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MARKET EFFICIENCY AND VOLATILITY IN A PERIOD OF RAPID GROWTH OF PASSIVE INVESTING: EMPIRICAL EVIDENCE FROM THE U.S. AND CROATIAN CAPITAL MARKETS

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Abstract

This paper examines how the growth of passive investing impacts market efficiency and volatility, focusing on the U.S. and Croatian capital markets. In the U.S. market, where passive funds hold a significant share, the analysis considers abnormal returns and volatility changes associated with S&P 500 rebalancing. The results indicate that passive capital flows affect prices and market dynamics, with differing effects for stocks entering and leaving the index. In the Croatian market, active portfolio management using the Markowitz model is compared with passive investing via the 7CRO ETF. The findings suggest that actively constructed portfolios may achieve higher returns than passive strategies, raising questions about the level of market efficiency relative to more developed markets.

Keywords: Croatian capital market, Market efficiency, Passive investing, United States capital market, Volatility

1. INTRODUCTION

1.1. Research Motivation, Objectives and Structure of the Paper

Passive investing has, over the past few decades, become one of the leading approaches in modern financial markets, significantly reshaping the way capital is allocated and managed. The expansion of index funds and exchange-traded funds (ETFs) has played a key role in this process, contributing to a steady increase in the share of passively managed assets, both globally and across individual markets.

Despite the clear advantages commonly associated with passive investing, most notably lower costs, broad diversification, and a high degree of transparency, its growing prominence has raised important questions about its broader implications for the functioning of capital markets. In particular, the debate has focused on its potential effects on market efficiency and volatility. On the one hand, passive investing is grounded in the assumption that markets are largely efficient, implying that consistently outperforming the market is difficult in practice. On the other hand, the increasing presence of passive strategies may influence the process of price formation and the behaviour of market participants, potentially leading to new forms of inefficiency or more pronounced price fluctuations.

The motivation for this study arises from the need to better understand these seemingly opposing effects and to assess whether the growth of passive investing contributes to structural changes in financial markets. This issue becomes especially relevant when considering differences between developed and less developed markets, where the role and implications of passive investing may vary considerably.

Accordingly, the aim of this paper is to examine the relationship between passive investing, market efficiency, and volatility across two distinct market environments: the developed U.S. capital market and the relatively small and less liquid Croatian capital market. By combining these two perspectives, the paper seeks to provide a more comprehensive view of how passive investing is associated with market dynamics under different conditions.

The contribution of the paper is twofold. First, it provides empirical evidence on the effects of passive capital flows in a developed market through the analysis of S&P 500 index rebalancing events, with particular attention to abnormal returns and changes in volatility. Second, it examines the Croatian capital market by comparing the outcomes of active portfolio management, based on the Markowitz model, with passive investment through ETFs, thereby offering insights into market efficiency in a smaller, emerging market context.

The remainder of the paper is organised as follows. Section 1.2 reviews the existing literature on passive investing. Section 1.3 outlines the theoretical background and key concepts. Section 2 describes the methodology and data used in the empirical analysis, while Section 3 presents the results. Finally, Section 4 discusses the findings and concludes the paper.

1.2. Literature Review

Given global trends in passive investing, it is unsurprising that the effects of its rapid expansion have attracted significant interest from both the academic community and financial regulators. The number of research studies on this topic has increased markedly over the past decade, as confirmed by the systematic analysis of Malhotra (2024), which documents an exponential rise in published studies on passive investing over the last ten years. Malhotra (2024) provides a comprehensive overview of prior research using a systematic literature review (SLR) methodology. The analysis covers 943 scholarly articles (1998–2022) indexed in the Web of Science and Scopus databases, employing the PRISMA framework for systematic searching and bibliometric tools for data processing. The findings show that the past decade has witnessed a substantial increase in publications and citations related to passive investing, accompanied by significant growth in interdisciplinary and international research scope (von Moltke & Sløk, 2024). This expansion of the literature is closely linked to structural changes in financial markets following the global financial crisis, which intensified both academic and regulatory interest in passive investment strategies (Malhotra, 2024)

Three leading thematic clusters were identified, collectively accounting for more than 50% of all published work in the field of passive investing. The first cluster focuses on comparisons between active and passive management, including studies examining performance, costs, and behavioral differences between active and passive funds. This stream of research includes extensive empirical work on fund performance persistence, cost structures, and investor flows (Gruber, 1996; Elton et al., 1996; Hortacsu & Syverson, 2004). The second cluster investigates the effects of passive investing on price formation and market structure—covering topics such as price discovery, market efficiency, volatility, liquidity, and other market-wide changes resulting from the rise of passive strategies. In this context, a substantial body of literature examines the role of ETFs in price discovery and information transmission, as well as their impact on volatility and market microstructure (Hasbrouck, 2003; Tse & Martinez, 2007; Gleason et al., 2004). The third cluster encompasses studies addressing structural aspects of markets and institutions, such as corporate governance in an era dominated by passive investors, changes in firm behavior (e.g., share repurchase or dividend policies) due to evolving ownership structures, and regulatory perspectives on the growth of passive investing (von Moltke & Sløk, 2024).

In addition to these areas, several emerging themes have gained visibility, ranging from analyses of specific ETF market anomalies and the impact of new products (such as inverse and leveraged ETFs) to the evaluation of tracking error, pricing efficiency, and portfolio construction techniques in ETF-based investing (Johnson, 2009; Shin & Soydemir, 2010). Research on passive investing in the context of sustainability (ESG) has also expanded significantly, driven by the growth of ESG index funds and ongoing debates about how passive investors influence the implementation of ESG principles within firms. Recent literature further highlights the increasing importance of financial innovations such as

leveraged ETFs and algorithm-assisted portfolio allocation, reflecting the ongoing evolution of passive investment strategies (Avellaneda & Zhang, 2010; Schoenfeld, 2017). As passive investing continues to grow and evolve, further research expansion is expected (von Moltke & Sløk, 2024). Future studies are likely to focus on the dynamic equilibrium between active and passive investing, long-term implications for capital allocation in the economy, and the effects of newly emerging passive products (e.g., actively managed ETFs, crypto indexes, and similar instruments). Within this broader research agenda, it is relevant to examine individual markets—such as Croatia's—which have only recently begun to experience the full influence of passive investing. This perspective is consistent with findings that investor awareness, education, and behavioural biases significantly influence the effectiveness and suitability of passive investment strategies, especially in environments with lower market maturity (Malhotra, 2024)

In addition, recent research highlights the importance of financial literacy and investor behaviour in shaping investment decisions and market participation, particularly in smaller and less developed markets. These factors may play an important role in the context of passive investing, where the accessibility and simplicity of investment products can influence retail investor behaviour and, consequently, overall market dynamics (Bulog et al., 2026; Suljić Nikolaj et al., 2026).

These findings indicate that the relationship between passive investing and market outcomes remains complex and context-dependent. In particular, existing literature suggests that the effects of passive investing vary depending on market structure, level of development, and the balance between active and passive participants, highlighting the need for context-specific empirical analysis.

1.3. Theoretical Background of Passive Investing

Passive investing has become one of the dominant investment approaches in global financial markets over the past decades, introducing structural changes in the way capital is managed. This approach is based on constructing a portfolio that replicates the composition of a selected market index, such as the S&P 500, MSCI World, or any other relevant benchmark depending on the investor's strategy and objectives, with minimal adjustments over time and with the goal of achieving returns equivalent to the market index.

Passive investors do not attempt to predict short-term price movements or "beat" the market. Instead, they aim to earn market-level returns at the lowest possible cost. In practice, this is most commonly achieved through investments in index funds and exchange-traded funds (ETFs), which offer broad diversification and transparency at low fees (CFA Institute Research Foundation, 2024).

The key distinction between passive and active investing lies in the decision-making approach and the frequency of trading. Active fund management involves analysing individual securities, selecting those expected to outperform the

market, and trading more frequently to capture short-term opportunities. Such a strategy generates higher costs and depends heavily on the manager's skill. Passive strategies, on the other hand, rely on long-term market tracking, infrequent transactions, and lower fees, which generally provide a cost advantage over active approaches.

It is important to note that the boundary between active and passive investing is not always clear-cut. Some funds are nominally active but effectively engage in "closet indexing," meaning they hold portfolios that closely resemble the index while charging high fees that are disproportionate to the actual active component (Malhotra, 2024). The European Securities and Markets Authority (ESMA) – the EU's independent supervisory authority responsible for safeguarding financial market stability and investor protection – has recognised this issue and estimates that between 5% and 15% of all EU equity funds practice passive management under the guise of active management (Malhotra, 2024).

Conversely, the market has also witnessed the emergence of so-called active ETFs and other hybrid products that blur the traditional distinction. However, this paper focuses primarily on classical passive investing strategies that follow broad market indices.

Moreover, several financial theories support the rationale for passive investing. For instance, Sharpe (1991), in *The Arithmetic of Active Management*, demonstrates that because all investors collectively constitute the market, the average active investor earns the market return before costs, while after costs the average active return must lag behind passive returns by the amount of higher fees. This statement holds mathematically when considering the aggregate of all active and passive investors. In practice, the logic still applies on average, although different styles of active management ensure that some managers do outperform the market through active strategies, even though most fail to do so consistently over the long term (Pedersen, 2018).

In other words, in today's environment where passive investing occupies an increasingly large share of the market, Sharpe's arithmetic remains useful for understanding the average outcome. However, it does not imply that no active strategy can succeed – only that the statistical advantage lies with passive investing due to lower costs. This is further supported by data from a Morningstar report, cited by *Barron's* (2025), showing that only 31% of U.S. actively managed equity funds outperformed their passive counterparts over the one-year period ending June 2025.

According to the CFA Institute Research Foundation (2024), passive investing – primarily through index funds and ETFs – has experienced substantial growth over the past decades, evolving from a marginal investment approach into a dominant strategy in global capital markets. By the end of 2021, passively managed funds accounted for approximately 32% of total global mutual fund assets, while in the United States they surpassed actively managed funds in total assets for the first time (USD 10.2 trillion versus USD 9.4 trillion). More recent

data indicate a continuation of this trend, with the global share of passive funds rising to 40% by the end of 2023 (PWL Capital, 2024).

This upward trend is closely linked to lower costs, greater transparency, and long-term performance that has encouraged many investors to shift from active to passive strategies. One of the key factors accelerating this transition has been the introduction of an increasing number of ETFs across global markets. The first ETF was launched in 1993 (SPDR S&P 500 ETF Trust, ticker: SPY). The advent of this financial instrument enabled investors to trade an entire index as a single security, with very low management fees. Investment costs therefore declined dramatically, as the administrative expenses of ETFs are significantly lower than those of traditional actively managed mutual funds. The broad availability of low-cost ETFs has fueled substantial capital inflows into passive strategies worldwide.

Furthermore, technological progress and the widespread availability of information have also accelerated the expansion of passive investing. Online platforms and mobile applications have enabled retail investors to access global index funds and ETFs easily, without the need for substantial capital or complex investment procedures (CFA Institute Research Foundation, 2024).

As a result of these factors, assets under passive management have grown rapidly (Investment Company Institute [ICI], 2025). This shift within the investment industry is reshaping market structure: capital is increasingly flowing from active to passive strategies, and competition among index fund providers has driven fees to historically low levels (Morningstar, 2025). While passive investing was considered a niche approach for a small group of institutional investors in the 1990s, it has now become an increasingly popular choice for both institutional and retail investors (Bogle, 2017). The rise of passive investing reflects investors' preference for broad diversification at low cost, as well as the recognition that a large share of active funds fails to outperform the market over the long term. A combination of active fund underperformance, lower fees on passive products, and structural changes within the financial industry has contributed to a massive reallocation of capital from active to passive strategies (ICI, 2025).

In recent years, passive investing has gained significant traction in Croatia as well. Historically, the Croatian capital market was dominated by actively managed funds and direct investments by retail investors in a small number of domestic equities (InterCapital, Asset Management, 2025). Local index funds accessible to the broader public did not exist, and the level of awareness and financial literacy related to the advantages of passive investing was low. The introduction of ETFs to the Croatian market was enabled by the coordinated efforts of several institutions: the Central Depository & Clearing Company (SKDD), which provided the infrastructure for settlement and custody; the Croatian Financial Services Supervisory Agency (HANFA), which established the regulatory framework; the Zagreb Stock Exchange (ZSE), which provided the trading platform; and InterCapital Asset Management, which initiated and launched the first Croatian ETFs (InterCapital, Asset Management, 2025).

The first Croatian ETF – InterCapital CROBEX10tr UCITS ETF – was launched in February 2020. It tracks the domestic stock market index CROBEX10tr, which includes the ten most liquid stocks listed on the Zagreb Stock Exchange, with dividends reinvested. Since then, the range of ETFs available on the ZSE has expanded; in 2025, five ETFs issued by InterCapital Asset Management are traded on the exchange (Zagreb Stock Exchange, 2025). Although most of them track equity indices, they are not limited exclusively to equity markets. The ETFs 7CRO, 7SLO, and 7BET follow the equity indices of Croatia (CROBEX10tr), Slovenia (SBITOP TR), and Romania (BET-TRN), respectively; 7GROM tracks a Romanian government bond index with maturities between five and ten years; and 7CASH is a euro-denominated money market ETF.

For the first time, domestic investors gained access to exchange-traded funds covering different asset classes, enabling simpler and more cost-efficient portfolio diversification, along with additional advantages such as lower management fees, tax efficiency through automatic dividend reinvestment, high transparency, and improved liquidity due to straightforward trading on the stock exchange.

The main differences between passive and active investing stem from their investment philosophies and cost structures. Passive investing is grounded in the assumption of market efficiency, which holds that it is difficult to consistently outperform the market average over the long term; therefore, it is more rational to replicate a market index than to invest resources in forecasting price movements (Malhotra, 2024). Active investing, on the other hand, is based on the premise that market inefficiencies exist and that skilled financial managers can exploit them to generate excess returns ("alpha"). However, research demonstrates that most active funds fail to outperform comparable passive benchmarks over the long run once costs are taken into account, with higher management fees and more frequent trading being key factors behind weaker net returns (Malhotra, 2024).

One of the key theoretical foundations of passive investing is the Efficient Market Hypothesis (EMH), formally defined by Fama (1970). According to the EMH, security prices reflect all available information at any point in time, thereby limiting the possibility of consistently achieving returns above the market average, particularly after costs. Three forms of market efficiency are typically distinguished: weak form (prices reflect all information contained in past prices), semi-strong form (prices incorporate all publicly available information), and strong form (prices reflect both public and private information).

In the investment context, the EMH implies that attempts to outperform the market through active security selection or market timing are not sustainable in the long run for the average investor. If markets are indeed efficient, actively managed portfolios based on fundamental, technical, or quantitative analysis cannot consistently beat the market. Instead, the rational strategy becomes passive replication of a market index through index funds or ETFs, allowing investors to earn market returns at minimal cost.

Empirical evidence consistently shows that actively managed funds, on average, do not outperform passive benchmarks over longer periods. Numerous studies – including those conducted by S&P (SPIVA reports) and Morningstar – have found that the majority of active funds underperform equivalent passive products after accounting for management fees (S&P Dow Jones Indices, 2025). For example, Morningstar's fund analysis indicates that approximately 90% of active managers lag behind their benchmark index over a 10-year horizon (Morningstar, 2023). Empirical research also shows that the few active funds that do outperform the market over shorter intervals rarely sustain this performance consistently over longer periods, making the identification of future "winning" funds extremely challenging for investors (Malhotra, 2024).

It is important to emphasize that these findings do not imply that no one can outperform the market. There are always some exceptionally successful managers or hedge funds that achieve above-average returns. However, such cases are rare and difficult to identify in advance. For the vast majority of investors – especially in highly efficient markets such as the United States – a passive index-based approach delivers highly competitive outcomes with significantly lower costs and risks compared to the average active fund. This explains why investors have reallocated capital from active to passive products on such a large scale in recent years.

However, the growth of passive investing raises new questions regarding its impact on market efficiency. The Efficient Market Hypothesis (EMH) assumes the existence of a sufficient number of active participants who conduct analyses and thereby ensure that prices reflect all available information. If passive funds – which do not engage in such analysis – become overly dominant, the question arises whether the price discovery process can be maintained at the same level (Anadu et al., 2020). In other words, the paradox of passive investing lies in the fact that it relies on the assumption of market efficiency, yet its expansion may reduce the level of active effort required to sustain that efficiency.

Since passive funds do not analyze individual securities but instead include them mechanically in a portfolio based on index composition, the amount of research related to the true values of companies may decline, even though such research is essential for accurate asset valuation. Because passive funds invest in all index constituents regardless of company quality, this can lead to overvaluation of index stocks and the neglect of those excluded from the index. Moreover, if an excessively large share of capital flows into passive funds, overall market flexibility and the speed of price adjustment may weaken.

In addition, the literature documents the existence of various market anomalies – such as the value effect, momentum, and seasonal return patterns – that challenge a strict interpretation of the EMH (Fama & French, 1992; Jegadeesh & Titman, 1993). Although these anomalies suggest that above-average returns may be achievable under certain conditions, empirical evidence shows that their

persistence is typically short-lived, as the associated advantages often dissipate once the anomalies become widely known.

At the macro level, research by Ben-David et al. (2018) indicates that the expansion of passive investing may amplify collective price movements among index constituents and increase their mutual correlations. This raises important questions about the potential long-term implications for both market efficiency and market volatility (Ben-David et al., 2018).

The analysis and simulations conducted in Bednarek (2023) further illuminate this issue. The author shows that the growth of passive investing between 2000 and 2017 was associated with a measurable increase in asset price volatility in capital markets. The model estimates that approximately 10% of the volatility recorded in 2017 can be directly attributed to a decline in price informativeness, and indirectly to the rising share of passive strategies in overall investment activity. As an increasing proportion of market participants adopt passive strategies, a smaller amount of information about asset fundamentals is collected and incorporated into prices. Consequently, prices adjust more slowly and less accurately to new information, leading to more frequent and persistent misvaluations. Such misvaluations – unsupported by fundamental factors – heighten price fluctuations and thereby contribute to increased volatility. Bednarek (2023) concludes that if the downward trend in passive management fees continues, the share of passive investing is likely to grow further, which, according to the study, would amplify market volatility.

Taken together, these findings indicate that the relationship between passive investing and market efficiency is not straightforward. While the EMH provides a theoretical foundation for the success of passive strategies, the growing share of passive investments in global financial flows raises the question of whether the core assumptions of market efficiency can be sustained over the long run (Anadu et al., 2020). For most investors, the passive approach remains a rational choice, but at the market-wide level, further expansion of passive strategies may generate new challenges for the price discovery process (Malhotra, 2024).

From the perspective of volatility, existing research suggests that the rise of passive investing may contribute to greater price fluctuations by reducing the role of active participants in price discovery and increasing mechanical price movements within indices (Bednarek, 2023).

Overall, the theoretical and empirical literature suggests that passive investing is grounded in well-established financial principles, yet its rapid expansion introduces potential challenges for market functioning. In particular, the interaction between passive strategies and the price discovery process remains an open question, which motivates further empirical investigation.

Despite the growing body of research on passive investing, many aspects remain insufficiently explored. Existing literature primarily focuses on large and highly developed markets, while considerably less attention has been devoted to

smaller and less liquid capital markets where passive investing has only recently become accessible to a broader group of investors. Furthermore, relatively few studies simultaneously examine the relationship between passive investing, market efficiency, and volatility across different market environments, combining developed and emerging markets within a single research framework.

This paper aims to address this gap by analysing the U.S. market through S&P 500 index rebalancing events and the Croatian market through a comparison of actively optimized portfolios and passive investment via ETFs. Given that ETFs have been introduced relatively recently in the Croatian capital market and that the number of index composition changes is limited, it is not possible to apply a uniform empirical approach to both markets. Therefore, the study employs methodologically adapted approaches that allow for the derivation of relevant and context-specific conclusions for each market.

Accordingly, the research question for the developed market focuses on examining the impact of passive capital flows on price movements and volatility of stocks included in S&P 500 index rebalancing events, while for the Croatian market the analysis investigates whether actively constructed portfolios, based on the Markowitz model, can outperform passive investment through ETFs, and what such a relationship implies about the level of market efficiency.

The value of the paper lies in combining two different empirical approaches and market contexts, thereby enabling a broader understanding of the role and implications of passive investing under different levels of market development.

2. METHODOLOGY AND DATA

To examine the relationship between passive investing, market efficiency, and volatility, we conduct an empirical analysis of the U.S. and Croatian capital markets. The U.S. market is selected due to its level of development and its high degree of passive fund participation, while the Croatian market is relevant as a frontier market with a relatively short history of passive investment instruments. The analysis for the U.S. market focuses on assessing the impact of the large share of passive investing on the efficiency and volatility of such a sizable and developed market. On the other hand, due to the lack of adequate data for the relatively small Croatian market, the same analysis cannot be conducted in an identical manner, and the approach is therefore adapted. In the Croatian case, returns from actively managed portfolios based on Markowitz's portfolio optimization model (Markowitz, 1952) are compared with passive investments through ETFs. By comparing these returns, we can assess the degree of market efficiency, that is, whether active strategies are able to outperform passive ones.

For the U.S. market, the analysis relies on daily closing prices and net capital flows of stocks entering and exiting the S&P 500 index. The data were obtained from the Refinitiv Eikon database (formerly Thomson Reuters), one of

the most comprehensive global financial data sources (Refinitiv, 2025). Although several stocks entered and left the S&P 500 index during the observed period – from 1 March 2024 to 31 May 2025 – some were excluded from the analysis due to missing data. Consequently, the final sample consists of 33 stocks, with their details presented in Table 1.

Table 1 Sample of Stocks Added to and Removed from the S&P 500 Index with Announcement and Implementation Dates (March 2024 – May 2025)

Announcement Date	Implementation Date	Added to Index	Removed from Index
01/03/2024	18/03/2024	Supermicro (SMCI), Deckers Brands (DECK)	Whirlpool (WHR), Zions Bancorp (ZION)
27/03/2024	03/04/2024	–	Dentsply Sirona (XRAY), VF Corp (VFC)
03/05/2024	08/05/2024	Vistra (VST)	–
07/06/2024	24/06/2024	KKR (KKR), CrowdStrike (CRWD), GoDaddy (GDDY)	Robert Half (RHI), Comerica (CMA), Illumina (ILMN)
06/09/2024	23/09/2024	Palantir Technologies (PLTR), Dell Technologies (DELL), Erie Indemnity (ERIE)	American Airlines (AAL), Etsy (ETSY), Bio-Rad (BIO)
06/12/2024	23/12/2024	Apollo Global Management (APO), Workday (WDAY), Lennox International (LII)	Qorvo (QRVO)
07/03/2025	24/03/2025	DoorDash (DASH), TKO Group (TKO), Williams-Sonoma (WSM), Expand Energy (EXE)	BorgWarner (BWA), Teleflex (TFX), Celanese (CE), FMC (FMC)
12/05/2025	19/05/2025	Coinbase Global (COIN)	Discover Financial Services (DFS)

Source: Authors' compilation based on S&P Dow Jones Indices announcements and the Refinitiv Eikon database (2025).

For each stock in the sample, data on daily closing prices and net capital flows were collected for a period spanning 250 days (approximately one year) prior to the index rebalancing date and 35 days after its implementation. To ensure comparability, the data were aligned so that the implementation date of the rebalancing is denoted as t_0, while the days before and after are labeled using relative time indices from t_{-250} to t_{35}.

The analysis focuses on three key periods (event windows):

1. *Pre-implementation window (from the announcement date to the day before implementation):*
   This window captures the market's reaction to the announcement of index composition changes and provides insight into the behavior of active investors who anticipate the future mechanical buying and selling that passive funds will be required to execute due to the rebalancing. For example, if the inclusion of a stock is announced, all ETFs and index funds

tracking that index will need to purchase that stock on the implementation date. Active investors know this in advance and may begin buying earlier in order to profit from the expected price increase driven by upcoming passive demand. Conversely, if a stock is set to be removed from the index, active investors may start selling before passive funds are forced to do so.

2. *Event window around the implementation date:*
   This is captured by a narrow window $\{t_{-1}, t_0, t_1\}$. This period measures the direct effects of mandatory purchases and sales executed by passive funds at the time of index rebalancing.

3. *Post-implementation window (from t_2 to t_{35}):*
   This broader post-event window allows for examination of price behavior after the index changes have been executed and passive funds have completed their buys or sells.

Two effects are especially relevant in this period: 1) Price reversal, which occurs if prices that initially jumped or dropped due to passive flows gradually return toward their pre-rebalancing levels; 2) Changes in volatility**,** which may reveal whether prices become more stable or more volatile once the market has absorbed the impact of the rebalancing.

Based on the daily closing prices $P_{i,t}$ $i = 1, 2, ..., 33$, logarithmic daily returns are calculated as:

$$R_{i,t} = \ln \frac{P_{i,t}}{P_{i,t-1}} \tag{1}$$

where $P_{i,t}$ is the closing price of stock *i* on day *t*.

For each stock, the expected (normal) return is defined using returns from t_{-250} to t_{-20}, calculated as the average return over this estimation window. The subsequent days are not included in the estimation of normal returns because they may already be affected by the announcement of the rebalancing, which would distort the estimation of typical return behavior. Including these days would introduce bias, as market participants may begin anticipating future passive flows and adjusting their positions accordingly, meaning returns would no longer reflect normal pre-event behavior.

Using these expected returns, abnormal returns (AR) are computed for each day in the event windows as the difference between the realized return on that day and the expected return. Abnormal returns therefore show how much a stock's actual return deviates from what would normally be expected under typical conditions without the effect of the rebalancing event. Positive abnormal returns indicate that a stock earned a higher return than expected—suggesting that index inclusion or increased passive demand had a positive effect on its price. Negative abnormal returns indicate the opposite, as often seen in index deletions.

Based on ARs, cumulative abnormal returns (CAR) are calculated as the sum of abnormal returns within each defined window. CARs are examined separately for each of the three windows described earlier. CAR is crucial because it allows the effect of the rebalancing to be evaluated as a whole rather than only through daily price movements. While individual ARs capture short-term, day-to-day reactions, CAR aggregates these effects over the event window and provides a clearer picture of the overall market impact. A significantly positive or negative CAR in any window indicates that the index rebalancing had a measurable effect on stock prices.

Furthermore, to measure the effect of the rebalancing on volatility, the standard deviation of returns is calculated for the periods from t_{-20} to t_{-1} and from t_1 to t_{20}.

$$\sigma_{i,pre} = \sqrt{\frac{1}{N-1}\sum_{t=-20}^{-1}\left(R_{i,t} - \mu_{i,pre}\right)^2}, \sigma_{i,post} = \sqrt{\frac{1}{N-1}\sum_{t=1}^{20}\left(R_{i,t} - \mu_{i,post}\right)^2} \quad (2)$$

where μ denotes the average return in the observed period. The difference $\Delta\sigma_i = \sigma_{i,pre} - \sigma_{i,post}$ is interpreted as the change in volatility caused by the rebalancing.

To examine the relationship between price movements and passive flows, the analysis also includes net capital flows − that is, inflows and outflows in USD at the moment of implementation. Capital flows capture the actual movement of money into and out of passive funds, indicating how much capital entered or exited during the relevant period. If a large inflow is observed at the time of implementation, this indicates that passive funds had to increase demand for the stocks added to the index, which may explain upward price pressure. Conversely, capital outflows indicate reduced demand and may contribute to downward price pressure.

By including capital flows, it becomes possible to investigate whether the magnitude of these inflows/outflows is associated with cumulative abnormal returns (CAR) and volatility. In other words, capital flows serve as a quantitative measure of the intensity of passive strategies: the larger the flows, the more likely it is that prices are influenced by mechanical transactions of passive funds.

Based on the calculated data, the empirical analysis of the U.S. capital market is conducted. The analysis is performed separately for stocks entering the index and those exiting it to determine whether asymmetric effects exist. For both groups, the following are tested:

1. *Significance of average CARs in the selected windows* – The aim is to determine whether stocks added to the index systematically exhibit positive abnormal returns, and those removed exhibit negative ones, and whether this effect is statistically significant. If the average CAR deviates from zero and the difference is significant, we can conclude that the index rebalancing indeed affects prices. Analysing three event windows allows

us to distinguish between the market's reaction to the announcement, the mechanical effect of passive flows, and any post-event price reversals.

2. *Changes in volatility* – The standard deviation of returns before and after rebalancing is compared to assess whether price fluctuations increase or decrease. An increase in volatility after implementation may indicate that passive flows caused stronger short-term oscillations. A decline in volatility would suggest price stabilization once the market absorbs the rebalancing. This allows us to examine whether passive investing affects not only price levels but also price stability.
3. *Relationship between CARs and changes in volatility and net capital flows* – Examined using correlation analysis. This approach tests whether stocks with larger inflows or outflows of capital tend to experience stronger abnormal returns and more pronounced changes in volatility. The goal is not to establish causality, but to identify statistical associations between the variables.

For the Croatian capital market, given the smaller number of stocks and the limited sample of index inclusions and exclusions since the introduction of ETFs, we will apply a different approach. We analyse the returns achieved through active portfolio management compared to passive investing via ETFs. Active management is based on the application of the Markowitz model, which is used to estimate the efficient frontier for a sample of stocks included in the CROBEX10 index, while the passive approach is represented by the 7CRO ETF, which tracks the CROBEX10tr index.

The Markowitz model, which relies on expected return and variance – or standard deviation as a measure of risk – is the first formal framework for quantitatively constructing a portfolio by optimising the trade-off between expected return and risk. It enables the determination of the efficient frontier, i.e. the set of portfolios that deliver the highest expected return for a given level of risk, or the lowest risk for a given level of return. Although more sophisticated models are available today, this simple and historically significant approach is sufficient for our analysis, as it clearly illustrates the basic principles of investment optimisation.

Mathematically, the problem of finding the efficient portfolio using the Markowitz model can be formulated as follows:

$$\max E(R_\pi) = \pi` E(R) = \sum_{i=1}^{N} \pi_i E(R_i) \quad (3)$$

subject to:

$$\pi`\mathrm{S}\ \pi = \mathrm{c}$$

$$\sum_{i=1}^{N} \pi_i = 1$$

$$\pi_i \geq 0, \quad i = 1,2,\dots,N$$

where *c* represents a constant denoting the level of risk the investor is willing to accept, measured by variance. E(R) denotes the vector of expected returns of the stocks, and *S* is the variance–covariance matrix. The unknown variables are the

portfolio weights of individual stocks, represented by the vector π (Aljinović, Marasović & Šego, 2011).

Data on daily closing prices for the selected stocks, as well as for the observed ETF, were obtained from the website of the Zagreb Stock Exchange. Table 2, presenting the selected stocks and their tickers, is shown below.

Table 2 Sample of Stocks and ETF Included in the Croatian Market Analysis with Corresponding Tickers

Ticker	Stock name
ADRS2	Adris Grupa d.d. (Povlaštena)
ATGR	Atlantic Grupa d.d.
ERNT	Ericsson Nikola Tesla d.d.
HPB	Hrvatska poštanska banka d.d.
HT	Hrvatski Telekom d.d.
KODT	Končar – distributivni i specijalni transformatori d.d.
KOEI	Končar elektroindustrija d.d.
PODR	Podravka d.d.
RIVP	Valamar Riviera d.d.
SPAN	Span d.d.
7CRO	ETF 7CRO – InterCapital Asset Management

Source: Zagreb Stock Exchange (2025).

The methodological framework of the analysis is divided into two steps. In the in-sample part of the analysis, daily closing price data between two index rebalancing dates – from 21 March 2025 to 12 June 2025 – are used. Based on the logarithmic daily returns for this period, the average returns and the covariance matrix of the stocks were estimated, which enabled the construction of the efficient frontier. The portfolios were constructed under the assumption that short selling is not allowed (all weights must be non-negative) and that the sum of weights equals 1. The average return and risk of the 7CRO ETF were also plotted on the efficient frontier for the same period, allowing for a comparison of active and passive approaches under identical market conditions.

In the out-of-sample part, the period from 13 June to 1 August 2025 is analysed. Based on stock and ETF prices during this period, total realised returns were calculated. For each stock, the starting price on 13 June and the ending price on 1 August 2025 were used, while the returns of the efficient portfolios were obtained by weighting these individual stock returns using the weights determined in the in-sample phase. The total return of the 7CRO ETF was also calculated for the same period. In this way, it is possible to assess the extent to which portfolios constructed using historical data succeed in achieving competitive future performance and whether passive ETF investing represents a more efficient alternative to active management in the Croatian capital market. All calculations in the study were conducted using Excel, MATLAB and Python.

3. RESULTS OF THE ANALYSIS

First, the results of the empirical analysis of the effects of S&P 500 index rebalancing on movements in the U.S. market will be presented. The analysis was conducted on a sample of 33 stocks that entered or exited the index during the observed period, with data aligned to the index rebalancing implementation date (t_0).

Table 3 Results of Statistical Significance Tests of Average Cumulative Abnormal Returns (CAR) Across Selected Event Windows for Stocks Added to and Removed from the S&P 500 Index

Group	Period	Avg. CAR	t-test (p)	Corrado rank (p)	Sign test (p)	Result
Addition	Window 1	+3,95 %	0,006	0,008	0,020	significant
Addition	Window 2	+0,72 %	0,17	>0,10	>0,10	ns
Addition	Window 3	+0,15 %	>0,10	>0,10	>0,10	ns
Deletion	Window 1	+1,81 %	0,25	>0,10	>0,10	ns
Deletion	Window 2	−2,26 %	0,026	0,045	0,030	significant
Deletion	Window 3	+1,65 %	>0,10	>0,10	>0,10	ns

Source: Authors' calculations based on Refinitiv Eikon data (2025).

Table 3 presents the results of significance testing for the average CARs in the selected event windows. The tests examine whether the cumulative abnormal returns deviate statistically significantly from zero. The results show that, for additions to the index, there is a positive and statistically significant effect in the first window (+3.95%), while in the subsequent windows the effect weakens and becomes insignificant. For deletions, the effect in the first window is small and insignificant, whereas in the second window there is a significant negative deviation (−2.26%), indicating a decline in prices following removal from the index. Multiple tests (t-test, Corrado rank test, and sign test) were conducted to ensure robustness, as they rely on different assumptions and thereby reduce the risk that the conclusions depend on the specifics of any single test.

The results confirm several important patterns. For additions to the index, abnormal returns are generated primarily in the first window between the announcement and the implementation of the rebalancing, suggesting that active investors react to the announcement and anticipate passive flows, generating a positive price effect prior to the actual implementation. The implementation itself does not generate additional abnormal returns, and the effects stabilise thereafter. In contrast, for deletions from the index, significant abnormal returns occur in the second window around the implementation date, when passive funds mechanically sell the stocks. Although this negative effect is not long-lasting, it leads to a statistically significant short-term decline in prices.

In addition to analysing abnormal returns, changes in volatility were examined in the period immediately before and after the rebalancing implementation. Volatility was measured as the standard deviation of daily returns

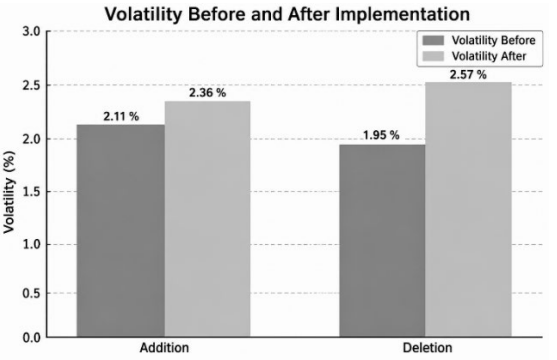
in windows from t_{-20} to t_{-1} and from t_1 to t_{20}. The results are presented in Table 4 and Figure 1.

Table 4 Changes in Return Volatility (Δσ) Before and After S&P 500 Index Rebalancing for Stocks Added to and Removed from the Index

Group	Volatility Before	Volatility After	Change (Δσ)	t-test (p)	Sign test (p)	Result
Addition	2.11 %	2.36 %	+0.25 p.p.	0.059	0.08	borderline significant
Deletion	1.95 %	2.57 %	+0.62 p.p.	0.007	0.03	significant

Source: Authors' calculations based on Refinitiv Eikon data (2025).

Figure 1 Average Volatility Before and After S&P 500 Index Rebalancing for Stocks Added to and Removed from the Index



Source: Prepared by the author based on Refinitiv Eikon data (2025).

The results show that, for stocks added to the index, volatility on average increases from 2.11% to 2.36%, which represents a borderline significant change ($p < 0.10$). This effect may be associated with increased investor interest and higher trading volume following index inclusion. For stocks removed from the index, volatility rises from 1.95% to 2.57%, and this difference is statistically significant at the 1% level. This suggests that index removal leads to heightened uncertainty and reduced liquidity, as passive investors withdraw capital and the resulting lower demand causes larger price fluctuations.

Testing volatility before and after the rebalancing confirms that changes in index composition have a significant impact on trading dynamics and price stability. To gain a better understanding of the mechanism through which passive investing affects prices and volatility, we examined the relationship between cumulative abnormal returns (CAR) and changes in volatility (Δσ) and the net capital flows at the moment of rebalancing implementation. The results are presented in Table 5.

Table 5 Correlation Between Cumulative Abnormal Returns (CAR), Changes in Return Volatility (Δσ), and Net Capital Flows During S&P 500 Index Rebalancing

Group	Indicator	Correlation (r)	p-value	Result
Addition	CAR (announcement window)	+0.48	0.048	significant
Addition	Δσ (announcement window)	+0.22	>0.10	ns
Deletion	CAR (implementation window)	−0.52	0.036	significant
Deletion	Δσ (implementation window)	+0.41	0.090	borderline significant

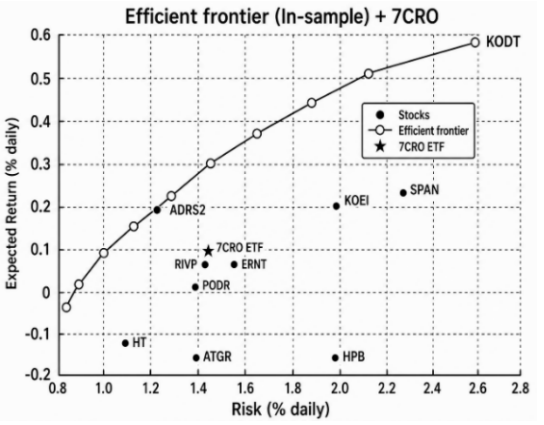
Source: Authors' calculations based on Refinitiv Eikon data (2025).

The results show that for stocks added to the index, there is a positive and statistically significant correlation between capital inflows and abnormal returns in the announcement window. This confirms the hypothesis that active investors anticipate future passive flows and react already after the announcement. On the other hand, changes in volatility for additions are not significantly related to capital flows.

For stocks removed from the index, the results differ: larger net capital outflows are statistically significantly associated with negative abnormal returns in the implementation window, while the increase in volatility is borderline significant, suggesting that large-scale sales by passive funds may temporarily destabilise the price discovery process.

We subsequently conducted an analysis of the Croatian capital market as explained in the previous chapter. The goal was to compare active portfolio management based on the Markowitz model with passive investing through the 7CRO ETF, which tracks the CROBEX10tr index. The analysis was carried out in two steps: an in-sample period, covering daily closing price data between two index rebalancings (from 21 March to 12 June 2025), and an out-of-sample period from 13 June to 1 August 2025.

Figure 2 Efficient frontier and the position of the 7CRO ETF and sample stocks based on in-sample data (21 March – 12 June 2025)



Source: Prepared by the author based on Refinitiv Eikon data (2025).

Based on the in-sample data, the efficient frontier was constructed. Figure 2 shows the graph of the resulting efficient frontier. Ten efficient portfolios, evenly distributed along the frontier, represent the optimal combinations of return and risk that could have been achieved during the observed period. The graph additionally includes the average daily return and volatility of the 7CRO ETF, as well as all stocks in the sample, allowing for a visual comparison of the active and passive approaches. It is evident that the 7CRO ETF is positioned below the efficient frontier, indicating that while the passive strategy provides a diversified solution, it would theoretically be possible to construct portfolios with a more favourable risk–return trade-off. Table 6 presents the resulting efficient portfolios along with their corresponding expected daily returns and risks.

Table 6 Composition, Expected Returns, and Standard Deviation of Efficient Portfolios Constructed Using the Markowitz Model (In-Sample Period)

ADRS2	ATGR	ERNT	HPB	HT	KODT	KOEI	PODR	RIVP	SPAN	Expected return	Standard deviation
21.30%	21.04%	0.00%	0.00%	41.59%	0.00%	0.00%	16.07%	0.00%	0.00%	-0.04%	0.82%
39.87%	9.93%	4.54%	0.00%	32.04%	0.00%	0.00%	13.62%	0.00%	0.00%	0.03%	0.85%
58.95%	0.00%	8.94%	0.00%	21.40%	0.00%	0.00%	10.72%	0.00%	0.00%	0.09%	0.95%
68.02%	0.00%	7.39%	0.00%	10.73%	7.08%	0.00%	6.78%	0.00%	0.00%	0.16%	1.09%
75.33%	0.00%	5.03%	0.00%	0.75%	13.86%	0.00%	2.18%	0.00%	2.86%	0.23%	1.27%
67.10%	0.00%	0.00%	0.00%	0.00%	28.46%	0.00%	0.00%	0.00%	4.44%	0.30%	1.47%
49.54%	0.00%	0.00%	0.00%	0.00%	46.25%	0.00%	0.00%	0.00%	4.21%	0.37%	1.72%
31.99%	0.00%	0.00%	0.00%	0.00%	64.03%	0.00%	0.00%	0.00%	3.98%	0.44%	2.00%
14.44%	0.00%	0.00%	0.00%	0.00%	81.82%	0.00%	0.00%	0.00%	3.75%	0.51%	2.29%
0.00%	0.00%	0.00%	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.58%	2.61%

Source: Authors' calculations based on Refinitiv Eikon data (2025).

To assess the robustness of the in-sample results, the second step involved calculating the realised returns of the same portfolios in the out-of-sample period from 13 June to 1 August 2025. For each stock and the ETF, the starting price on 13 June and the ending price on 1 August were used to compute total returns. Portfolio returns were obtained by weighting these realised returns with the portfolio weights determined in the in-sample optimisation.

Table 7 Realised total returns of the portfolios and the 7CRO ETF in the out-of-sample period (13 June – 1 August 2025)

Efficient Portfolios	Return (%)
Portfolio_01	7.41
Portfolio_02	10.24
Portfolio_03	13.27
Portfolio_04	16.61
Portfolio_05	20.21
Portfolio_06	21.84
Portfolio_07	21.22
Portfolio_08	20.60
Portfolio_09	19.98
Portfolio_10	19.33
7CRO_ETF	9.83

Source: Authors' calculations based on Zagreb Stock Exchange data (2025).

From Table 7, it is evident that almost all efficient portfolios achieved higher returns than the 7CRO ETF in the observed out-of-sample period. While the ETF recorded a total return of 9.83%, the returns of the efficient portfolios ranged from 7.41% to 21.84%. The lowest return was achieved by the portfolio with the lowest expected risk, which is consistent with the theoretical assumptions of the Markowitz model. As the level of risk increased, the portfolios generally achieved higher returns, with the best results recorded for the portfolios positioned in the middle and upper sections of the efficient frontier.

These findings suggest that, in the observed period, actively constructed portfolios based on the Markowitz model could have generated higher returns than passive investment in the ETF. However, it should be emphasised that the results refer to a specific short period, and one cannot conclude unequivocally that an active strategy will always outperform a passive one. Nevertheless, the analysis indicates that the theoretical portfolio optimisation framework can serve as a useful tool for investors in the Croatian market who are seeking more favourable risk–return combinations compared to standardised passive investing.

4. DISCUSSION AND CONCLUSION

The results of the conducted analysis provide a multidimensional insight into the relationship between passive investing, market efficiency, and volatility. The empirical examination of abnormal returns and changes in volatility around S&P 500 index rebalancing events reveals patterns that cannot be fully explained by fundamental factors alone, but instead point strongly to the influence of passive capital flows.

For stocks entering the index, abnormal returns occur primarily during the announcement window, while the implementation date itself does not produce additional effects. This dynamic confirms that active investors anticipate the future mechanical demand from passive funds and seek to capitalize on it. Furthermore, index inclusion is associated with a slight and borderline significant increase in volatility.

In contrast, for stocks exiting the index, negative abnormal returns are concentrated on the implementation date, when passive funds execute sales. This supports the view that index deletions generate short-term price distortions, even though they are not accompanied by fundamental changes in company performance. At the same time, volatility following deletion shows a pronounced increase, suggesting that capital outflows heighten price fluctuations.

The analysis of the relationship with net capital flows further reinforces these conclusions. Inflows to passive funds around index additions are significantly associated with positive abnormal returns during the announcement phase, while outflows around deletions are linked to negative returns and increased volatility.

Within a broader theoretical context, the findings point to an ambivalent relationship between passive investing and market efficiency. On one hand, passive investing is grounded in the assumptions of the Efficient Market Hypothesis

(EMH) and provides a rational framework for most investors, particularly due to lower costs and greater transparency. On the other hand, the massive expansion of passive funds may weaken the price discovery process itself by reducing the relative role of active participants in incorporating information into prices. With respect to volatility, the results align with the literature (e.g., Bednarek, 2023; Ben-David et al., 2018), which suggests that the rise of passive investing can amplify collective price movements and lead to greater short-term fluctuations.

Regarding the Croatian capital market, the findings indicate that the actively constructed portfolios in this study outperform the passive ETF, suggesting that the Croatian market does not exhibit a high level of efficiency. According to the Efficient Market Hypothesis, active strategies should not systematically outperform passive ones in the long run. However, in smaller and frontier markets such as Croatia, the process of incorporating information into prices is often slower due to the limited presence of institutional investors and analysts, lower liquidity, and more pronounced informational asymmetries. These factors create conditions in which optimization models such as Markowitz's can generate portfolios that achieve above-average returns in certain periods. The obtained results may therefore be viewed as empirical evidence of the lower degree of efficiency of the Croatian market compared with more developed capital markets. However, this result should be interpreted with caution. The observed outperformance may be influenced by the relatively short time horizon, market-specific characteristics, and limited availability of passive instruments. Therefore, while the findings suggest potential inefficiencies in the Croatian market, they do not provide definitive evidence of persistent market inefficiency.

It is important to note that the results obtained for the U.S. and Croatian markets are not directly comparable due to differences in market size, liquidity, data availability, methodological approach, as well as the length of the observed time period. While the U.S. analysis captures the effects of passive capital flows in a highly developed market, the Croatian analysis provides indirect evidence on market efficiency through the comparison of active and passive strategies. Therefore, the conclusions should be interpreted within the specific context of each market rather than as universally generalizable findings.

Despite the significant findings of this study, several limitations should be acknowledged. For the U.S. market, the analysis was conducted on a sample of stocks entering and exiting the S&P 500 index over a relatively short period, which limits the ability to generalize the results to longer time horizons or to other indices. Although the use of abnormal returns (AR and CAR) proved useful for measuring the impact of passive flows, the results rely on the assumption of stable expected returns—a simplification that may not fully capture the dynamics of financial markets. Moreover, changes in volatility were examined using relatively short event windows, making it difficult to draw conclusions about long-term effects.

For the Croatian market, additional limitations stem from its size and liquidity. The analysis was based on stocks included in the CROBEX10 index and

the 7CRO ETF, but the set of available instruments remains limited. Furthermore, the in-sample and out-of-sample periods used in the study cover only a few months, meaning that the results are influenced by the specific market conditions prevailing during that time. Therefore, conclusions regarding the lower efficiency of the Croatian capital market should be interpreted cautiously and within a broader context.

Directions for future research extend along several lines. For developed markets, it would be beneficial to conduct analyses over longer periods to examine the cumulative effects of the growth of passive investing on efficiency and volatility. Additionally, the role of passive flows during periods of crisis and financial shocks represents an especially relevant area for further investigation. For smaller markets such as Croatia, additional studies covering longer periods and a broader set of instruments—including newly introduced ETFs—would enable more robust conclusions about the level of market efficiency and the implications of passive investing for the domestic capital market. Finally, future research could include comparative analyses across different frontier markets, providing deeper insights into the specific challenges and opportunities associated with the expansion of passive investing beyond developed economies.

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TRŽIŠNA UČINKOVITOST I VOLATILNOST U RAZDOBLJU BRZOG RASTA PASIVNOG ULAGANJA: EMPIRIJSKI DOKAZI S AMERIČKOG I HRVATSKOG TRŽIŠTA KAPITALA

Sažetak

Rad analizira učinke rasta pasivnog ulaganja na tržišnu učinkovitost i volatilnost, s naglaskom na američko i hrvatsko tržište kapitala. Američko tržište, obilježeno visokim udjelom pasivnih fondova, ispituje se kroz abnormalne prinose i promjene volatilnosti povezane s rebalansom indeksa S&P 500. Rezultati pokazuju da tokovi pasivnog kapitala imaju mjerljiv utjecaj na cijene i tržišnu dinamiku, pri čemu se učinci razlikuju ovisno o tome ulaze li dionice u indeks ili iz njega izlaze. Na hrvatskom tržištu provodi se usporedba aktivnog upravljanja portfeljem temeljenog na Markowitzevu modelu i pasivnog ulaganja putem 7CRO ETF-a. Nalazi upućuju na to da aktivno konstruirani portfelji mogu ostvariti veće prinose od pasivnih strategija, što otvara pitanje razine tržišne učinkovitosti u odnosu na razvijenija tržišta.

Ključne riječi: hrvatsko tržište kapitala, tržišna učinkovitost, pasivno ulaganje, američko tržište kapitala, volatilnost.

JEL klasifikacija: G11, G14, G15.