied to the general equilibrium theory. It is strange to have such long-lasting and unquestionable faith of the general public – and generally the majority of the

economics profession – in a hypothesis that wasn't flawless from the start: it needed to divide market efficiency into three models (or theories) to cover up empiric evidence and give "testable implications" to proposed models ("But some such assumption is the unavoidable price one must pay to give the theory of efficient markets empirical content", as it was explained). LeRoy (1976) reveals another "not minor" flow: that the equations supposed to characterize "market efficiency" were, amazingly, "true as tautologies", and "because the equations imply no restrictions on the data, they cannot possibly generate testable implications contrary to Fama's clear implication".

Before we continue, we must fully understand that the efficient-market hypothesis (EMH) is the theory that holds that the market is always right. It considers stock and bond markets as nearly perfect, even during obvious crazes as the dot-com mania was at the beginning of the century, and that prices on the (stock) exchanges instantly and accurately reflect all available information about publicly traded securities. In 1984, Yale University economist Robert Shiller (1984), who later got more public exposure after the market crash of 1987, which the efficient-markets professors had trouble explaining, called that belief "one of the most remarkable errors in the history of economic thought" when he was explaining one argument for the efficient market hypothesis (that "because real returns are nearly unforecastable, the real price of stocks is close to the intrinsic value, that is, the present value with a constant discount rate of optimally forecasted future real dividends"), yet the same belief in almighty markets contributed mightily to the mortgage bust and the current economic crisis, the biggest one after the "Great Depression" (Fox, 2009). The weight of this crumbling myth is maybe best acknowledged by the former Federal Reserve chairman Alan Greenspan, a vocal proponent of the hands-off policy (believing in the self-regulation efficiency of financial markets – leave the markets to regulate themselves). On October 23, 2008, he admitted in his testimony to the U.S. Congress: "The whole intellectual edifice, however, collapsed in the summer of last year" (WSJ, 2008). His predecessor, another former Federal Reserve chairman Paul Volcker thinks alike, saying it's "clear that among the causes of the recent financial crisis was an unjustified faith in rational expectations, (and) market efficiencies" (Volcker, 2011). Another example is from the book co-written by the U.S. business editor of The Economist and a former British government official, and they state: "The crisis showed conclusively that the efficient market hypothesis is flawed" (Bishop and Green, 2010). We don't need to stay in the present, we can as well go further into the past to see what some of the widely recognized economic minds thought about rational market agents and about the romanticism that is today known as the "efficient-market hypothesis". One aphorism usually attributed to economist and speculator John Maynard Keynes, known for advocating government intervention and deficit spending during economic crises, says: "markets can remain irrational longer than you can remain solvent" (Montier and Strategy, 2002). Keynes wrote of the influence of "animal spirits" (irrational psychological behaviors) on the economy. Another name best known for the free-market philosophy of "The Wealth of Nations" (1937), Adam Smith, also emphasized the importance of psychological values in his lesser-known book "The Theory of Moral Sentiments" (1822).

Nowadays, we are all witnesses that extreme events do happen in financial markets. Nothing in the efficient-market hypothesis can explain the inconvenient truth that some shrewd investors can indeed do better than the market for a very long time (think Warren Buffet), nor can explain speculative bubbles and their busts, or bizarre stock valuations. All of this shows that people are emotional, and when they get emotional they decide to buy (or sell) in unison. This crashes the markets. People crash it. Shiller (1989) goes as far

as to claim that "mass psychology may well be the dominant cause of movements in the price of the aggregate stock market". Even technical analysis books are aware of the human element: "Security prices are determined by money managers and home managers, students and strikers, doctors and dog catchers, lawyers and landscapers, and the wealthy and the wanting. This breadth of market participants guarantees an element of unpredictability and excitement" (Achelis, 2000). Behavioral finance, a now solidly established field that is still rapidly developing as an alternative to the EMH – although still generally embracing the paradigm of market equilibrium – believes that financial man is far from the perfect, mechanical trader depicted in textbooks. He is a rather neurotic fellow who follows the crowd, fails to plan, and often makes mistakes – to think that his every price is perfect is a remarkable error indeed (Lowenstein, 2009). In our century, the assumptions of investor rationality and perfect arbitrage are overwhelmingly contradicted by both psychological and institutional evidence, showing that actual financial markets are inefficient, with less than fully rational investors (Shleifer, 2000). And more than 40 years ago it was well explained that "a full understanding of human limitations will ultimately benefit the decision-maker more than will naive faith in the infallibility of his intellect" (Slovic, 1972) – who knows, if we had put that to good use on time, maybe we could've even evaded the "Great Depression II" whose consequences we still feel.

3. FACE OF CHANGES

According to Gajic and Budinski-Petkovic (2013), Facebook, considering its "intrinsic" value, which is based on its fundamental properties like the number of users and their potential growth, was largely overvalued at its IPO and even before, fueled by the numerous articles that re-tweeted the (fake) belief in its further growth potential. A whole chapter of the prominent book is exactly about the importance of such stories in determining behavior: a historical example would be repeatedly told a story that house prices will always rise, which caused many additional people to invest in housing following the dot-com bust of 2000 (Akerlof and Shiller, 2009). When Facebook made its IPO NASDAQ debut on May 17, 2012, its shares were valued at $38.23 apiece at closing time on the first day. Then the FB share price more than halved in the first four months after the IPO, and since then it was generally slowly trending up[2], fueled by the various stories about new ways of monetarization and new advertisement models like the Facebook Exchange (Carlson, 2012), but it was s still a way off even from the starting level. Now, let's compare this fact with the words from the godfather of efficient markets, as this is how the famous Fama talks about financial prices before he became famous: "Competition among the many intelligent participants leads to a situation where, at any point in time, actual prices of individual securities already reflect the effects of information based both on events that had already occurred and on events which, as of now, the market expects to take place in the future. In other words, in an efficient market at any point in time, the actual price of a security will be a good estimate of its intrinsic value" (Fama, 1965). Fama explains that this intrinsic value he mentions is an "equilibrium price" which "depends on the earning potential of the security". So, to put this into good use, according to EMH the IPO price of Facebook shares reflected everything that happened before IPO, as well as everything that the market

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[2]*Source:* NASDAQ, https://www.nasdaq.com

expected to happen afterward. As not much has happened before the IPO, at least financially (with a price-earnings ratio of 104, and it is known that the P/E ratio is often used to estimate true or "intrinsic" value, if annual profit remained the same and fully paid to shareholders who never sell their shares, the initial investment in Facebook would turn a profit after more than a century!), we can only conclude that the investors believed the greatest things are yet to come. And they were mistaken, not only because of the steep price drop of the shares in the next months – but the "earning potential" of Facebook is marketed to be greatly dependent on the further growth of its users (this is also stated in Facebook's US Securities and Exchange Commission Registration), and this growth can't continue in the future in the presented and expected pace simply because the world population is limited! What we are witnessing here is not efficient market behavior – it's hard to imagine that none of the investors had good information when they all should generally know all according to EMH. Why was the price that high initially, then? In this paper we are trying to show how that was the result of a deliberate campaign by both the company and the investment banks responsible for IPO, aimed to psychologically influence potential investors and convince them into buying the overpriced shares. One-time cash-in for Facebook, and the world's economy it was just another financial bubble that burst soon after. If we believe that the market is always right, then nothing was wrong here. But, if we decide to give a benefit of a doubt to the "all-knowing" market from the textbooks, can there be a methodology that could have helped us determine the "real" – or we should also say "intrinsic" – value of the Facebook and similar firms at the time we needed it? Several people believe that there was a methodology for social networks like this (Cauwels and Sornette, 2011), and here we also stated and demonstrated how "intrinsic" value based on the fundamental properties should not be tied to the elusive, psychologically influenced market price.

Before we go to the next more technical chapter, we need to, almost like the definition, expand the already used term of "intrinsic value" to a value that is based on the "fundamental" properties (or how much the company/asset is "really worth", and not how much people are willing to pay for it, which is the current market value). This usage of the term is coherent with its usage in Ecology, where: "Intrinsic value is the value that an entity has in itself, for what it is, or as an end" (Sandler, 2012), and it is also in line with the most common usage of the term in recent non-academic financial literature (although we will restrain from discounting the expected future incomes, as this method particularly uses the unpredictable market influences – psychological factors – which we try avoiding in the estimation of "intrinsic value"). It is important to note that "intrinsic value" of the company may be different if we use different techniques to calculate it (as this is yet to be standardized, because not all companies have the same fundamentals, and not all people may agree on these), and it will always be further modified (sometimes quite substantively) into market price in accordance to the patterns in investors' minds – these patterns are the result of their education, past experiences, current mood and the way they forecast the future (similar to the concept of "behavioral adjusted present value" in Shefrin, 2008), and are also influenced from the outside (e.g. with word-of-mouth or newspaper stories that something is "hot or not" – according to Shiller (2003) feedbacks may even "be an essential source of much of the apparently inexplicable 'randomness' that we see in financial market prices"). So, "intrinsic value", as we use it here, is not the equilibrium concept – the market price probably won't strive for this (although it is the "most probable" or the "fair" price if we present it like numeral); instead, the market price will move unexpectedly and chaotically as it always does, fluctuating based on changes in perceived desirability – but the value of the concept lies in the fact that one needs to have a theory of how prices are

supposed to behave if he wants to estimate are they right or wrong (too high or too low) at the precise moment in time. There is a need to value something, as in finance "the central unifying concept is asset valuation. Certainly, the theory of value, and comparisons of price and value, is what much of finance is about" (De Bondt et al., 2008). And investors are always looking, whether they are aware of it or not, for less risky "bargains" where the "intrinsic" (true) value of the company/asset exceeds its current market valuation/price. This is what Warren Buffet is famous for – in his own words, "the basic ideas of investing are to look at stocks as business, use the market's fluctuations to your advantage, and seek a margin of safety" (Outlook, 2022), and here we accept that margin of safety (or safety margin) is the difference between the intrinsic value of a stock and its market price. This is contrary to Malkiel's (2003) view of efficient financial markets where increased returns can only be achieved by taking greater, not lesser, levels of risk.

4. TESTING MARKET EFFICIENCY HYPOTHESIS

After we demonstrated and explained some of the big problems (and some are yet to come) of Economics theory today, in this chapter we try to suggest the right directions for further research in the search for solutions. As stated in the introduction, we are not trying to give definite answers as most of them are beyond the scope of this paper, but some guidelines may be of use to future researchers. First of all, some theory of asset valuation is necessary to compare prices and values, and the "intrinsic value" proposed here considers the fundamental properties of the asset, making it a good starting point for all "non-EMH" (or shall we, for easier reference, just change the first letter from Efficient to Inefficient, leaving us with the abbreviation IMH) theories and models. Secondly, it is important to understand that the vast majority of the past knowledge, or the building blocks of Economics, can still be used if we question or even reject the EMH. And thirdly, if we accept the concept of inefficient markets, we need to get used to thinking in probabilities: the "intrinsic value" itself is the most probable price guideline in the "moment zero", but it is being substantively modified into the market price after passing through the "human emotion filters". From the moment when the first market price or "emotionally-influenced outcome" is known, all that various models can accomplish is the calculation of the probability of any outcome or price. That is, we can calculate (a) the most probable outcome or price, (b) the probability for that (or any other) outcome or price to happen, and (c) which inputs have the biggest effect on the results. Beyond that is the limit, because of the awareness that markets are inefficient and agents operating on them are irrational, so basically, every outcome or price is possible. This is why there can never be a 100% sure prediction of outcome or price through models based on the concept of "intrinsic value" and inefficient markets (although some models can theoretically come close to this), but what about that? There are yet no economic models that can predict with 100% accuracy. The concept might be hard to grasp or accept at first, but its usefulness is indisputably proven in real life with widely accepted predictions like weather forecasting.

According to Pinches (1970): "The random-walk theory, in its general form, is suggested directly from the nature of the markets under consideration. If the security markets are perfect, or not too imperfect, the participants in such a market will eliminate any profits above the base minimum required to induce them to continue in the market, except for any profits which might accrue to someone who has private information. The price of a security should reflect all of the

information available to participants in the market. In such a market all changes in price should be independent of any past history about a company which is generally available to the public. Except for a possible trend related to the desired rate of return, future stock prices could just as well be determined by the flip of a coin (unless private information is available) as by any elaborate analysis of past data". Under the random walk model, the behavior of prices under the EMH will wander randomly around an increasing trend, with or without drift (Mollah, 2007):

$$X_{t+1} = \delta + X_t + \varepsilon_{t+1} \tag{1}$$

where: ε_{t+1} identically and independently distributed random variable; δ drift.

EMH claims that a market is efficient if a particular information set cannot be used to generate above-average profits over a longer period of time (Hájek, 2007). Moreover, weak form market efficiency implies that the stock prices traded on the market cannot be predicted by using historical price information, which means they are not serially correlated (Borges, 2010). Accordingly, to examine whether the market is efficient or not, we will test the next research hypothesis:

H0: The market follows a random walk, i.e. the market is efficient in the weak form
H1: The market doesn't follow a random walk, i.e. the market is not efficient in the weak form

5. METHODOLOGY AND DATA ANALYSIS

Because econometric models favor the use of daily data in time series analysis (Morse, 1984), for this study we have used Stoxx Europe 600 index historical closing daily prices[3], for the period from Jan 2012–Oct 2022. Stoxx Europe 600 is a stock index of European stocks representing large, mid, and small capitalization companies among 17 European countries: the United Kingdom (composing around 22.3% of the index), France (composing around 16.6% of the index), Switzerland (composing around 14.9% of the index) and Germany (composing around 14.1% of the index), as well as Austria, Belgium, Denmark, Finland, Ireland, Italy, Luxembourg, the Netherlands, Norway, Poland, Portugal, Spain, and Sweden (Stoxx, 2021). To test the research hypothesis and increase the reliability of the research we will use both non-parametric and parametric tests, such as the Kolmogorov–Smirnov Goodness of Fit test (K–S), run–test for random order, and ARIMA regression as the dynamic time series technique. The descriptive statistics for the log-transformed closing daily prices (lnClose) are presented in Table 1.

Table 1 Descriptive statistics

Variable	Obs	Mean	Std.Dev.	Min	Max	Skewness	Kurtosis
lnClose	2799	5.884	.154	5.455	6.203	-.466	2.949

As we can see in Table 1, the prices are skewed negatively, with large negative prices tending to be larger than large positive prices. The level of excess kurtosis is positive, indicating that the price distribution is leptokurtic and therefore has a higher peak than expected from a normal distribution. Negative skewness and leptokurtic frequency

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[3] *Source:* NASDAQ, https://www.nasdaq.com

distribution of the price series indicate that the distribution is not normal, i.e. the non-normal frequency distributions of the price series deviate from the prior condition of the random walk model (Molahh, 2007). To confirm this, we also used the non-parametric Kolmogorov-Smirnov Goodness of Fit test (K–S) which provides evidence of whether the distribution fits a normal distribution or not. According to Stata (2013), the directional hypotheses are evaluated with the statistics:

$$
\begin{aligned}
D^+ &= \max_x \{F(x) - G(x)\} \\
D^- &= \min_x \{F(x) - G(x)\}
\end{aligned}
\tag{2}
$$

where: $F(x)$ and $G(x)$ are the empirical distribution functions for the sample being compared. The combined statistic is:

$$
D = max(|D^+|, |D^-|)
\tag{3}
$$

and the p-value for this statistic may be obtained by evaluating the asymptotic limiting distribution.

The results from K–S test are presented the Table 2 and they indicate that prices can be distinguished from normally distributed data (we see the p-value provided is .000 and therefore we have significant evidence to reject the null hypothesis that the variable follows a normal distribution).

Table 2 One-sample Kolmogorov-Smirnov test

Smaller group	D	P-value	Corrected
lnClose	.043***	.000	
Cumulative	-.068***	.000	
Combined K–S	.068***	.000	.000

Notes: D - distance. Significance: *** p<.01, ** p<.05, * p<.1.

Another non-parametric test that we used here is the run–test. According to Stata (2013) this test performs a nonparametric test of the hypothesis that the observations occur in a random order by counting how many runs there are above and below a threshold. The expected number of runs under the null is:

$$
\mu_r = \frac{2n_0 n_1}{\bar{N}} + 1
\tag{4}
$$

the variance is:

$$
\sigma_r^2 = \frac{2n_0 n_1 (2n_0 n_1 - N)}{N^2(N-1)}
\tag{5}
$$

and the normal approximation test statistic is:

$$
\hat{Z} = \frac{\hat{r} - \mu_r}{\sigma_r}
\tag{6}
$$

The result of the run–test is shown in Table 3. Following Bujang and Sapri (2018), since the test statistics (z = -50.84) is greater than the critical value (+1.96) with significance level at .01, we should reject the null hypothesis.

Table 3 Run–test for random order

Variable	N (runs)	z	Prob>z
lnClose	56	-50.84[***]	.000

Notes: Significance: [***] p<.01, [**] p<.05, [*] p<.1.

Finally, the normality test of both descriptive statistics and the K–S test, as well as the run–test results, confirm our alternative research hypothesis that the market doesn't follow a random walk, i.e. the market is not efficient in the weak form.

On the other side, to test the EMH we have also used a parametric test, i.e. ARIMA regression − the dynamic time series technique − which stands for Autoregressive Integrated Moving Average and which is one of the most popular and widely used techniques for forecasting based on the past values of the time series. The Box Jenkins methodology (Box and Jenkins, 1970) was named after the authors George Box and Gwilym Jenkins, who proposed a three steps method to select an appropriate ARIMA model which will have the ability to forecast economic variables: 1) identification, 2) estimation, and 3) diagnostics and forecasting. ARIMA is written as ARIMA (p, d, q) where "p" is the order of the autoregressive component, "d" is the times we need to differentiate the variable to achieve stationarity, and "q" is the order of the moving average component. The estimating equation for the ARIMA model can be presented as follows:

$$Y_t = c + \sum_{i=1}^{p} \alpha Y_{t-i} + \sum_{j=1}^{q} \theta E_{t-j} + E_t \tag{7}$$

where: c constant; p order of the autoregressive component; q order of the moving average component; α coefficient of the autoregressive model; θ coefficient of the moving average model; E_t error term.

If we look at Figure 1, which presents Stoxx Europe 600 historical closing daily prices, from 2012–2022, we can see that there is definitively a positive trend in the movement of the prices, which indicates the existence of non-stationarity. This can be also confirmed by looking at Figure 2, which shows autocorrelations of our variable of interest (lnClose), where we can see that the decay is very slow, which again indicates the existence of non-stationarity. After confirming non-stationarity, the next step would be to check stationarity again, but this time we should use the first difference of our variable of interest (lnClose). Accordingly, if look at Figure 3, which presents differenced prices (d.lnClose), now we can see that, after differencing, our variable of interest is stationary.
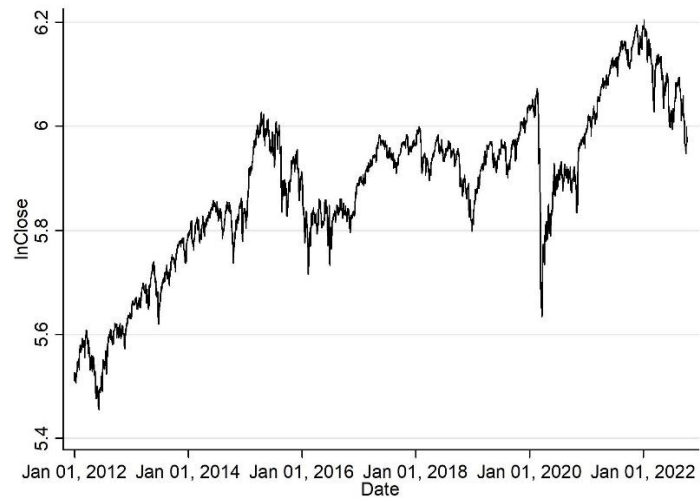
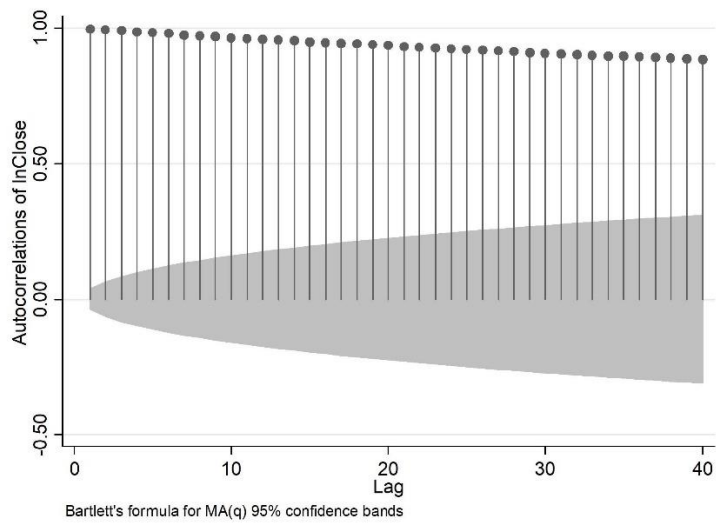**Fig. 1** lnClose prices from 2012–2022

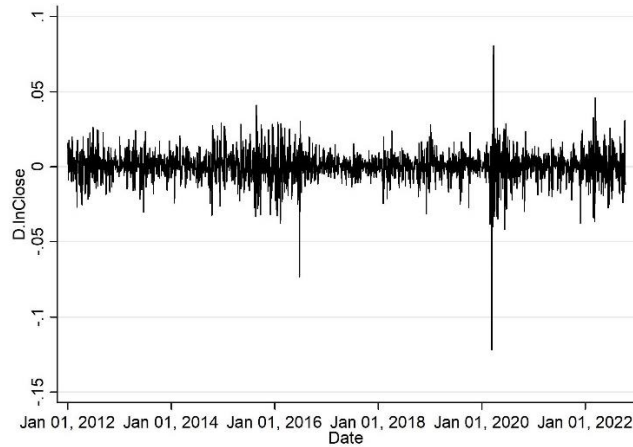**Fig. 2** Autocorrelations of lnClose prices

Fig. 3 Differenced lnClose prices from 2012–2022

To confirm these assumptions, we will use the augmented Dickey-Fuller test for unit root. According to Stata (2013), the augmented Dickey-Fuller test fits a model of the form:

$$\Delta y_t = \alpha + \beta y_{t-1} + \delta t + \zeta_1 \Delta y_{t-1} + \zeta_2 \Delta y_{t-2} + \cdots + \zeta_k \Delta y_{t-k} + \epsilon_t \tag{8}$$

where: k is the number of lags.

The null hypothesis is that the variable contains a unit root, and the alternative is that the variable was generated by a stationary process. Because the data show a clear upward trend, we include a constant and time trend in the augmented Dickey-Fuller regression. The results were reached by extracting the levels and differences, respectively. The result of the test indicated that, when the level and difference values of the series are analyzed with intercepts and trends, the prices are non-stationary and stationary, respectively. So, according to the results from ADF test (Table 4) we can see: (a) that we can't reject null

Table 4 Augmented Dickey–Fuller test

	Level	1st difference
lnClose	Coef.	Coef
L1.	-.008***	-1.019***
	(.003)	(.025)
_trend	.000**	-.001
	(.000)	(.000)
_cons	.047***	.000
	(.015)	(.000)
Test statistic	-3.169	-41.323
1% critical value	-3.960	-3.960
5% critical value	-3.410	-3.410
10% critical value	-3.120	-3.120

Notes: This table presents results for unit root tests with an intercept and a trend.
Significance: *** p<.01, ** p<.05, * p<.1. Standard errors in parentheses.
MacKinnon approximate p-value for Z(t) = .091 (level) and p-value for Z(t) = .000 (1st difference).

hypothesis that (lnClose) has unit root, therefore (lnClose) is non-stationary (MacKinnon approximate p-value for Z(t) = .091), and (b) that we can reject null hypothesis that differenced (d.lnClose) has unit root, therefore differenced (d.lnClose) is stationary (MacKinnon approximate p-value for Z(t) = .000).

We have verified that (lnClose) is non-stationary in levels, but stationary in first differences (d.lnClose). Consequently, we use the variable of interest in the first differences (d.lnClose) to identify the order of the autoregressive and moving average components. To determine the order of the autoregressive component ("p"), we have to check the partial autocorrelations of (d.lnClose), which can be seen in Figure 4.

The values that exceed the confidence bands suggest the possible order of the autoregressive component and we can see that two lags (the first and the second) are exceeding the confidence bands and that there are two possible AR components. To determine the order of the moving average component ("q"), we have to check the autocorrelation of (d.lnClose), which can be seen in Figure 5. We can see that two lags (the first and the last) exceed the confidence bands and that there are two possible MA components. So, we will estimate two cases, ARIMA (1,1,2) and ARIMA (2,1,2), and decide which model is the better one. To choose the appropriate model we will look at the significance of the coefficient estimates and the model selection criteria, such as Akaike's and Bayesian information criteria.

The model with the smallest values in the model selection criteria and the most significant coefficient estimates will be the appropriate one. ARIMA regression estimations, including Akaike's and Bayesian information criterion, for the two models, are presented in Table 5.
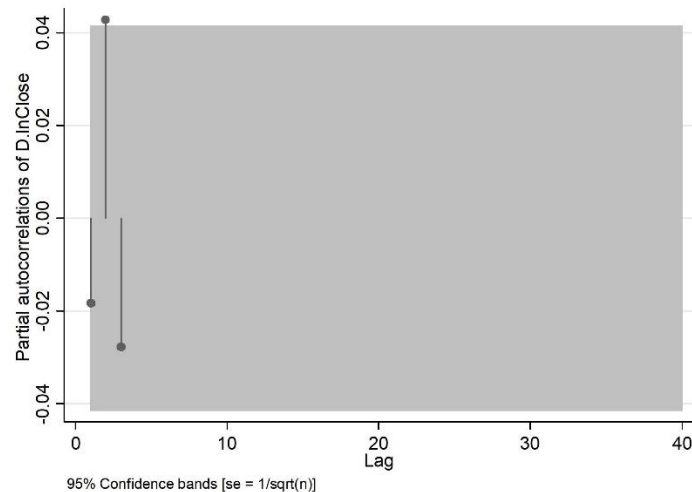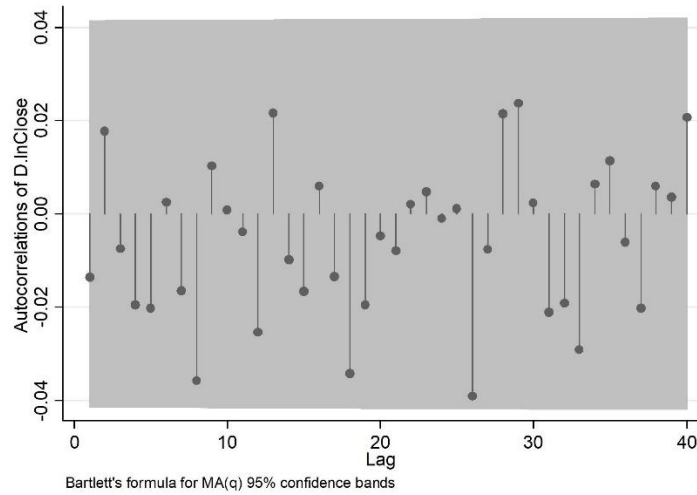

Fig. 4 Partial autocorrelations of d.lnClose

Fig. 5 Autocorrelations of d.lnClose

Table 5 ARIMA regression

	Model (1,1,2)	Model (2,1,2)
lnClose	Coef.	Coef.
Constant	.000	.000
	(.000)	(.000)
arL	-.203	-.306***
	(.688)	(.037)
arL2		-.904***
		(.036)
maL	.186	.285***
	(.691)	(.034)
maL2	.032	.948***
	(.026)	(.035)
/sigma	.01***	.01***
	(.000)	(.000)
AIC	-14149.77	-14159.54
BIC	-14121.21	-14125.27

Notes: ar - autoregressive component; ma - moving average component.
Significance: *** p<.01, ** p<.05, * p<.1. Standard errors in parentheses.

Based on the significance of the coefficient estimates and based on Akaike's and Bayesian information criteria we can conclude that the second model, ARIMA (2,1,2), is the more appropriate one. More precisely, in Model 2 − ARIMA (2,1,2) − all coefficient estimates are statistically significant at a significance level of .001. Also, AIC and BIC values for Model 2 are smaller compared to the same values for Model 1.

Next, we need to check whether this univariate process is stable. Figure 6 shows the residuals and we can see that values are constantly around the mean, which indicates that residuals are white noise. This can be confirmed by the White-Noise test which produces a cumulative periodogram (Figure 7), where we can see that the values never appear outside the confidence bands. The test statistic has a p-value of .629, so we can conclude that the process is not different from the white noise.
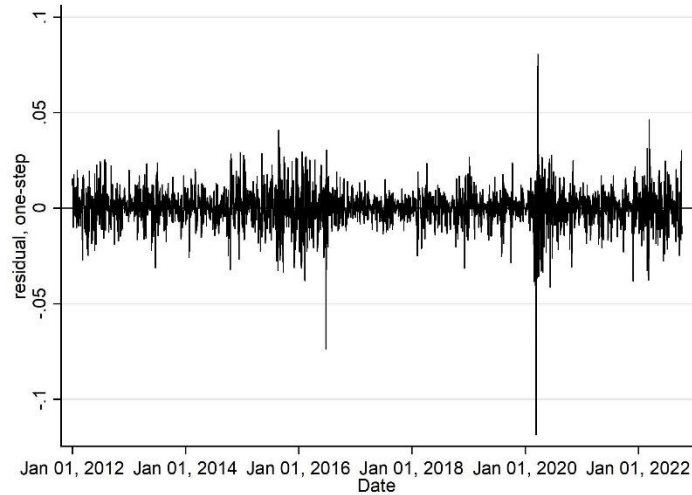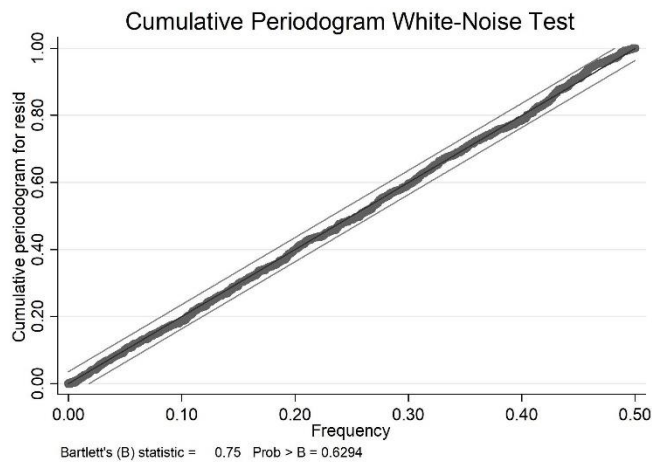

Fig. 6 Residuals (one-step)

Bartlett's (B) statistic =   0.75   Prob > B = 0.6294
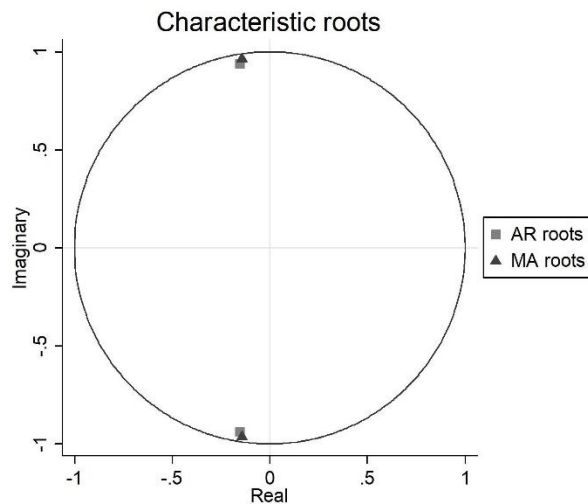
Fig. 7 Cumulative periodogram

Fig. 8 Characteristic roots

Also, the AR and MA roots of the characteristic polynomials (Figure 8) are not out of the circle which proves that the process is stationary, invertible, and stable for prediction. Finally, the results from the ARIMA regression imply that the stock prices traded on the market can be predicted using historical price information which confirms our alternative research hypothesis that the market doesn't follow a random walk, i.e. the market is not efficient in the weak form. Interestingly, besides a few researchers who didn't validate the EHM (e.g. Hájek, 2007), our results are quite opposite to the findings from most of the studies which examined both developed and emerging European markets (Worthington and Higgs, 2004; Hasanov and Omay, 2007; Pele and Voineagu, 2008; Borges, 2010; Narayan and Smyth, 2007; Dragota and Tilica, 2014; Hepsag and Akcali, 2015; Anlas and Toraman, 2016; Tokić et al., 2018). However, the previous research tested the weak form of the EMH using different methods which were mainly based on the unit root analysis (Erdas, 2019), in which stationarity represented the rejection criterion of the null hypothesis that the market is efficient in the weak form. Our opinion is that the unit root analysis is incomplete and that researchers should not rely only on this approach when testing the EMH. Since EMH implies that stock prices traded on the market cannot be predicted by using historical price information, one should actually evaluate the stability of the prediction process which assumes differencing approach in the case of non-stationarity. This is the reason why we went beyond the unit root analysis and used ARIMA regression as the dynamic time series technique for testing the weak form of EMH − which, besides data novelty, could be seen as the originality of this study. However, as shown in previous studies, the results vary from market to market. Extending the analysis to other markets can also serve as a good foundation for future research direction.

6. Conclusion

For decades, the prevailing paradigm of Economy is the paradigm of market equilibrium, in which markets are abstracted as systems with the perfect competition that equalizes supply and demand and participants that are behaving perfectly rationally. However, practice shows that real-life markets operate differently. As we stated at the beginning , the paradigm of market equilibrium (and the "efficient-market hypothesis" tied to it, dealing specifically with the behavior of capital markets) has no explanation for financial bubbles and their bursting that is leading to stock market crashes. Accordingly, the main goal of this paper was to discuss the inefficiency of markets, with examples of corporate decisions that directly abuse such inefficiency to psychologically motivate desired behavior of potential customers. To avoid such manipulations, we expand the concept of "intrinsic value" as the foundation upon which the new theory could be built. Using both non-parametric and parametric tests, we have proved the stability of the stock price prediction process. This means that the stock prices traded on the market can be predicted using historical price information and that the market is not efficient in the weak form because it doesn't follow a random walk. After all that is said, what should we do with this EMH? Simply put, it's hard to reject the claim that prices are right unless you have a theory of how prices are supposed to behave, or, as Fama (1976) puts it himself, "any test is a joint test of efficiency and the model of equilibrium". Let's think for a moment about something that Bill Bryson (2003) said in his bestseller "A Short History of Nearly Everything" when explaining years of scientists' reluctance to embrace the idea of continental drift: "Interestingly, oil company geologists had known for years that if you wanted to find the oil you had to allow for precisely the sort of surface movements that were implied by plate tectonics. But oil geologists didn't write academic papers; they just found oil." This is the right place to, for the first time, completely agree with Fama's term "efficient markets" – he concluded that the notion of market efficiency could not be rejected without an accompanying rejection of the model of market equilibrium (e.g. the price setting mechanism). In the end, we agree with the problem and propose the solution: the joint rejection of the "efficient markets" hypothesis and all market equilibrium models – that is, the rejection of the whole romanticized paradigm of market equilibrium known as the general equilibrium theory.

Why not? Because of Montaigne's axiom that "nothing is so firmly believed as that which least is known"? Why are we holding to malfunctioning theories so firmly, after so many crashes and crises? That's probably just a psychological effect of risk aversion, as it may be too terrifying to leave something as clean and simple as the equilibrium paradigm for something else that embraces chaos. But, if we want our economic theories to reflect real-life behaviors instead of being outdated dogmas, we shouldn't panic. If something is chaotic, it doesn't mean it can't be predicted. Nature teaches us that. We don't know exactly how long the desert storm will last or how strong it will be, but we can still predict, with underlying certainty, the regular linear forms it will leave on the dunes. We don't know exactly how long the rain will last, but if it lasts longer than some predictable threshold, we can be sure it will leave a pool of water in our backyard. To quote Bill Bryson (2003) and his bestseller about the science for the second time: "Complexity is a natural, spontaneous, entirely commonplace event. There may or may not be a great deal of life in the universe at large, but there is no shortage of ordered self-assembly, in everything from the transfixing symmetry of snowflakes to the comely rings of Saturn". We should learn from nature and discover the methods – and design systems and models – for predicting

chaotic behaviors of the financial markets. It may take a leap of fate to get it started, but the human race has done so much more in the past, and here we argued only the need for switching the paradigm to better explain reality. Not very much, but we may be on the verge of a new and exciting era for economic science.

REFERENCES

Achelis, S. B. (2000). *Technical Analisys from A to Z*. McGraw–Hill.

Akerlof, G. A., & Shiller, R. J. (2009). *Animal Spirits: How Human Psychology Drives the Economy, and Why It Matters for Global Capitalism*. Princeton University Press, Princeton.

Anlas, T., Toraman, C. (2016). Analysing the efficiency of the Turkish stock market with multiple structural breaks. *International Journal of Academic Research in Business and Social Sciences, 6*(12), 721-740. http://dx.doi.org/10.6007/IJARBSS/v6-i12/2531

Bishop, M., & Green, M. (2010). *The Road From Ruin: How To Revive Capitalism and Put America Back On Top*. Crown Business, New York.

Borges, M. R. (2010). Efficient market hypothesis in European stock markets. *The European Journal of Finance, 16*(7), 711-726. https://doi.org/10.1080/1351847X.2010.495477

Box, G., & Jenkins, G. (1970). *Time Series Analysis: Forecasting and Control*. Holden–Day, San Francisco.

Bryson, B. (2003). *A short history of nearly everything*. Broadway.

Bujang, M. A., & Sapri, F. E. (2018). An application of the runs test to test for randomness of observations obtained from a clinical survey in an ordered population. *The Malaysian Journal of Medical Sciences: MJMS, 25*(4), 146. https://doi.org/10.21315/mjms2018.25.4.15

Carlson, N. (2013). It's Become Tragically Clear That Facebook Chased the Wrong Business For Years. *Business Insider* [online]. Available at: http://www.businessinsider.com/facebook-fbx-2012-9 [Accessed 12 January 2022].

Cauwels, P., & Sornette, D. (2011). Quis Pendit Ipsa Pretia: Facebook Valuation and Diagnostic of a Bubble Based on Nonlinear Demographic Dynamics. *Swiss Finance Institute Research Paper*, 11-58, Available at: SSRN: http://ssrn.com/abstract=1965431 [Accessed 22 March 2022].

De Bondt, W., Muradoglu, G., Shefrin, H. & Staikouras, S. K. (2008). Behavioral Finance: Quo Vadis?. *Journal of Applied Finance, 19*, 7-21.

Dragota, V., Tilica, E. (2014). Market efficiency of the post–communist east European stock markets. *Central European Journal of Operations Research, 22*(2), 307-337. http://dx.doi.org/10.1007/s10100-013-0315-6

Erdas, M. L. (2019). Validity of weak–form market efficiency in Central and Eastern European countries, CEECs, Evidence from linear and nonlinear unit root tests. *Review of Economic Perspectives, 19*(4), 399-428. http://dx.doi.org/10.2478/revecp-2019-0020

Fama E. (1965). Random Walks in Stock Market Prices. *Financial Analysis Journal, 76*, 75-80. https://doi.org/10.2469/faj.v51.n1.1861

Fama, E. (1965). The Behavior of Stock Market Prices. *Journal of Business, 38*, 34-105. https://www.jstor.org/stable/2350752

Fama, E. (1976). Efficient Capital Markets: Reply. *Journal of Finance, 31*(1), 143-145. https://doi.org/10.2307/2326404

Fama, E. F. (1970). Efficient Capital Markets: A Review of Theory and Empirical Work. *Journal of Finance, 25*(2), 383-417. https://doi.org/10.2307/2325486

Fox, J. (2009). *The Myth of the Rational Market: A History of Risk, Reward, and Delusion on Wall Street*. HarperBusiness, New York.

Gajic, N., & Budinski–Petkovic, L. (2013). Ups and Downs of Economics and Econophysics – Facebook Forecast. *Physica A, 392*(1), 208-214. https://doi.org/10.1016/j.physa.2012.08.018

Guerrien, B., & Gun, O. (2011). Efficient Markets Hypothesis: what are we talking about?, *Real–World Economics Review, 56*, 19-30. Available at: http://www.paecon.net/PAEReview/issue56/GuerrienGun56.pdf. [Accessed 15 March 2022].

Hájek, J. (2007). Czech capital market weak-form efficiency, Selected issues. *Prague Economic Papers, 16*(4), 303-318. http://dx.doi.org/10.18267/j.pep.310

Hasanov, M., & Omay, T. (2007). Are the transition stock markets efficient? Evidence from non–linear unit root tests. *Central Bank Review, 2*, 1-12.

Hepsag, A., & Akcali, B. Y. (2015). The analysis of weak–form efficiency with asymmetric nonlinear unit root test: The case of G–7 and E–7 countries. *BDDK Bankacılık ve Finansal Piyasalar, 9*(2), 73–90.

LeRoy, S. F. (1976). Efficient Capital Markets: a Comment. *Journal of Finance, 31*(1), 139-141. https://doi.org/10.1111/j.1540-6261.1976.tb03204.x

Lowenstein, R. (2009). *Book Review: The Myth of the Rational Market by Justin Fox*. Available at: http://www.washingtonpost.com/wp-dyn/content/article/2009/06/05/AR2009060502053.html [Accessed 21 January 2022].

Malkiel, B. (2003). The Efficient Market Hypothesis and Its Critics. *Journal of Economic Perspective, 1*(1), 59-82. http://dx.doi.org/10.1257/089533003321164958

Mollah, A. S. (2007). Testing weak–form market efficiency in emerging market: Evidence from Botswana stock exchange. *International Journal of Theoretical and Applied Finance, 10*(6), 1077-1094. http://dx.doi.org/10.1142/S021902490700455X

Montier, J., & Strategy, G. E. (2002). *Applied behavioural finance: Insights into irrational minds and market*. Unpublished manuscript. Available at: https://www.trendfollowing.com/whitepaper/James-Montier-2.pdf [Accessed 18 February 2022].

Morse, D. (1984). An econometric analysis of the choice of daily versus monthly returns in tests of information content. *Journal of Accounting Research, 22*(2), 605-623, https://doi.org/10.2307/2490667

Narayan, P. K., & Smyth, R. (2007). Mean reversion versus random walk in G–7 stock prices evidence from multiple trend break unit root tests. *Journal of International Financial Markets, Institutions and Money, 17*(2), 152-166. https://doi.org/10.1016/j.intfin.2005.10.002

Outlook. (2022). *Be Greedy When Others Are Fearful: Warren Buffett's Top Five Investing Lessons*, Available at https://www.outlookindia.com/business/be-greedy-when-others-are-fearful-warren-buffett-s-top-five-investing-lessons-news-220197 [Accessed 02 September 2022]

Pele, D. T., & Voineagu, V. (2008). Testing market efficiency via decomposition of stock return: Application to Romanian capital market. *Romanian Journal of Economic Forecasting, 5*(3), 63-79.

Pinches, G. E. (1970). The random walk hypothesis and technical analysis. *Financial Analysts Journal, 26*(2), 104-110.

Sandler, R. (2012). Intrinsic Value, Ecology, and Conservation. *Nature Education Knowledge, 3*(10), 4.

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

Shefrin, H. (2008). Risk and Return in Behavioral SDF–Based Asset Pricing Models. *Journal of Investment Management, 6*(3), 1-19.

Shiller, R. J. (1984). Stock Prices and Social Dynamics. *Booking Papers on Economic Activity, 2,* 457-498. https://doi.org/10.2307/2534436

Shiller, R. J. (1989). *Market Volatility*. MIT Press, Cambridge.

Shiller, R. J. (2003). From Efficient Markets Theory to Behavioral Finance. *The Journal of Economic Perspectives, 17*(1), 83-104. https://doi.org/10.1257/089533003321164967

Shleifer, A. (2000). *Inefficient Markets: An Introduction to Behavioral Finance*. Oxford University Press, New York.

Slovic, P. (1972). Psychological Study of Human Judgment: Implications for Investment Decision Making. *Journal of Finance, 27*(4), 779-799. https://doi.org/10.1111/j.1540-6261.1972.tb01311.x

Smith, A. (1822). *The theory of moral sentiments*, 1st Ed., MetaLibri.

Smith, A. (1937). *The wealth of nations* [1776] , Vol. 11937, n.a.

Stata. (2013). Stata 13 Base Reference Manual. College Station, TX: *Stata Press*. Available at: https://www.stata.com/manuals13/mvpca.pdf [Accessed 10 May 2022].

Stoxx. (2021). *Stoxx Index Methodology Guide*, STOXX. Available at: https://www.stoxx.com/document/Indices/Common/Indexguide/stoxx_index_guide.pdf [Accessed 23 April 2022].

The Wall Street Journal, WSJ, Blogs. (2008). *Greenspan Testimony on Sources of Financial Crisis*. Available at: http://blogs.wsj.com/economics/2008/10/23/greenspan-testimony-on-sources-of-financial-crisis/ [Accessed 05 February 2022].

Tokić, S., Bolfek, B., & Peša, A. R. (2018). Testing efficient market hypothesis in developing eastern European countries. *Investment Management and Financial Innovations, 15*(2), 281-291. http://dx.doi.org/10.21511/imfi.15(2).2018.25

Volcker, P. (2011). *Financial Reform: Unfinished Business*. New York Review of Books. Available at: http://www.nybooks.com/articles/archives/2011/nov/24/financial-reform-unfinished-business [Accessed 17 January 2022].

Worthington, A., & Higgs, H. (2004). Random walks and market efficiency in European equity markets. *Global Journal of Finance and Economics, 1*(1), 59-78.

TESTIRANJE EFIKASNOSTI TRŽIŠTA:
PUT KA UTVRĐIVANJU SUŠTINSKE VREDNOSTI

Paradigma tržišne ravnoteže i za nju vezana „hipoteza efikasnog tržišta", koja se posebno bavi ponašanjem tržišta kapitala, nema objašnjenja za finansijske mehure i njihovo pucanje koje dovodi do kraha berze. Shodno tome, osnovni cilj ovog rada je da se diskutuje o neefikasnosti tržišta, uz primere korporativnih odluka koje direktno zloupotrebljavaju takvu neefikasnost da bi psihološki motivisale željeno ponašanje potencijalnih kupaca. Za testiranje hipoteze efikasnosti tržišta koristili smo Stoxx Europe 600 indeks istorijskih dnevnih cena akcija u periodu od 2012–2022. Koristeći neparametarske i parametarske testove, kao što su Kolmogorov–Smirnov test, run–test i ARIMA regresija, odbacujemo hipotezu da je tržište efikasno u slabom obliku jer ne prati slučajni hod. Takođe, u radu su analizirani i osnovni problemi ekonomske teorije, naglašavajući stav da je možda došlo vreme da se fundamenti ekonomske teorije usklade sa osnovnim konceptima koji se godinama koriste u praksi.

Ključne reči: *tržište, efikasnost, akcije, cena, predviđanje*