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The Relationship Between Bitcoin Prices and Ethereum Trading Volume

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Abstract: The paper aimed to investigate the statistical relationship between Bitcoin prices and Ethereum trading volumes, as well as to create a simple predictive model for Ethereum trading volumes based on Bitcoin prices. To perform Spearman's rank correlation analysis and to construct an artificial neural network (ANN) model, daily closing prices of Bitcoin in USD and daily trading volumes of Ethereum were utilized. The timeframe covered by the data starts May 1, 2020 and ends November 22, 2025. In this study, Ethereum volumes were treated as the dependent variable, while Bitcoin prices served as the independent variable. The findings indicate a significant, moderate, positive correlation between Bitcoin prices and Ethereum volumes, and the ANN model successfully predicted Ethereum volumes with a high level of accuracy. These results reinforce existing evidence regarding the relationships among cryptocurrencies. Furthermore, by confirming the efficacy of artificial neural networks (ANN) in predicting trends within the cryptocurrency market, the study also makes a methodological contribution. In addition, the study also offers a simpler modelling approach that highlights the significance of bilateral interactions among major cryptocurrencies through a single-input model. Based on the impressive performance of the ANN model, exchanges, fintech companies, and investment firms could incorporate lightweight machine-learning systems into their forecasting tools to provide real-time analytics with minimal processing requirements.

Keywords: Bitcoin prices, Ethereum trading volume, cryptocurrencies, Spearman's rank correlation, artificial neural networks (ANN)
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1. Introduction

The term "cryptocurrency" gained popularity after the publication of Nakamoto's (2008) foundational work. According to Polasik et al. (2015), cryptocurrency (Bitcoin) transactions have risen significantly since 2010. With the increasing popularity of these digital currencies, numerous retailers around the globe are beginning to accept blockchain-powered currencies as a form of payment (Salcedo & Gupta, 2021; Salisu & Ogbonna, 2021).

Digital assets are bought and sold online through a blockchain-based public network, which offers potential rewards but also carries speculative risk (W.R. Martin & Papadimitriou, 2022). Cryptocurrencies are considered a safe-haven asset owing to their low correlation with traditional markets (Klein et al., 2018; Shahzad et al., 2019; Smales, 2022). They are also used for portfolio diversification (Liu et al., 2016; Platanakis & Urquhart, 2019).

Katsiampa (2017) argued that cryptocurrencies are very volatile and related to substantial returns. According to Gil-Alana et al. (2020), investing in cryptocurrency can help diversify portfolios and amplify market gains. Predicting financial markets is a difficult task (Chen et al., 2022).

Granger causality has been utilised for predicting movements in cryptocurrency markets (Tu & Xue, 2019; Canh et al., 2019; Fagarazzi, 2025). Additionally, a multitude of research papers sought to forecast either cryptocurrency values (Indera et al., 2017; Poyser, 2017; Sovbetov, 2018; Jang & Lee, 2017; Fahmi et al., 2018; Lahmiri & Bekios, 2019; Ji et al., 2019; Uras et al., 2020; Pabuçcu et al., 2020), volatility (Walther et al., 2019), returns (Polasik et al., 2015; Abu Bakar & Rosbi, 2017; Liu & Tsyvinski, 2021; Azari, 2019) or direction (Greaves & Au, 2015; Spilak, 2018; Ji et al., 2019).

Several studies have highlighted the interconnectedness of key cryptocurrencies (Aslanidis et al., 2021; Bouri et al., 2021; Elsayed et al., 2022; Kumar et al., 2022; Sila et al., 2024), highlighting the risk spread within the system (Chen et al., 2024). However, there is a lack of research on how Bitcoin prices impact Ethereum trading volume.

This research had two objectives. The first objective was to examine whether there is a statistical relationship between Bitcoin prices and Ethereum trading volumes. The second objective was to develop a simple predictive model for Ethereum trading volumes based on Bitcoin prices. To fulfil the objectives, Spearman's rank correlation analysis and artificial neural network (ANN) were used.

The findings help better understand the relationships between cryptocurrencies, namely between Bitcoin prices and Ethereum trading volume. They show that artificial neural networks (ANNs) can accurately estimate trade volumes, making a methodological addition to quantitative finance research and market modelling. Furthermore, these findings serve as a platform for future research on volatility spillovers, liquidity dynamics and predictive modelling in cryptocurrency markets. For traders and investors, ANN's ability to predict Ethereum's volume based on Bitcoin price fluctuations might help them develop more informed trading strategies. Portfolio managers and fund operators may use this information to manage risk and optimise portfolios that include Bitcoin holdings. Furthermore, regulators and market analysts may use this knowledge to track market trends, assess possible risk transfer between cryptocurrencies and create more effective monitoring or regulatory frameworks.

2. Literature review

While the application of neural networks in analysing time series is still developing, they have proven to be an effective tool for making predictions. As noted by Khashei and Bijari (2010), among 96 studies, conventional methods surpassed neural networks in only 18% of cases, while neural networks either performed adequately or excelled in 72%. This is a key reason for their frequent use in forecasting cryptocurrencies.

ARIMA models for predicting Bitcoin have resulted in significant prediction inaccuracies (Azari, 2019; Abu Bakar & Rosbi, 2017), as they fail to accommodate sudden price fluctuations. McNally (2018) indicates that the prediction errors for ARIMA models in forecasting Bitcoin are notably high, with error rates of 5.45%, 53.47% and 6.87%, suggesting that recurrent neural networks (RNNs) have a superior performance compared to other linear and nonlinear models. ARIMA models can serve as a useful

instrument for short-term predictions or during specific periods when the time series behaviour remains relatively stable (Azari, 2019).

Most research studies have utilised neural networks to predict Bitcoin prices or returns. Indera et al. (2017) demonstrate that the Non-Linear Autoregressive with Exogenous Inputs (NARX) model can estimate Bitcoin values using OHLC prices and Moving Average (MA) technical indicators over various time intervals; however, this study lacks a comparison with other models. Another research also assessed multiple models against neural networks. Fahmi et al. (2018) employ internal variables to forecast Bitcoin prices while comparing Linear Regression (LR), neural networks, Bayesian LR and Boosted Decision Tree Regression. The findings indicate that regression models yield more effective predictions. However, they fail to describe the dataset utilised to assess the model or provide a comprehensive explanation of the method.

Jang and Lee (2017) illustrate that Bayesian Neural Networks surpass both linear and nonlinear models in predicting Bitcoin prices and accounting for their significant volatility through internal and external factors. Lahmiri and Bekios (2019) implement Long Short-Term Memory (LSTM) and General Regression Neural Network (GRNN) techniques to forecast the prices of Bitcoin, Digital Cash and Ripple. LSTM demonstrates considerably higher predictive power compared to GRNN.

Uras et al. (2020) forecast the prices of Bitcoin, Litecoin and Ethereum using delayed Open-High-Low-Close (OHLC) prices and volumes, with Simple and Multiple Linear Regression (LR), Feedforward Neural Network (FNN) and LSTM models employed. The best results are achieved by utilising multiple previous prices along with regression models and LSTM, yet neural networks did not perform well. Nevertheless, they only conducted in-sample evaluations because linear regression often shows strong performance in-sample. The model's effectiveness should always be tested out of sample, particularly in regions where neural networks excel.

Ji et al. (2019) investigate deep neural networks (DNN), LSTM, convolutional neural networks, deep residual networks and their combinations with support vector machines (SVM), gated recurrent units (GRU) and linear/logistic regression for predicting Bitcoin prices. The GRU and linear/logistic regression models performed either poorly or comparably with SVM. The findings indicate that LSTM outperforms other models when it comes to predicting Bitcoin prices. DNN excelled over various techniques in forecasting the direction of prices. They used internal variables for predicting Bitcoin values and determined that 20 inputs were sufficient for regression and 50 inputs for classification. However, they employed random sample division instead of sequential sampling, which lacks econometric justification and has an excessive number of inputs.

Dutta et al. (2020) employed an established set of internal and external factors as exogenous and endogenous variables to predict daily Bitcoin values, showing that the GRU model surpasses traditional neural networks and LSTM. Additionally, RNN and LSTM significantly exceed traditional time series models in predicting cryptocurrency prices.

Chen et al. (2020) projected Bitcoin prices at different frequencies (daily and high frequency). LR and Discriminant Analysis (DA) for daily Bitcoin price forecasting with high-dimensional features achieved an accuracy of 66%, outperforming more advanced models. Random Forest, XG-Boost, Quadratic DA, SVM and LSTM had better performance than statistical methods in anticipating Bitcoin prices at 5-minute intervals, achieving an accuracy of 67.2%.

Faghih Mohammadi Jalali and Heidari (2020) employed the first-order grey model (GM (1,1)) for Bitcoin price predictions. GM outperformed RNN and Bayesian neural network (BNN), but did not clarify how the comparisons were drawn using different methodologies.

Studies on predicting cryptocurrency volatility are limited, either relying on high-frequency data (Zhang et al., 2022) or concentrating solely on GARCH-type models (Chu et al., 2017; Walther et al., 2019). Nybo (2021) suggests that neural networks should be applied to forecast the volatility of low-volatility assets, whereas GARCH models are better suited for medium and high-volatility assets.

Šestanović (2021) assesses feed-forward neural networks (FNNs) against logistic regression (LR) for forecasting Bitcoin direction, determining if prices will rise or fall the following trading day. Šestanović (2024) presents an extensive analysis of Bitcoin's price, returns, direction and volatility forecasts. The author evaluated ARIMA and GARCH models alongside neural network (NN) autoregression and Jordan NN concerning their predictive performance, considering both internal and external factors. The comparison of various performance metrics across different time intervals yielded inconclusive results regarding predictions of price, return, or volatility. Results for return and volatility forecasting were consistently observed, irrespective of the model or time period analysed.

Behera et al. (2024) employed three metaheuristic approaches to develop optimal ANNs with minimal control parameters: fireworks algorithm (FWA), chemical reaction optimisation (CRO) and teaching-learning-based optimisation (TLBO) individually. These hybrid models were utilised to simulate and predict the behaviour of four rapidly appreciating cryptocurrencies: Bitcoin, Litecoin, Ethereum and Ripple. Real-time Bitcoin data and hybrid ANNs were used for experiments, applying four performance measures. They analysed the forecasting models' performance and conducted Friedman tests to demonstrate their superiority and statistical relevance. The ANN trained with CRO, TLBO and FWA achieved average ranks of 1, 2 and 2.75, respectively (Behera et al., 2024).

In line with the aforementioned, the following hypothesis was formed:

H1. *Bitcoin prices are significantly related to Ethereum trading volumes.*

3. Methodology

The research adopted a quantitative approach and utilised secondary data. The source of the data was CoinMarketCap. It was reported by Omanović et al. (2020) that cryptocurrency portfolios quickly recovered from April 2020 after underperforming in March 2020. In line with Omanović et al. (2020), the data used covers the period from May 1, 2020, to November 22, 2025. Bitcoin daily closing prices in USD and Ethereum daily trading volume were utilised. The Bitcoin prices served as an independent variable, while Ethereum volumes operated as a dependent variable. The analyses were executed in the programming language R.

Correlation analysis was used for the investigation of the relationship between the Bitcoin price and Ethereum volume. Bitcoin price and Ethereum volume data are non-normally distributed (data contains extreme values, outliers). With the aforementioned, correlation coefficients mustn't be determined from the actual values, but from the ranks of the data. The coefficients Spearman's rho (denoted as r_s) and Kendall's tau were specifically developed for this objective. Kendall's tau extends Spearman's rho. Kendall's tau should be employed when the same rank is repeated too many times in a small dataset. The Bitcoin price and Ethereum trading volume data exhibit almost no tied ranks, meaning that the assumptions requiring the use of Kendall’s tau over Spearman’s rho are not met.

Neural network analysis is extremely versatile in modelling linear and highly complicated nonlinear relationships, with solid prediction competencies (Leong et al., 2013), outperforming several aspects of other machine-learning models (Kraus et al., 2020). The conventional backpropagation approach was used (Günther & Fritsch, 2012), using the logistic activation function to train each network given by the neuralnet package in R. Since there was only one independent and one dependent variable, 1 node in the

hidden layer was logical. To prevent overfitting during the training phase, a 10-fold cross-validation was implemented using a training and testing data set ratio of 90:10 (Chan & Chong, 2012; Liéban-Cabanillas et al., 2017). Other approaches were utilised to evaluate the neural network-based model's superior performance. In particular, linear regression (LR), Random Forest Regression (RFR) and Support Vector Regression (SVR).

4. Results and discussion

The results of Spearman's rank correlation are presented in Table 1.

Table 1. Results of Spearman's rank correlation

p-value	**rho (r_s)**
3.95e-140	0.518

Source: The author (2026)

In line with the interpretation table of Spearman rank-order correlation coefficients by Dancey & Reidy (2007), there is a significant moderate positive relationship between Bitcoin prices and Ethereum volumes. This indicates that the variables tend to move in the same direction. When one increases, the other is likely to increase as well and when one decreases, the other tends to decrease.

The results can be connected with the herding theory, co-movement, spillover effect and limited attention theory. Herding refers to the tendency of individuals to follow the actions of others and replicate group behaviours, instead of making independent decisions based solely on their own private information. The concept of herding originates from Keynes, who examined the reasons behind imitating and aligning with the crowd in uncertain environments (Keynes, 1930).

Bikhchandani & Sharma (2000) wrote about herd behaviour in financial markets. In order for an investor to copy the actions of others, the investor needs to be conscious of and influenced by those actions. Essentially, a person can be considered to be following the crowd if they had proceeded with an investment regardless of other investors' choices, but opted not to invest upon discovering that others have chosen not to invest. Conversely, she engages in herd behaviour when awareness of others investing alters her decision from not investing to going ahead with the investment (Bikhchandani & Sharma, 2000).

Financial markets often exhibit similar trends, highlighting their co-movements. The primary factors accounting for these co-movements among financial markets are economic integration and the characteristics of stock markets (Pretorius, 2002). Bitcoin is the most interconnected cryptocurrency, significantly influencing the spillover risk in the cryptocurrency market (Moratis, 2021).

Limited attention results from the overwhelming amount of information present in our surroundings and the constraints of our ability to process that information. Focus needs to be intentional and demands effort, involving the reallocation of cognitive resources from different tasks (Kahneman, 1973). Individual investors are limited to analysing and evaluating the information that captures their interest the most, which subsequently influences their investment behaviour and results in short-term price discrepancies (Aboody et al., 2010).

A scatter plot with a LOESS trend line is shown in Figure 1.

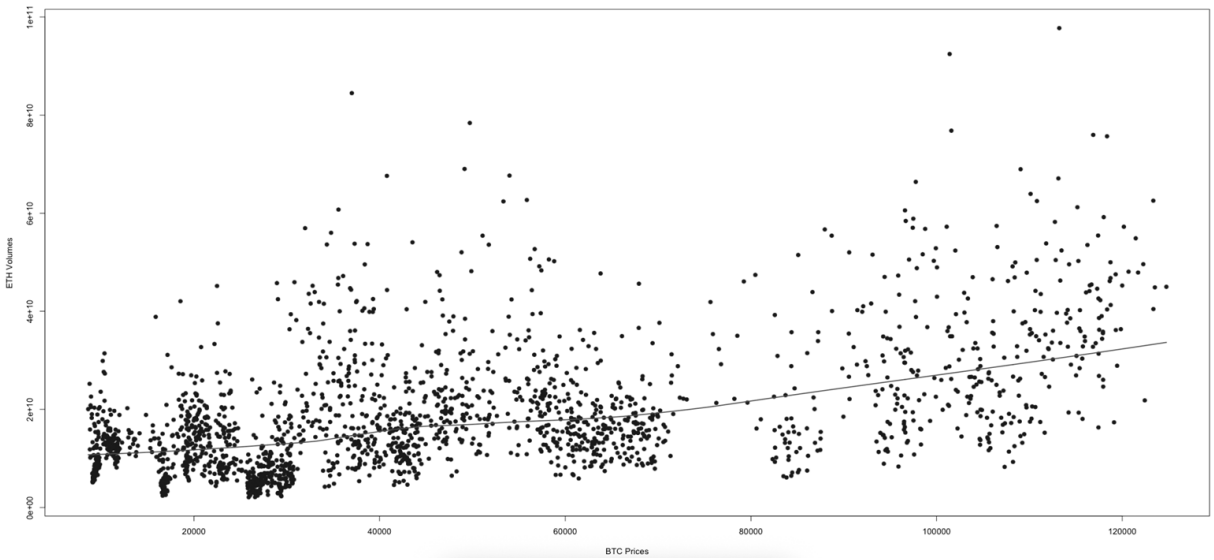

Figure 1. A scatter plot with a LOESS trend line
Source: The author (2026)

Artificial neural network (ANN), linear regression (LR), random forest regression (RFR) and support vector regression (SVR) prediction accuracy (RMSE) are presented in Table 2.

Table 2. Artificial neural network (ANN), linear regression (LR), random forest regression (RFR) and support vector regression (SVR) prediction accuracy (RMSE)

N	**ANN RMSE train**	**ANN RMSE test**	**LR RMSE test**	**RFR RMSE test**	**SVR RMSE test**
1	0.112	0.100	0.100	0.105	0.101
2	0.107	0.141	0.139	0.123	0.142
3	0.111	0.113	0.126	0.101	0.126
4	0.112	0.106	0.107	0.115	0.105
5	0.113	0.095	0.110	0.110	0.109
6	0.112	0.104	0.112	0.108	0.112
7	0.111	0.112	0.109	0.115	0.112
8	0.112	0.102	0.101	0.112	0.095
9	0.112	0.101	0.105	0.121	0.102
10	0.111	0.116	0.111	0.127	0.115
Mean	0.111	0.109	0.112	0.114	0.112
SD	0.002	0.013	0.012	0.008	0.014

Source: The author (2026)

The RMSE values for all methods on both training and test data were satisfactory. The ANN model exhibits the lowest mean RMSE on the test set, indicating superior predictive performance compared to the other methods. Although the ANN shows the best average performance, its standard deviation is relatively moderate, suggesting that while the model performs well overall, its predictive accuracy varies across folds slightly more than in some competing models. Additionally, ANN models are capable of efficiently capturing nonlinear relationships between independent variables and the dependent variable.

The weak form of the Efficient Market Hypothesis (EMH) suggests that all information based on historical prices is incorporated into the current price. Nonetheless, several studies (Urquhart, 2016; Al-Yahyaee et al., 2018; Kristoufek & Vosvrda, 2019) show that the cryptocurrency markets do not operate with complete efficiency. This opens up possibilities for developing and employing predictive models that use past price data to forecast future trends, effectively demonstrated by an artificial neural network (ANN) model.

Cryptocurrency markets act as complex adaptive systems, characterised by extensive interconnections, changing patterns and nonlinear interactions among different variables. As stated in chaos theory and nonlinear dynamics (Peters, 1994), financial markets, especially emerging and less mature ones like the crypto market, do not follow linear trends but are shaped by unpredictable and chaotic fluctuations that are often overlooked in linear models. Artificial Neural Network (ANN) models excel in detecting these intricate patterns and relationships among variables because of their ability to learn from data and represent nonlinear connections.

The first objective was to investigate whether there is a statistical relationship between Bitcoin prices and Ethereum trading volumes. This objective was achieved by utilising Spearman's rank correlation, which indicated a significant moderate positive correlation between the two variables. This indicates that fluctuations in Bitcoin prices are generally in sync with variations in Ethereum trading volumes, affirming that a substantial relationship exists.

The second objective was to create a straightforward predictive model for Ethereum trading volume based on Bitcoin prices. This objective was also accomplished. Various predictive methods were evaluated and the ANN model produced the lowest mean RMSE on the test set, showcasing the best predictive performance. While the ANN exhibited marginally greater variation between folds than some other models, its overall precision and capacity to identify nonlinear patterns suggest that a reliable predictive model was effectively developed. In line with the aforementioned, the formed hypothesis was accepted.

4.1. Theoretical contributions

The research provides several theoretical advancements to existing literature. Firstly, by showcasing a notable moderate positive relationship between Bitcoin prices and Ethereum trading volumes, the study reinforces the current evidence regarding interconnections among cryptocurrencies. This adds to theories concerning co-movement, spillover effects and herding behaviour, which propose that market participants frequently respond collectively to information or price cues from dominant cryptocurrencies.

Furthermore, the results broaden the perspectives of behavioural finance, especially herding theory and limited attention theory, within the realm of cryptocurrency markets, illustrating that investor actions and constraints in information processing contribute to synchronised market responses. The study also offers methodological contributions by validating the effectiveness of artificial neural networks (ANN) in predicting cryptocurrency market trends.

Despite using a limited set of features, the ANN successfully identified nonlinear patterns, providing additional proof that machine-learning methods can surpass traditional linear approaches in forecasting the dynamics of digital assets. Additionally, by employing a single-input model, the research presents a simplified modelling framework that highlights the significance of bilateral relationships among major cryptocurrencies.

4.2. Practical implications

Several managerial implications arise from these results. Traders and market analysts can take advantage of the insight that Ethereum trading patterns react to movements in Bitcoin prices, allowing Bitcoin to act as an early signal of changes in Ethereum market demand. This understanding facilitates more strategic trading approaches, especially for short-term decisions. Portfolio managers can leverage the established correlation to enhance risk management, as coordinated fluctuations between leading cryptocurrencies could increase liquidity risks during volatile market conditions. The impressive performance of the ANN model indicates that exchanges, fintech companies and investment institutions may incorporate lightweight machine-learning systems into their forecasting tools to enable real-time analytics without heavy computational demands. Furthermore, these findings are beneficial for financial institutions and firms looking into algorithmic trading solutions, showing that even basic ANN frameworks can yield significant predictive insights. From a regulatory perspective, grasping the interconnectedness of cryptocurrencies can assist oversight agencies in pinpointing potential systemic risks that emerge from interrelated market behaviours, particularly in times of increased volatility or speculative spikes.

5. Conclusion

The goals of the study were to investigate if there is a statistical connection between Bitcoin prices and Ethereum trading volumes and to create a straightforward predictive model for Ethereum trading volumes based on Bitcoin prices. Daily closing prices of Bitcoin in USD and daily trading volumes of Ethereum were utilised to perform Spearman's rank correlation analysis and to build an artificial neural network (ANN) model. The findings indicate a significant, moderate, positive correlation between Bitcoin prices and Ethereum volumes and the ANN model successfully predicted Ethereum's volume with a high level of accuracy. In general, the research demonstrates significant interconnections among leading cryptocurrencies and underscores the usefulness of machine-learning methods for predicting trends in the digital asset market.

This study has several limitations that need to be mentioned. The research design is correlational and predictive, rather than causal, indicating that the analysis cannot ascertain whether fluctuations in Bitcoin prices lead to alterations in Ethereum trading volume. The analysis is based solely on one predictor variable, which streamlines the modelling approach but fails to take into account the wider array of factors that are recognised to impact Ethereum trading activity, including market sentiment, macroeconomic indicators, on-chain metrics and regulatory developments.

Future research could enhance the modelling framework by integrating various explanatory factors, such as measures of investor sentiment, blockchain network activity, macroeconomic indicators, or volatility indices, to refine predictive accuracy and reveal deeper behavioural patterns. Scholars might also utilise more advanced neural network architectures, like LSTM or GRU models, which are particularly effective for time-series forecasting in financial contexts. Conducting comparative analyses across different cryptocurrencies could yield wider insights into cross-market spillovers and lead–lag relationships. In addition, future investigations could examine causal inference methods (for instance, Granger causality, VAR models, or structural modelling) to assess whether fluctuations in Bitcoin prices influence Ethereum trading behaviour. Lastly, analysing the impacts across various market conditions, such as bull markets, crashes, or times of regulatory changes, would help in evaluating the strength and consistency of the identified relationships.

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Odnos između cijene Bitcoina i obujma trgovanja Ethereumom

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Sažetak: Ciljevi rada bili su ispitati postoji li statistička veza između cijena Bitcoina i volumena trgovanja Ethereumom te razviti jednostavan prediktivni model za volumene trgovanja Ethereumom na temelju cijena Bitcoina. Dnevne cijene zatvaranja Bitcoina u USD i dnevni volumeni trgovanja Ethereumom korišteni su za provođenje Spearmanove analize korelacije rangova i za razvoj modela umjetne neuronske mreže (ANN). Vremenski okvir obuhvaćen podacima je od 1. svibnja 2020. do 22. studenog 2025. Volumeni Ethereuma funkcionirali su kao zavisna varijabla, a cijene Bitcoina kao nezavisna varijabla. Rezultati otkrivaju značajnu, umjerenu, pozitivnu vezu između cijena Bitcoina i volumena Ethereuma te da je model ANN učinkovito predvidio volumene Ethereuma s visokim stupnjem točnosti. Rezultati podržavaju sadašnje dokaze o vezama između kriptovaluta. Potvrđujući učinkovitost umjetnih neuronskih mreža (ANN) u predviđanju obrazaca na tržištu kriptovaluta, studija također daje metodološki doprinos. Osim toga, studija nudi jednostavniji pristup modeliranju koji naglašava važnost bilateralnih interakcija među glavnim kriptovalutama korištenjem modela s jednim ulazom. Burze, fintech tvrtke i investicijske institucije mogu integrirati lagane sustave strojnog učenja u svoje alate za predviđanje kako bi ponudile analitiku u stvarnom vremenu bez značajnih zahtjeva za obradom, u skladu s izvrsnim performansama ANN modela.

Ključne riječi: cijene Bitcoina, volumen trgovanja Ethereumom, kriptovalute, Spearmanova korelacija rangova, umjetne neuronske mreže (ANN)
JEL klasifikacija: G10, G12, C45

Prognoziranje realizirane volatilnosti: empirijski nalazi referentnog europskog dioničkog indeksa

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Sažetak: Realizirana volatilnost temelji se na intradnevnim visokofrekventnim prinosima i standardna je mjera stvarne, premda nepoznate, integrirane volatilnosti financijske imovine. Iako je realizirana volatilnost determinirana ex-post, u posljednjem desetljeću razvijeno je nekoliko modela za njezino predviđanje, koji se razlikuju prema svojstvima koja nastoje obuhvatiti, kao što su duga memorija, heteroskedastičnost, cjenovni skokovi, asimetrična reakcija na pozitivne i negativne šokove te mikro strukturni šum, kao i prema tome modeliraju li realiziranu volatilnost izravno ili posredno. Uspješnost takvih modela još je uvijek nedovoljno istražena, osobito na europskim tržištima kapitala, za razliku od američkih tržišta koja su zastupljenija u dosadašnjim studijama. Stoga je cilj ovoga rada usporediti uspješnost odabranih modela u prognoziranju realizirane volatilnosti indeksa DAX, koji se smatra referentnim europskim dioničkim indeksom. U tu svrhu uspoređuju se HAR, MEM, HEAVY i realizirani GARCH modeli ne samo radi utvrđivanja modela s najvećom prognostičkom točnošću, već i radi ispitivanja ovisi li njihova učinkovitost o frekvenciji uzorkovanja i izboru realizirane mjere koja se prognozira. Time rad doprinosi literaturi u kojoj ne postoji konsenzus o najprikladnijim modelima za prognoziranje pojedinih realiziranih mjera volatilnosti. Empirijski nalazi pružaju implikacije za upravljanje rizicima i vrednovanje financijskih instrumenata na europskim tržištima kapitala, osobito u razdoblju neizvjesnosti obuhvaćenom analizom. Istraživanje se temelji na jednominutnim zaključnim cijenama indeksa DAX, dok se prognostička točnost vrednuje primjenom više kriterija.

***Ključne riječi*:** realizirana volatilnost, prognostički modeli, referentni dionički indeks
***JEL klasifikacija*:** C53, C58, D53, G17

1. Uvod

Implementacijom visokofrekventnih podataka, opaženih u vrlo kratkim vremenskim intervalima, u postojeće modele znatno je poboljšana preciznost procjene i prognoze volatilnosti financijske imovine. U empirijskim istraživanjima najzastupljeniji je GARCH model (engl. *Generalized Autoregressive Conditional Heteroskedasticity*) za prognozu dnevne volatilnosti na temelju niskofrekventnih zaključnih cijena te se, zbog svoje superiornosti, često koristi kao referentni model u usporednim analizama

(Hansen i Lunde, 2005). Riječ je o parametarskom modelu uvjetne volatilnosti (engl. *conditional volatility*), koja je vremenski promjenjiva i uvjetovana informacijama iz prošlosti (Bollerslev, 1986). Osnovna ideja GARCH modela je da trenutna varijanca prinosa ovisi o varijanci prinosa iz prethodnog razdoblja, čime se opisuje autoregresijsko ponašanje volatilnosti. Zbog takve dinamike ona se može jednostavno prognozirati. Razvoj GARCH metodologije izravno je povezan s Robertom Engleom, koji je 1982. predstavio ARCH model (Engle, 1982), preteču današnjih GARCH modela te je za svoj pionirski doprinos 2003. godine nagrađen Nobelovom nagradom za ekonomiju. GARCH modeli od tada su postali standardni alat, ne samo u prognoziranju i upravljanju tržišnim rizikom, već i u optimizaciji portfelja, vrednovanju financijskih izvedenica, modeliranju učinaka zaraze i prelijevanja volatilnosti te u utvrđivanju svojstava različitih vrsta imovine, poput sigurnog utočišta ili diverzifikatora. S vremenom su formulirane brojne specifikacije GARCH modela, od asimetričnih (EGARCH, APARCH, TGARCH, GJR-GARCH i dr.) do multivarijatnih (CCC, DCC, BEKK, DVEC i dr.), s ciljem opisivanja dinamike volatilnosti u različitim tržišnim uvjetima, ne ograničavajući se samo na jednu imovinu.

Uz parametarske modele, koji djeluju ex-ante, razvijeni su i neparametarski modeli volatilnosti, no njihova je prognostička moć ograničena jer zbog svoje konstrukcije djeluju ex-post. Realizirana volatilnost, odnosno realizirana varijanca RV (engl. *realized variance*), neparametarska je mjera dnevne integrirane volatilnosti utemeljena na intradnevnim opažanjima (Andersen et al., 2001) i kao takva ne modelira izravno svoju buduću dinamiku. Stoga se nameće istraživačko pitanje: Može li se realizirana volatilnost, iako je ex-post determinirana, uspješno prognozirati? Odgovor na to pitanje nije neposredan jer u radu s visokofrekventnim podacima potrebnima za procjenu RV postoji niz izazova koje treba svladati, kao što su mikrostrukturni šum (engl. *microstructure noise*), cjenovni skokovi i nesinkroniziranost opažanja. Prema Arnerić i Matković (2019), visokofrekventni podaci često su kontaminirani mikrostrukturnim šumom, koji stvara prividnu volatilnost zbog oscilacija između kupovne (engl. *bid*) i prodajne (engl. *ask*) cijene, nesinkronog trgovanja, cjenovnih skokova i niske likvidnosti, osobito na izranjajućim tržištima (engl. *emerging markets*). Te anomalije precjenjuju RV i narušavaju učinkovitost prognostičkih modela. Autori nadalje ističu važnost filtriranja visokofrekventnih podataka, optimalnog odabira frekvencije uzorkovanja i uporabe realiziranih mjera robusnih na mikrostrukturni šum i cjenovne skokove. Pronalazak „najbolje“ realizirane mjere, ne nužno realizirane varijance RV, preduvjet je za njezino modeliranje i prognoziranje. Prvi iskorak u tom smjeru dao je Corsi (2009), koji je uveo heterogeni autoregresijski model realizirane volatilnosti HAR-RV (engl. *Heterogeneous Autoregressive Realized Volatility*) i pokazao da se dinamika volatilnosti može opisati linearnom kombinacijom prošlih vrijednosti na dnevnom, tjednom i mjesečnom horizontu, prema pretpostavci heterogene strukture tržišta (različite skupine tržišnih sudionika reagiraju na informacije u različitim vremenskim horizontima). Nadalje, razvijen je model multiplikativne pogreške MEM (engl. *Multiplicative Error Model*), koji omogućuje fleksibilnije modeliranje volatilnosti polazeći od umnoška uvjetne sredine realizirane mjere i slučajne komponente koja poprima isključivo nenegativne vrijednosti s očekivanjem jednakim jedan (Engle, 2002; Engle i Gallo, 2006). Na njega se nadovezuje HEAVY model (engl. *High-frEquency-bAsed VolatilitY*) Shepharda i Sheparda (2010) u kojem se uvjetna varijanca i uvjetno očekivanje realizirane mjere zasebno modeliraju kao latentni, ali povezani dinamički procesi. Budući da HEAVY model smanjuje perzistentnost volatilnosti, implicira da je duga memorija GARCH modela posljedica zanemarivanja visokofrekventnih informacija (Nguyen et al., 2024). Primjene HEAVY modela doživjele su i multivarijatna proširenja (Noureldin et al., 2012; Shepard i Xu, 2019; Bauwens i Xu, 2023; Girardi i Caporin, 2025), analizirajući kovarijance prinosa više imovina istodobno.

Sljedeći ključni iskorak predstavili su Hansen i suradnici (2011) realiziranim GARCH modelom (engl. *Realized GARCH*), koji povezuje dnevne prinose, uvjetnu varijancu i realiziranu mjeru volatilnosti. Za razliku od standardnog GARCH modela, realizirani GARCH model uključuje i visokofrekventne podatke kroz realiziranu mjeru volatilnosti u dodatnoj mjernoj jednadžbi (engl. *measurement equation*). Empirijske studije pokazuju da realizirani GARCH sustavno nadmašuje standardne GARCH modele u predviđanju volatilnosti, osobito na kratkim horizontima gdje je realizirana volatilnost najinformativnija (Sharma i Vipul, 2016). Model su dodatno proširili Hansen i Huang (2016) realiziranim EGARCH modelom, što omogućuje uključivanje asimetričnih volatilnih reakcija i više realiziranih mjera (Naimoli et al., 2022). Paralelna istraživačka struja nastoji postići slične ciljeve kombiniranjem postojećih modela, pri čemu su Huang i suradnici (2016) predložili realizirani HAR-GARCH model, koji spaja HAR komponente duge memorije s GARCH modelom.

Dosadašnja istraživanja ponajprije su usmjerena na razvijena američka tržišta kapitala, dok su europska slabije zastupljena i nisu sustavno analizirana. Nedovoljno je istraženo koliko su modeli koji integriraju visokofrekventne podatke doista uspješni u prognoziranju realizirane volatilnosti na europskim tržištima unatoč njihovu progresivnom razvoju. Stoga se nameće potreba za popunjavanjem tog istraživačkog jaza evaluacijom i usporedbom različitih prognostičkih modela realizirane volatilnosti, što je u radu i učinjeno na primjeru njemačkog burzovnog indeksa DAX, jednog od najlikvidnijih predstavnika europskih dioničkih tržišta zbog visoke tržišne kapitalizacije i intenzivne trgovinske aktivnosti. U tu se svrhu uspoređuju HAR, MEM, HEAVY i realizirani GARCH modeli primjenom RMSE, MAPE i QLIKE kriterija dok se statistička značajnost razlika u prognostičkim sposobnostima formalno testira Diebold-Mariano testom. Nadalje, ostaje otvoreno pitanje ovisi li i u kojoj mjeri uspješnost odabranih modela o izboru realizirane mjere volatilnosti i frekvenciji uzorkovanja. Rasvjetljavanje tog pitanja dodatni je znanstveni doprinos, s važnim implikacijama za institucionalne investitore i praktičare u financijskom sektoru, jer pruža smjernice za učinkovitije modeliranje tržišnog rizika. Rezultati istraživanja korisni su i nositeljima ekonomskih politika u oblikovanju makroprudencijalnih mjera usmjerenih na očuvanje financijske stabilnosti, jer omogućuju rano prepoznavanje početka razdoblja povećane volatilnosti. Tržišni rizik, utemeljen na budućoj realiziranoj volatilnosti, izravno utječe i na minimalne kapitalne zahtjeve koje regulatorna tijela propisuju financijskim institucijama.

Ovaj članak, uz uvodni dio, obuhvaća četiri dodatna poglavlja. U drugom poglavlju analizira se relevantna literatura i ističu otvorena istraživačka pitanja. U trećem poglavlju opisuju se korišteni podaci i metode, nakon čega slijedi empirijska analiza i rasprava o rezultatima u četvrtom poglavlju. Rad završava petim poglavljem, koje donosi glavne zaključke, ograničenja i smjernice za buduća istraživanja.

2. Pregled literature i istraživački jaz

U suvremenoj literaturi razvijeno je mnogo pristupa koji nastoje unaprijediti modeliranje i prognoziranje volatilnosti uključivanjem visokofrekventnih podataka. Najjednostavniji među njima je GARCH-X, koji proširuje standardni GARCH model dodavanjem realizirane mjere volatilnosti kao egzogene varijable u jednadžbu uvjetne varijance. Međutim, GARCH-X model ne prognozira realiziranu volatilnost, već uvjetnu volatilnost, iako se koristi informacijama iz realizirane mjere (Engle, 2002). Mnogi radovi uspoređuju učinkovitost realiziranih GARCH modela i njihovih varijanti sa standardnim GARCH modelima, dok drugi uspoređuju alternativne modele, poput HEAVY i MEM modela.

Sharma i Vipul (2016) analiziraju više razvijenih tržišta i tržišta u razvoju (16 međunarodnih dioničkih indeksa) te pronalaze da realizirani GARCH nadmašuje standardne GARCH modele u kratkoročnim

prognozama i procjeni rizične vrijednosti VaR (engl. *Value-at-Risk*), osobito u razdobljima povišene volatilnosti. Do sličnog zaključka dolaze Frömmel i suradnici (2014) pri modeliranju dnevne volatilnosti spot cijena električne energije od veljače 2005. do travnja 2013. te Xiao i suradnici (2023) primjenom frakcijski integriranog realiziranog GARCH modela, tzv. FIGARCH-RV. Watanabe (2012) dodatno pokazuje da uključivanje realiziranih mjera poboljšava kvantilne prognoze prinosa i procjenu repnog rizika (engl. *tail risk*) S&P500 indeksa, pri čemu realizirani GARCH ostvaruje stabilnije rezultate u kombinaciji s pristupima temeljenima na teoriji ekstremnih vrijednosti EVT (engl. *Extreme Value Theory*).

Važan dio literature bavi se pitanjem složenosti modela i robusnosti prognoza. Xie i Yu (2020) empirijski pokazuju da su mnoge proširene specifikacije realiziranog GARCH modela prekomjerno parametrizirane te da jednostavnije varijante pružaju jednake ili čak bolje rezultate izvan uzorka (engl. *out-of-sample*). Autori uspoređuju tri varijante realiziranog GARCH modela na podacima 28 pojedinačnih dionica i zaključuju da parsimonijski modeli imaju stabilnije procjene i manje su osjetljivi na mikrostrukturni šum. Novija literatura produbljuje ovu spoznaju analizom informacijskog sadržaja različitih realiziranih mjera. Xu i suradnici (2024) pokazuju da realizirane mjere hvataju različite komponente volatilnosti, uključujući kontinuiranu komponentu i prekonoćne skokove (engl. *overnight jumps*) te upućuju na zaključak da je selektivno uključivanje informativnijih mjera korisnije od neselektivnog agregiranja više njih. Time se dodatno potvrđuje važnost parsimonije i promišljenog odabira realizirane mjere. Wu i suradnici (2024) naglašavaju da realizirani GARCH može korigirati pristranost realiziranih mjera, što su dokumentirali na primjeru dva glavna indeksa kineskog tržišta dionica (kompozitni indeks šangajske i šenženske burze). Fang i Han (2025) primjenjuju realizirani GARCH model u kontekstu vrednovanja opcija, koristeći podatke o američkim tržišnim indeksima S&P500, NASDAQ100 i Dow Jones Industrial Average (DJIA) te nalaze da uključivanje realizirane mjere smanjuje pogreške u određivanju cijena opcija u odnosu na standardne GARCH i BS modele (engl. *Black and Scholes*). Paralelno se primjenjuju i podatkovno utemeljeni pristupi za prognoziranje realizirane volatilnosti, poput neuronskih mreža, pri čemu Arnerić i suradnici (2018) pokazuju da jednosmjerne neuronske mreže FNN (engl. *Feedforward Neural Networks*) konstruirane kao nelinearna proširenja standardnih HAR-RV modela, uključujući komponente skokova i asimetrije, postižu bolju prilagodbu podacima i veću prognostičku točnost na temelju MSE i MAE kriterija, analizirajući njemački DAX.

Za razliku od realiziranih GARCH modela, HEAVY modeli polaze od pretpostavke da realizirane mjere izravno upravljaju dinamikom uvjetne volatilnosti i kvadriranih prinosa, čime se izbjegava potreba za zasebnom mjernom jednadžbom. Temeljni okvir HEAVY modela razvili su Shephard i Sheppard (2010), koji pokazuju da korištenje realizirane varijance dobivene iz intradnevnih podataka značajno poboljšava prognoze volatilnosti u odnosu na klasične GARCH modele, što je potvrđeno analizom 34 financijska instrumenta u razdoblju od 1996. do 2009. godine. Noureldin i suradnici (2012) proširuju taj pristup uvođenjem multivarijatnih HEAVY modela koji omogućuju modeliranje dinamike realizirane kovarijance i realizirane korelacije, uz znatno smanjene dimenzionalne zahtjeve naspram standardnih multivarijatnih GARCH specifikacija (MGARCH). Nadalje, Sheppard i Xu (2019) uvode faktorske HEAVY modele, čime omogućuju parsimonijsko modeliranje volatilnosti velikog broja financijskih instrumenata putem zajedničkih latentnih faktora. Njihov uzorak obuhvaća 93 likvidne dionice američkog S&P100 indeksa u razdoblju od siječnja 2000. do prosinca 2014. godine, a realizirane mjere volatilnosti izračunavaju se iz 5-minutnih intradnevnih prinosa. Konačno, Bauwens i Xu (2023) integriraju HEAVY pristup sa strukturama dinamičke korelacije, razvijajući DCC-HEAVY i DECO-

HEAVY modele te empirijski pokazuju njihovu superiornu prognostičku sposobnost na primjeru 29 dionica, sastavnica DJIA indeksa, u razdoblju koje uključuje dot-com krizu i globalnu financijsku krizu. HEAVY modeli često se povezuju s MEM modelima s obzirom na to da oba pristupa polaze od multiplikativne strukture volatilnosti, iako se u potonjima realizirane mjere tretiraju latentnim varijablama. S jedne strane MEM modeli primjenjuju se za proširenje GARCH-X specifikacija, a s druge strane za pojednostavljenje realiziranog GARCH modela, čime se reducira parametarska složenost i poboljšava prognostička učinkovitost (Nguyen et al., 2024). MEM modeli posebno su prikladni za kratkoročno i srednjoročno prognoziranje volatilnosti te se mogu lako integrirati s drugim modelima, poput MIDAS (engl. *Mixed Data Sampling*) modela (Amendola et al., 2024). Engle i Gallo (2006) provode empirijsku analizu koristeći intradnevne podatke visoke frekvencije za S&P500 indeks i devizni tečaj USD/DEM, s 5-minutnim prinosima u razdoblju od 2. siječnja 1996. do 31. prosinca 2002. Autori konstruiraju više realiziranih mjera volatilnosti i ugrađuju ih u MEM model, pokazujući da se njihovom kombinacijom značajno poboljšava procjena latentne dnevne volatilnosti. Nguyen i suradnici (2024) koriste američke dionice iz indeksa S&P500 u razdoblju od 1. siječnja 2000. do 31. prosinca 2020., uspoređuju klasične GARCH-X i MEM modele s njihovim proširenjima temeljenima na dubokom učenju (engl. *deep learning*) te zaključuju da takva proširenja postižu točniju kratkoročnu i srednjoročnu prognozu. Amendola i suradnici (2024) empirijski primjenjuju dvostruke MEM modele, analizirajući realiziranu volatilnost S&P500 indeksa, a rezultati impliciraju da razdvajanje volatilnosti na dugoročnu i kratkoročnu komponentu dovodi do boljih prognoza naspram standardnih MEM i GARCH specifikacija.

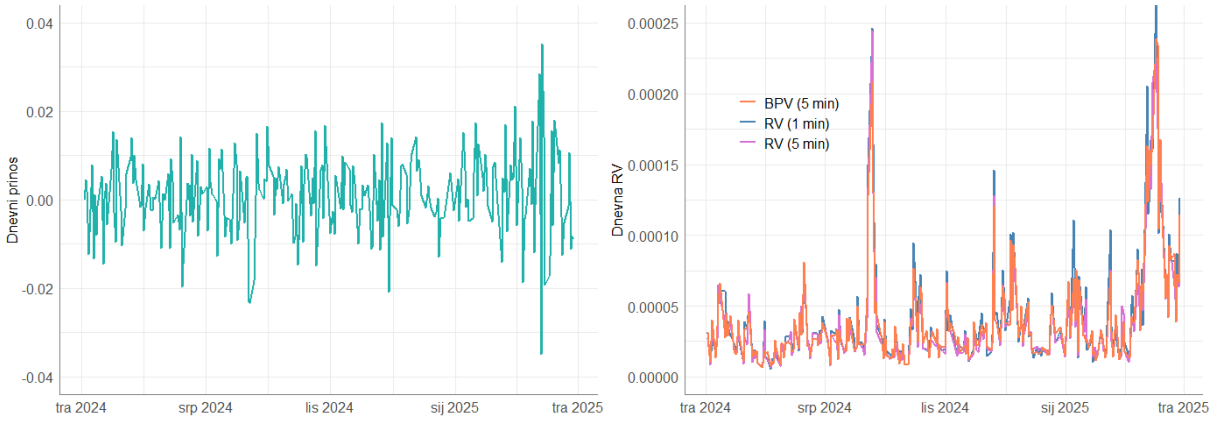
Među najjednostavnijima je HAR model, široko prepoznat po svojoj interpretabilnosti i računskoj učinkovitosti (Corsi, 2009), koji često postiže jednaku prognostičku točnost ili čak nadmašuje složenije specifikacije, poput tehnika strojnog učenja (Chassot i Audrino, 2025), osobito kada se u obzir uzmu vremenski promjenjivi parametri (Wang et al., 2016). Postoje brojne varijante i proširenja HAR modela, poput HARJ, HARCJ, HARQ, HARQJ, CHAR i CHARQ, koje se razlikuju prema načinu uključivanja skokova i kontinuirane komponente volatilnosti, upotrebi kvantilnih mjera umjesto realiziranih mjera, te proširenju osnovne HAR strukture na zajedničko modeliranje prinosa i volatilnosti. Corsi (2009), koji uvodi HAR-RV model, primjenjuje tri agregirane komponente realizirane volatilnosti (dnevnu, tjednu i mjesečnu) te pokazuje da ova jednostavna struktura uspješno replicira empirijsko svojstvo duge memorije i postiže zadovoljavajuću prognozu dnevne realizirane volatilnosti S&P500 indeksa. Na to se nadovezuju Corsi i Reno (2012), koji proširuju HAR model realizirane volatilnosti S&P500 indeksa iz 5-minutnih cijena, opaženih od 1996. do 2009. godine, pokazujući da eksplicitno modeliranje asimetrije poboljšava kratkoročne prognoze. Daljnje unaprjeđenje HAR modela donose Bollerslev i suradnici (2016), koji predlažu da se prognoze volatilnosti korigiraju korištenjem pogrešaka prethodnih prognoza i pokazuju da takvi modeli imaju veću prediktivnu sposobnost u odnosu na standardne HAR i GARCH modele.

Zaključno, prethodne studije koje integriraju visokofrekventne podatke u prognoziranje volatilnosti konvergiraju prema nekoliko zajedničkih spoznaja. Prvo, gotovo svi radovi potvrđuju da uključivanje realiziranih mjera volatilnosti konstruiranih iz intradnevnih cijena poboljšava prognozu u odnosu na standardne GARCH modele, neovisno o tržišnom režimu i vrsti imovine, to jest realizirani GARCH modeli dosljedno nadmašuju standardne GARCH modele u kratkoročnim prognozama, osobito tijekom nestabilnosti tržišta. Drugo, sve više autora slaže se da složenost modela ne jamči bolje prognoze, dok parsimonijski modeli pružaju stabilnije i robusnije *out-of-sample* rezultate. Alternativni pristupi poput HEAVY i MEM modela pokazuju da izravno inkorporiranje realizirane mjere u dinamiku uvjetne (latentne) volatilnosti osigurava značajna prognostička poboljšanja, naročito u multivarijatnom

kontekstu. Treće, unatoč primjeni metoda strojnog učenja, najjednostavniji HAR ostaje iznimno konkurentan. Time se u recentnoj literaturi oblikuje konsenzus da je ključ uspješnog prognoziranja realizirane volatilnosti u selekciji informativnih i robusnih realiziranih mjera i jednostavnosti modela (načelo parsimonije). Pored fragmentiranih nalaza, ostaje izražen istraživački jaz. Većina empirijskih istraživanja provedena je na američkim i kineskim tržištima, dok su europska tržišta slabije zastupljena i nisu sustavno analizirana. Relativna uspješnost pojedinih modela rijetko se ispituje s obzirom na izbor realizirane mjere dnevne volatilnosti i frekvencije uzorkovanja, iako HAR, MEM, HEAVY i realizirani GARCH modeli pretežno koriste realiziranu varijancu RV izračunatu na 5-minutnoj frekvenciji, uz eventualna proširenja na realizirane mjere otporne na cjenovne skokove, poput *bipower* realizirane varijance BPRV i realizirane mjere otporne na mikrostrukturni šum, poput realiziranog kernela RK. Također, 5-minutna frekvencija uzorkovanja u referiranim radovima smatra se razumnom kao balans između pristranosti i efikasnosti realiziranih mjera, ali osim tog obrazloženja autori ne nude empirijske dokaze da je ista optimalna, i ne analiziraju osjetljivost spomenutih modela pri drugim frekvencijama uzorkovanja. Jedan od rijetkih radova koji preispituje je li zaista 5-minutna frekvencija optimalna, uzimajući u obzir 104 realizirane mjere ne analizira uspješnost HAR, MEM, HEAVY i realiziranog GARCH modela koji bi te mjere inkorporirali, a empirijski rezultati ograničeni su na energetsko tržište odnosno na volatilnost cijene sirove nafte (Lyu et al., 2025). Ova ograničenja upućuju na potrebu za empirijskom usporedbom različitih modela i realiziranih mjera na europskim dioničkim tržištima, uz eksplicitnu analizu robusnosti prognoza na izbor frekvencije uzorkovanja.

3. Podaci i metode

Od 2. travnja 2024. do 28. ožujka 2025. opaženo je 120 231 zadnja cijena u jednako udaljenim, nepraznim i nepreklapajućim intervalima od jedne minute, što u prosjeku odgovara približno 8,5 sati dnevnom trgovanju na frankfurtskoj burzi s pomoću elektroničkog sustava Xetra tijekom 253 radna dana, uzimajući u obzir skraćeno radno vrijeme u pojedinim danima. Dnevni prinosi i odabrane realizirane mjere volatilnosti DAX indeksa prikazani su na Slici 1. Dnevni prinosi osciliraju oko nule, u rasponu od -3,48 % do 3,53 % (Tablica 1.), s povremenim periodima pojačane varijabilnosti (fenomen grupiranja volatilnosti). Realizirane mjere volatilnosti jasno odražavaju vremensku promjenjivost, pri čemu je dnevna realizirana varijanca temeljena na jednominutnim prinosima osjetljivija na mikrostrukturni šum u odnosu na petominutnu RV mjeru (Slika 1.). Istodobno, *bipower* realizirana varijanca (BPRV) izračunata na petominutnoj frekvenciji ima blaže izražene ekstreme, što je čini otpornijom na cjenovne skokove, ali ne nužno i na mikrostrukturni šum. Dnevna RV (1 min) kreće se u rasponu od gotovo 0 % do 2,59 %. Uz uobičajene pokazatelje deskriptivne statistike, u fazi prije procjene odabranih modela, koji su detaljno opisani u nastavku, provedena je dijagnostička provjera kako bi se ispitali preduvjeti za njihovu primjenu (Tablica 1.).



Slika 1. Dnevni prinosi i dnevne realizirane mjere volatilnosti DAX indeksa
Izvor: izrada autora u programu RStudio na temelju podataka iz Refinitiv Eikon baze (2025)

Za dnevnu RV pri najvišoj frekvenciji uzorkovanja od jedne minute potvrđena je prisutnost mikrostrukturnog šuma (Box-Ljung test autokorelacije i udio šumovite varijance), cjenovnih skokova (AJ test prema Aït-Sahalia i Jacod (2009)) i duge memorije (GPH test prema Geweke i Porter-Hudak (1983)), dok su za dnevne prinose dokazani heteroskedastičnost (ARCH test), teški repovi distribucije (mjera zaobljenosti i Jarque-Bera test) te asimetrija informacija (CCF test).

Tablica 1. Deskriptivna statistika i dijagnostička provjera svojstava dnevnih prinosa i dnevne realizirane varijance DAX indeksa pri najvišoj frekvenciji uzorkovanja

Dnevni prinosi		Dnevna realizirana varijanca (1 min)	
Najmanja vrijednost	-0,034835	Najmanja vrijednost	0,000006
Najveća vrijednost	0,035284	Najveća vrijednost	0,000259
Srednja vrijednost	0,000856	Srednja vrijednost	0,000037
Standardna devijacija	0,009237	Standardna devijacija	0,000035
ARCH(5) test	62,41***	ACF(1) test	-0,0443**
Zaobljenost	7,082***	AJ test	8,69%
JB test	12,992**	NV omjer	23,54%
CCF(1) test	-0,0624**	GPH test	0,592***

Napomena: *, ** i *** označavaju statističku značajnost na razini signifikantnosti od 10 %, 5 % i 1 %
Izvor: izračun autora u programu RStudio na temelju podataka iz Refinitiv Eikon baze (2025)

Značajnost ARCH testa pri 5 vremenskih pomaka potvrđuje uvjetnu heteroskedastičnost, to jest vremenski promjenjivu varijancu dnevnih prinosa, dok visoka mjera zaobljenosti (znatno viša od 3) i značajan JB test dodatno upućuju na fenomen teških repova i odstupanje od normalnosti. Negativan i statistički značajan kros-korelacijski koeficijent prvog reda CCF(1), kojim se mjeri korelacija između tekućih kvadriranih dnevnih prinosa i prinosa prethodnog dana, ukazuje na prisutnost asimetrije informacija, tzv. efekt poluge, jer su negativni prinosi iz prethodnog dana povezani s povećanom volatilnošću tekućeg dana. Nadalje, negativna i statistički značajna autokorelacija prvog reda jednominutnih prinosa ACF(1) upućuje na prisutnost mikrostrukturnog šuma. AJ test proveden je za svaki trgovinski dan i pokazuje da su statistički značajni cjenovni skokovi prisutni u približno 8,7 % trgovinskih dana, što sugerira da su oni rijetki, ali snažni (slučaj konačne aktivnosti skokova – engl. *finite activity jumps*). Omjer NV (engl. *noise variance ratio*) oko 23,5 % je udio realizirane varijance

induciran šumom pri jednominutnoj frekvenciji uzorkovanja i dodatno potvrđuje utjecaj mikrostrukturnog šuma, zbog čega je dnevna RV pristrana. Konačno, GPH procjena frakcijskog integracijskog parametra d ≈ 0,59 statistički je značajna i ukazuje na izraženu dugu memoriju realizirane varijance (volatilnost je visoko perzistentna jer se sporo vraća na svoju prosječnu razinu nakon šoka). Shodno navedenome, empirijski je opravdana primjena odabranih modela koji uvažavaju navedena svojstva, imajući na umu da realizirane mjere volatilnosti tek treba pažljivo odabrati iako će se isti modeli koristiti za prognoziranje različitih realiziranih mjera i pri različitim frekvencijama uzorkovanja s ciljem ispitivanja njihove robusnosti i prediktivne sposobnosti.

Odabrane su četiri realizirane mjere volatilnosti: RV, BPRV, TTSRV i RTTSRV (Tablica 2.) i četiri prognostička modela: HAR, MEM, HEAVY i realizirani GARCH (Tablica 3.), koji će se, uz standardne apsolutne i relativne kriterije točnosti prognoze (RMSE i MAPE), vrednovati i s pomoću QLIKE (engl. *Quasi-Likelihood*) kao dodatnog kriterija koji je robustan na pogreške u realiziranim mjerama, čime omogućuje pouzdaniju usporedbu modela (Patton, 2011). Naposljetku, primjenjuje se Diebold-Mariano (DM) test za formalnu usporedbu prognostičke točnosti u testnom razdoblju, kojim se ispituje jesu li razlike u prognostičkim pogreškama između dvaju konkurentskih modela statistički značajne (Diebold i Mariano, 1995). Za svaku realiziranu mjeru provodi se šest DM testova s obzirom na to da se četiri modela uspoređuju u parovima.

Tablica 2. Realizirane mjere dnevne volatilnosti

Formulacija realizirane mjere	Otpornost na šumove	Otpornost na skokove
$RV_t^d = \sum_{i=1}^{M-1} r_{ti}^2$		
$BPRV_t^d = \frac{\pi}{2} \sum_{i=2}^{M-1} \lvert r_{t_{i-1}} \rvert \lvert r_{t_i} \rvert$		x
$TTSRV_t^d = \frac{1}{1-\frac{\bar{n}}{M-1}} \left(\frac{1}{S} \sum_{s=1}^{S} \sum_{i=1}^{n_s} r_{ti,s}^2 - \frac{\bar{n}}{M-1} \sum_{i=1}^{M-1} r_{ti}^2 \right)$	x	
$RTTSRV_t^d = \frac{1}{1-\frac{\bar{n}}{M-1}} c \left(\frac{1}{S} \sum_{s=1}^{S} \sum_{i=1}^{n_s} r_{ti,s}^2 I_i - \frac{\bar{n}}{M-1} \sum_{i=1}^{M-1} r_{ti}^2 I_i \right)$	x	x

Napomena: intradnevni prinos r_{ti} je prinos i-te frekvencije u danu t, M je broj intradnevnih intervala unutar 8,5 satnog radnog dana, $r_{ti,s}$ je prinos i-te frekvencije u danu t spore vremenske skale s, dok je I_i indikator funkcija.
Izvor: formulacija autora prema navedenoj literaturi

Najjednostavnija mjera je realizirana varijanca RV, kao zbroj kvadrata intradnevnih prinosa, koja konvergira prema integriranoj varijanci kako se frekvencija uzorkovanja povećava (Andersen i et al., 2001). Međutim, u praksi je RV kontaminirana mikrostrukturnim šumom, zbog čega je pristrana, a pristranost raste s porastom frekvencije uzorkovanja (Hansen i Lunde, 2005). Izvori šuma uključuju nesinkrono trgovanje, diskretna opažanja cijena i *bid-ask bounce* efekt, što dovodi do negativne autokorelacije u visokofrekventnim prinosima (Aït-Sahalia et al., 2011). Dodatno, RV nije otporna na cjenovne skokove, zbog čega može značajno precijeniti volatilnost u razdobljima naglih tržišnih promjena. Kako bi se izolirao utjecaj cjenovnih skokova, uvedena je *bipower* realizirana varijanca BPRV (Barndorff-Nielsen i Shephard, 2006), iako ostaje osjetljiva na mikrostrukturni šum. BPRV se

računa kao zbroj umnožaka apsolutnih vrijednosti susjednih intradnevnih prinosa, koji se normalizira za konstantu $\pi/2$. Problem mikrostrukturnog šuma adresira dvostruko skalirana realizirana varijanca TTSRV (engl. *Two-Times Scaled Realized Variance*), koju su razvili Zhang i suradnici (2005). Ključna ideja TTSRV je razdvajanje vremenskih skala na brzu i sporu. Brza vremenska skala odgovara najvišoj dostupnoj frekvenciji uzorkovanja, dok spora vremenska skala podrazumijeva nižu frekvenciju uzorkovanja. TTSRV se dobiva tako da se najprije izračuna prosjek realiziranih volatilnosti na sporijoj vremenskoj skali, a zatim se od tog prosjeka oduzme korekcija koja se temelji na realiziranoj volatilnosti izračunanoj iz svih visokofrekventnih prinosa na brzoj vremenskoj skali. Izbor spore vremenske skale određen je kompromisom između pristranosti i varijance procjenitelja. Arnerić i Matković (2019) predlažu praktičan pristup u kojem se brza vremenska skala fiksira na najvišu dostupnu frekvenciju, a optimizira se samo spora skala, što omogućuje zadržavanje svih intradnevnih podataka uz istodobno uklanjanje pristranosti. Iako je TTSRV otporna na šum, nije otporna na cjenovne skokove (Tablica 2.), odnosno TTSRV je konzistentan i asimptotski nepristran procjenitelj integrirane varijance samo u uvjetima odsutnosti cjenovnih skokova. Stoga Boudt i Zhang (2013) uvode robusnu varijantu dvostruko skalirane realizirane varijance RTTSRV (engl. *Robust Two-Times Scaled Realized Variance*), koja dodatno koristi indikatorsku binarnu funkciju $I_i \in \{0,1\}$ za identifikaciju ekstremnih intradnevnih prinosa koji se množe s nulom i na taj se način uklanjaju iz izračuna realizirane mjere, pri čemu uobičajena razina praga odgovara trima standardnim devijacijama od prosjeka.

Tablica 3. Prognostički modeli realizirane volatilnosti

Model	Specifikacija
HAR	$RV_t^d = \omega + \alpha RV_{t-1}^d + \beta\left(\frac{1}{5}\sum_{j=1}^{5} RV_{t-j}^d\right) + \gamma\left(\frac{1}{22}\sum_{j=1}^{22} RV_{t-j}^d\right) + \varepsilon_t$
MEM	$RV_t^d = \mu_t \varepsilon_t$ $\mu_t = \omega + \alpha RV_{t-1}^d + \beta\mu_{t-1}$
HEAVY	$r_t = \mu + z_t\sqrt{\sigma_t^2}$ $\sigma_t^2 = \omega + \alpha RV_{t-1}^d + \beta\sigma_{t-1}^2$ $RV_t^d = \mu_t \varepsilon_t$ $\mu_t = \gamma + \lambda RV_{t-1}^d + \theta\mu_{t-1}$
RGARCH	$r_t - \mu = z_t\sqrt{\sigma_t^2}$ $\sigma_t^2 = \omega + \alpha(r_{t-1} - \mu)^2 + \beta\sigma_{t-1}^2$ $ln\left(RV_t^d\right) = \lambda + \theta ln(\sigma_t^2) + \tau_1 z_t + \tau_2(z_t^2 - 1) + u_t$

Izvor: formulacija autora prema navedenoj literaturi

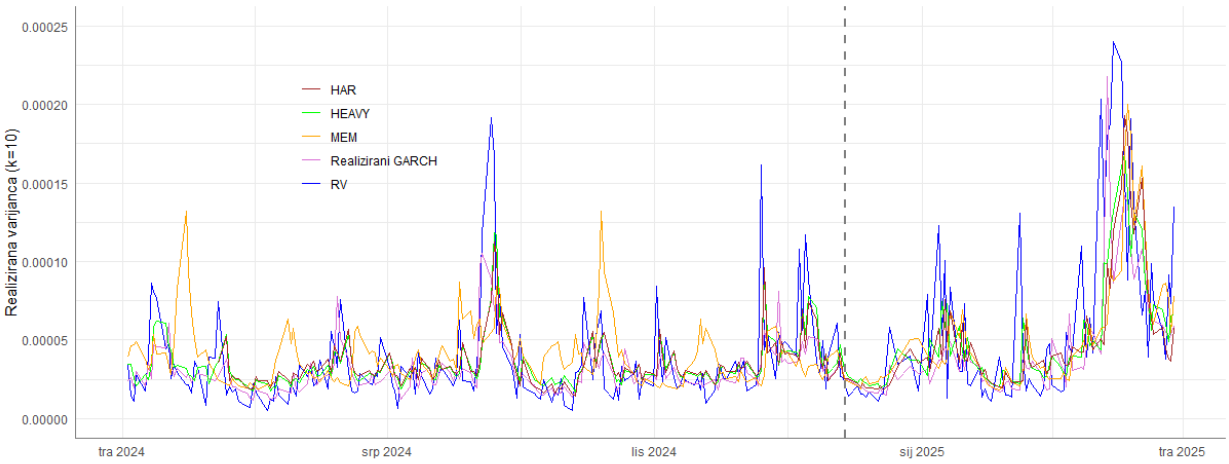
HAR model izravno modelira dnevnu realiziranu varijancu RV_t^d regresirajući je na dnevnu, tjednu i mjesečnu realiziranu varijancu iz prethodnog razdoblja, pri čemu je tjedna realizirana varijanca peteročlani pomični prosjek, a mjesečna dvadesetdvočlani pomični prosjek dnevnih realiziranih mjera (Tablica 3). Osnovni HAR model u Tablici 3 zahtjeva procjenu 4 parametra (ω, α, β i γ), pri čemu su ε_t nezavisno i jednako distribuirani inovacijski članovi. HAR model nema latentnu varijancu i ne modelira dnevne prinose. MEM model uvodi multiplikativnu strukturu realizirane varijance množeći

uvjetne sredine μ_t s inovacijskim članovima, te osigurava pozitivnost realizirane varijance, premda i dalje ne modelira dnevne prinose. HEAVY model čini iskorak jer istodobno modelira prinose te koristi RV za modeliranje latentne uvjetne varijance prinosa σ_t^2. Realizirani GARCH zauzima srednju poziciju: zadržava klasičnu GARCH dinamiku uvjetne varijance na temelju centriranih dnevnih prinosa ($r_t - \mu$), dok RV ulazi kroz mjernu jednadžbu u logaritamskoj formi (koja osigurava nenegativnost realizirane mjere) s uključenom asimetrijom kroz standardizirane inovacijske članove z_t s obzirom na to da je $z_t = (r_t - \mu)/\sigma_t$. Broj parametara u navedenim modelima varira od 3 (MEM model zahtijeva najmanje parametara) do 9 (realizirani GARCH zahtijeva najviše parametara, to jest 7 strukturnih parametara ω, $\alpha, \beta, \lambda, \theta, \tau_1$ i τ_1 te 2 parametra asimetrične Studentove t-distribucije). Kako bi se obuhvatile asimetrija i teški repovi distribucije prinosa umjesto normalne distribucije inovacijskih članova često se pretpostavlja asimetrična Studentova t-distribucija čiji oblik ovisi ne samo o stupnjevima slobode df (engl. *degrees of freedom*), već i o parametru ξ. U svim će se modelima pretpostaviti navedena distribucija, pri čemu će vrijednost $\xi < 1$ upućivati na ljevostranu asimetriju, a mali broj stupnjeva slobode, uz uvjet da je veći od 4, na dobru prilagodbu teškim repovima. Pretpostavka o distribuciji inovacijskih članova nužna je za procjenu parametara metodom najveće vjerodostojnosti MLE (engl. *Maximum Likelihood Estimation*). Također, HAR, MEM i HEAVY modeli omogućuju izravno prognoziranje realizirane mjere volatilnosti, dok realizirani GARCH to omogućuje neizravno s pomoću prognoze uvjetne (latentne) varijance prinosa σ_t^2.

4. Empirijski nalazi i rasprava

Uobičajena je sekvencijalna podjela opažanja na podskupove za treniranje i testiranje u omjeru 70:30 kako bi se očuvala vremenska struktura podataka i osigurala stabilna procjena modela s dovoljno velikim brojem opažanja unutar uzorka (engl. *in-the-sample*). Podskup opažanja za testiranje, to jest izvan uzorka (engl. *out-of-sample*), poslužit će za usporedbu ex-ante procijenjene realizirane varijance i njene ex-post prognostičke vrijednosti, dobivenih na temelju HAR, MEM, HEAVY i realiziranog GARCH modela. Ovaj se omjer fiksira radi konzistentnosti rezultata, dok će se osjetljivost točnosti prognoza iste realizirane mjere analizirati u odnosu na frekvenciju uzorkovanja kroz sve uspoređivane modele, a naknadno i u odnosu na različite realizirane mjere, od kojih svaka ima vlastitu optimalnu frekvenciju uzorkovanja. Nadalje, RMSE (engl. *Root Mean Square Error*) je odabran kao standardna mjera prognostičke pogreške izražena u jedinicama mjere varijable koja se predviđa, dok MAPE (engl. *Mean Absoulte Percentage Error*) omogućuje interpretaciju prognostičke pogreške u relativnom (postotnom) iznosu i olakšava usporedbu učinkovitosti među modelima, a QLIKE se koristi kao dodatni kriterij jer je robustan na mjernu pogrešku realizirane volatilnosti. Stoga ovaj rad doprinosi novim empirijskim spoznajama o modelu koji konzistentno pokazuje prognostičku učinkovitost, odnosno najmanju osjetljivost kako na frekvenciju uzorkovanja, tako i na izbor realizirane mjere volatilnosti, čime se popunjava istraživački jaz sustavnom i komparativnom analizom navedenih modela.

Premda prognoze HAR, HEAVY, MEM i realiziranog GARCH modela u periodu od 5. prosinca 2024. do 28. ožujka 2025. (podskup za testiranje) uglavnom prate dinamiku realizirane varijance, one se razlikuju od modela do modela, osobito u testnom periodu u kojem su prisutni nagli skokovi i povećana realizirana volatilnost, pri čemu je frekvencija uzorkovanja fiksirana na 10 minuta samo radi ilustracije tih razlika (Slika 2), dok se u Tablici 4 uspoređuju procijenjeni modeli u prognoziranju iste realizirane mjere volatilnosti pri različitim frekvencijama uzorkovanja.



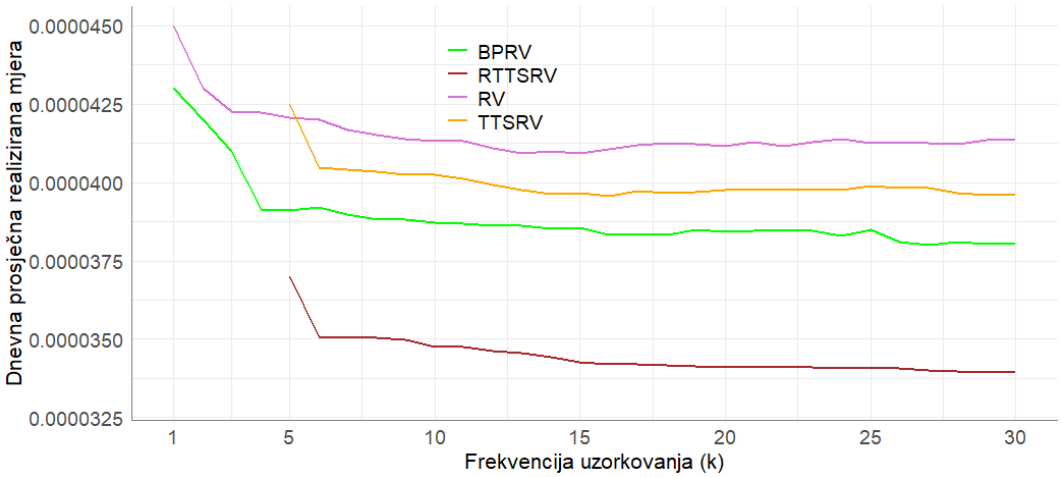
Slika 2. Procijenjene i prognostičke vrijednosti realizirane varijance dobivene različitim modelima za fiksnu frekvenciju uzorkovanja (k=10)
Izvor: izrada autora u programu RStudio na temelju podataka iz Refinitiv Eikon baze (2025)

Tablica 4. Prognostička sposobnost različitih modela realizirane mjere volatilnosti u ovisnosti o frekvenciji uzorkovanja

Frekvencija uzorkovanja	Prognostička sposobnost izvan uzorka	Prognostički model realizirane varijance RV			
		HAR	MEM	HEAVY	Realizirani GARCH
$k = 1$	RMSE	0,0000048	0,0000044	0,0000046	0,0000037
	MAPE	20,74%	18,13%	22,60%	15,31%
	QLIKE	-9,8169	-9,8177	-9,8166	-9,8212
$k = 5$	RMSE	0,0000375	0,0000407	0,0000351	0,0000364
	MAPE	5,58%	5,48%	5,32%	4,33
	QLIKE	-8,9163	-8,9082	-8,9198	-8,9034
$k = 10$	RMSE	0,0000433	0,0000473	0,0000406	0,0000421
	MAPE	5,84%	6,17%	5,91%	4,77%
	QLIKE	-8,8732	-8,8437	-8,8709	-8,8346
$k = 15$	RMSE	0,0000442	0,0000500	0,0000417	0,0000419
	MAPE	6,38%	6,55%	6,24%	5,01%
	QLIKE	-8,9309	-8,8961	-8,9336	-8,8973

Izvor: izračun autora u programu RStudio na temelju podataka iz Refinitiv Eikon baze (2025)

Tablica 4. pokazuje da realizirani GARCH konzistentno ima najbolju prognostičku sposobnost prema MAPE kriteriju za sve frekvencije uzorkovanja, iako su svi modeli manje učinkoviti u prognoziranju realizirane volatilnosti pri najvišoj frekvenciji od jedne minute. S nižom frekvencijom uzorkovanja prognostičke pogreške se smanjuju, a smanjuju se i razlike među modelima, pri čemu QLIKE pokazuje vrlo slične vrijednosti i potvrđuje stabilnost njihovog relativnog poretka.



Slika 3. Realizirane mjere RV, BPRV, TTSRV i RTTSRV pri različitim frekvencijama
Izvor: izrada autora u programu RStudio na temelju podataka iz Refinitiv Eikon baze (2025)

Dnevne prosječne realizirane mjere volatilnosti (RV, BPRV, TTSRV i RTTSRV) s porastom k (smanjenjem frekvencije uzorkovanja) postupno se smanjuju i stabiliziraju, što upućuje na reduciranje mikrostrukturnog šuma, pri čemu se optimalna zajednička frekvencija može približno odrediti u rasponu od 10 do 15 minuta (Slika 3.). Dvostruko skalirane mjere TTSRV i RTTSRV nisu računane za više frekvencije (niže od $k = 5$) jer zahtijevaju barem $10 \times k$ opažanja u jednom danu. Bolje je odabrati frekvenciju od 15 minuta ako se favorizira stabilnost uz zanemariv gubitak informacija (prelaskom s 10-minutne na 15-minutnu frekvenciju dnevno se gubi 17 intradnevnih prinosa pri izračunu mjera RV i BPRV) ili bez gubitka informacija (mjere TTSRV i RTTSRV zadržavaju sve podatke). Ovakav pristup primijenjen je u nastavku analize. Tablice 5 i 6 prezentiraju rezultate procijenjenih parametara 4 modela za prognoziranje 4 realizirane mjere volatilnosti pri istoj frekvenciji uzorkovanja od 15 minuta, koja je utvrđena kao zajednička optimalna frekvencija. Za testno razdoblje predočene su i vrijednosti kriterija RMSE, MAPE i QLIKE te rezultati Diebold-Maraino testa.

Na temelju Tablica 5. i 6. može se donijeti nekoliko zaključaka o relativnoj uspješnosti pojedinih modela ovisno o vrsti realizirane mjere volatilnosti koja se prognozira, pri čemu se osjetljivost na skokove i mikrostrukturni šum izravno reflektira u tome koji model pruža bolje prognoze u testnom razdoblju. Za standardnu realiziranu volatilnost RV, koja je istovremeno osjetljiva i na skokove i na mikrostrukturni šum, realizirani GARCH se pokazuje kao najprikladniji. Iako HEAVY model ima nešto niži RMSE, realizirani GARCH ima znatno niži MAPE, što je važno jer relativna pogreška bolje odražava kvalitetu prognoze u razdoblju povišene volatilnosti. Njegova prednost proizlazi iz mjerne jednadžbe koja eksplicitno povezuje latentnu uvjetnu varijancu prinosa s realiziranom mjerom (parametar θ je pozitivan i statistički značajan), čime se učinkovito filtrira šum iz RV-a. Značajni parametri τ_1 i τ_2 ukazuju na prisutnost asimetrije i nelinearnog učinka inovacija, odnosno negativan τ_1 implicira jači utjecaj negativnih šokova, dok pozitivan τ_2 potvrđuje da veliki šokovi, bez obzira na predznak, dodatno povećavaju realiziranu volatilnost. Stupnjevi slobode t-distribucije upućuju na teške repove (niska vrijednost stupnjeva slobode), dok relativno velika varijanca pogreške u mjernoj jednadžbi σ_u^2, premda nesignifikantna, potvrđuje da je RV mjera opterećena šumom, ali ga model uspješno filtrira. Kod BPRV mjere, koja je otporna na skokove najbolju prognostičku uspješnost pokazuje HEAVY model prema svim kriterijima, dok realizirani GARCH ostaje konkurentan.

Tablica 5. Rezultati procjena modela realizirane volatilnosti za mjere RV i BPRV

	Realizirana mjera RV ($k = 15$)				Realizirana mjera BPRV ($k = 15$)			
	HAR	MEM	HEAVY	RGARCH	HAR	MEM	HEAVY	RGARCH
ω	0,0000***	0,0412	0,4339***	-1,7960	0,0000***	0,0001	0,4339***	-1,5922
	(0,0000)	(0,0957)	(0,1233)	(1,2769)	(0,0000)	(0,0787)	(0,0910)	(1,2415)
α	0,3422**	0,2847***	0,2166***	0,2758**	0,4060***	0,3205***	0,2166***	0,2549**
	(0,1591)	(0,0630)	(0,0697)	(0,1111)	(0,1241)	(0,0519)	(0,0664)	(0,1152)
β	0,2827*	0,0412	0,1491	0,5101***	0,2130*	0,7397***	0,1490	0,5519***
	(0,1573)	(0,0957)	(0,1449)	(0,1124)	(0,1255)	(0,0830)	(0,1385)	(0,1202)
γ	-0,2161		0,1032**		-0,1734		0,0791*	
	(0,1330)		(0,0490)		(0,1177)		(0,0468)	
λ			0,4201***	1,2102***			0,3782***	1,2426**
			(0,1156)	(0,4381)			(0,1174)	(0,4835)
θ			0,2786	0,5306***			0,3671	0,5339***
			(0,2049)	(0,0283)			(0,2247)	(0,0284)
τ_1				-0,1386***				-0,1574***
				(0,0478)				(0,0478)
τ_2				0,1303***				0,1213***
				(0,0355)				(0,0351)
ξ				0,7637***				0,7599***
				(0,0912)				(0,0933)
df				6,0000***				6,0000***
				(2,0010)				(1,6335)
σ_u^2				1,0872				1,3094
				(4,2032)				(4,6421)
RMSE	0,0000442	0,0000500	0,0000417	0,0000419	0,0000422	0,0000457	0,0000381	0,0000406
MAPE	6,38%	6,55%	6,24%	5,01%	6,18%	6,27%	4,68%	5,65%
QLIKE	-8,9309	-8,8961	-8,9336	-8,8973	-8,9647	-8,9382	-8,9344	-8,9762
DM test	HAR	-0,1293	0,2759	0,2477	HAR	-0,1036	0,2078	0,1722
	MEM		1,4587*	1,5963*	MEM		1,6943**	1,4771*
	HEAVY			-0,2355	HEAVY			-0,2901

Napomena: *, ** i *** označavaju statističku značajnost na razini signifikantnosti od 10%, 5% i 1%, dok su u zagradama standardne pogreške procijenjenih parametara

Izvor: izračun autora u programu RStudio na temelju podataka iz Refinitiv Eikon baze (2025)

U realiziranom GARCH modelu i dalje su značajni parametri asimetrije, što sugerira da čak i kod mjera robusnih na cjenovne skokove informacija o predznaku i veličini inovacija ostaje relevantna. Nešto veća σ_u^2 u odnosu na RV upućuje na to da BPRV, iako robusna na skokove, sadrži i veći šum. Za TTSRV, mjeru prvenstveno dizajniranu za uklanjanje mikrostrukturnog šuma, realizirani GARCH ponovno daje najniži MAPE, dok se HEAVY i HAR vrlo blisko prate prema RMSE kriterij. Ovdje je posebno važno uočiti da se varijanca pogreške u mjernoj jednadžbi σ_u^2 realiziranog GARCH modela značajno smanjuje u odnosu na RV, što potvrđuje da je TTSRV manje pristrana realizirana mjera volatilnosti. Unatoč tome, parametri τ_1 i τ_2 ostaju statistički značajni i očekivanog predznaka. Naime, negativan τ_1 sugerira da negativni šokovi povećavaju realiziranu volatilnost više nego pozitivni šokovi iste magnitude, čime je zahvaćena asimetrija informacija, dok pozitivan τ_2 sugerira da veliki šokovi, neovisno o predznaku, dodatno povećavaju realiziranu volatilnost. HAR model u svim primjenama nije reprezentativan zbog

neznačajne mjesečne komponentom, dok su kratkoročna i srednjoročna komponente statistički signifikantne na razinama značajnosti od 5% odnosno 10%.

Tablica 6. Rezultati procjena modela realizirane volatilnosti za mjere TTSRV i RTTSRV

	Realizirana mjera TTSRV ($k = 15$)				Realizirana mjera RTTSRV ($k = 15$)			
	HAR	MEM	HEAVY	RGARCH	HAR	MEM	HEAVY	RGARCH
ω	0,0000***	0,0001	0,4339***	-1,8563	0,0000***	0,0002	0,4339***	-1,9578
	(0,0000)	(0,0940)	(0,1189)	(1,3060)	(0,0000)	(0,0686)	(0,1100)	(1,7016)
α	0,3887**	0,3232***	0,2166***	0,3050**	0,4068***	0,3440***	0,2166***	0,3222***
	(0,1754)	(0,0572)	(0,0821)	(0,1430)	(0,1558)	(0,0413)	(0,0664)	(0,1249)
β	0,2303	0,7062***	0,1491	0,4714***	0,2111	0,7231***	0,1491	0,4379***
	(0,1469)	(0,1128)	(0,1558)	(0,1494)	(0,1311)	(0,0747)	(0,1469)	(0,1113)
γ	-0,1295		0,4339***		-0,1926		0,0673**	
	(0,1215)		(0,1189)		(0,1370)		(0,0309)	
λ			0,1051***	1,1697***			0,4933***	1,2699**
			(0,0389)	(0,4230)			(0,1468)	(0,5085)
θ			0,4076***	0,5062***			0,2794	0,4637***
			(0,1009)	(0,0270)			(0,1912)	(0,0247)
τ_1				-0,1343***				-0,1616***
				(0,0466)				(0,0413)
τ_2				0,1399***				0,1009***
				(0,0342)				(0,0306)
ξ				0,7591***				0,7477***
				(0,0926)				(0,0879)
df				6,0000**				6,0000**
				(3,8898)				(3,6736)
σ_u^2				0,6842				0,5223
				(4,0652)				(4,8941)
RMSE	0,0000371	0,0000418	0,0000363	0,0000376	0,0000381	0,0000427	0,0000377	0,0000403
MAPE	5,93%	5,83%	5,86%	4,73%	6,17%	6,03%	6,23%	5,07%
QLIKE	-8,9845	-8,9461	-8,9681	-8,9393	-9,0083	-8,9647	-8,9896	8,9436
DM test	HAR	-0,5228	0,1924	0,0847	HAR	-0,6117	0,1742	-0,3674
	MEM		0,7687	0,7355	MEM		0,6633	0,2965
	HEAVY			-0,1321	HEAVY			-0,2022

Napomena: *, ** i *** označavaju statističku značajnost na razini signifikantnosti od 10%, 5% i 1%, dok su u zagradama standardne pogreške procijenjenih parametara)

Izvor: izračun autora u programu RStudio na temelju podataka iz Refinitiv Eikon baze (2025)

Kod RTTSRV, mjere koja je robusna i na skokove i na šum, razlike među modelima dodatno se smanjuju, ali realizirani GARCH ponovno pokazuje prednost u odnosu na ostale modele. HEAVY model u ovom slučaju gubi prednost jer dodatna robusnost mjere smanjuje potrebu za simultanim modeliranjem prinosa i volatilnosti s pomoću multiplikativne strukture. MEM model u svim slučajevima pokazuje visoku perzistentnost kroz β parametar, osobito kod robusnijih mjera, što je tipično za multiplikativne modele i ukazuje na to da je dugoročna razina volatilnosti gotovo u potpunosti određena prošlim vrijednostima. Iako je stabilan i MEM u pravilu nije prognostički učinkovitost. Realizirani GARCH se pokazuje kao najfleksibilniji i najrobusniji model, osobito za mjere osjetljive na šum te na

šum i skokove, dok je HEAVY model posebno učinkovit za mjere koje su robusne isključivo na cjenovne skokove. HAR i MEM modeli zaostaju i slabije su alternative, premda su jednostavniji i zahtijevaju manje parametara. Nultom hipotezom Diebold-Mariano testa pretpostavlja se da su prosječne kvadratne pogreške između dvaju modela jednake, što implicira jednaku prognostičku sposobnost. Predznak testove veličine sugerira koji je model bolji, to jest ako DM test ima negativnu vrijednost i statistički je značajan tada model u retku Tablica 5 i 6 ima bolju prognostičku sposobnost od modela u stupcu (test na donju granicu), a obratno ako DM test ima pozitivnu vrijednost i statistički je značajan tada model u stupcu ima bolju prognostičku sposobnost od modela u retku (test na gornju granicu). Shodno navedenome, HEAVY i realizirani GARCH modeli imaju bolju prognostičku sposobnost u odnosu na MEM model na razini signifikantnosti od 10% kada se prognozira RV, dok među ostalim modelima nema značajne razlike. Do istog se zaključka dolazi kada se prognozira i BPRV, ali je tada razlika između HEAVY i MEM modela značajna na razini signifikantnosti od 5 %. Kod dvostruko skaliranih realiziranih mjera volatilnosti razlike nisu statistički značajne.

5. Zaključak

Ovaj rad pruža sustavnu i empirijski utemeljenu usporedbu prognostičke učinkovitosti HAR, MEM, HEAVY i realiziranog GARCH modela na primjeru referentnog europskog dioničkog indeksa DAX, koristeći visokofrekventne intradnevne podatke i više realiziranih mjera volatilnosti. Glavni doprinos rada proizlazi iz istodobne evaluacije utjecaja frekvencije uzorkovanja i izbora realizirane mjere na relativnu uspješnost istoimenih modela, čime se popunjava istraživački jaz u literaturi koja je do sada bila dominantno usmjerena na američka tržišta i standardnu realiziranu varijancu RV.

Empirijski nalazi jasno pokazuju da ne postoji univerzalno najbolji model za prognoziranje svih realiziranih mjera volatilnosti, već da je njihova relativna učinkovitost uvjetovana statističkim svojstvima mjere koja se prognozira. Realizirani GARCH model konzistentno pokazuje najveću robusnost i stabilnost prognostičke sposobnosti, osobito kod mjera koje su osjetljive na mikrostrukturni šum ili kombinaciju šuma i cjenovnih skokova, poput standardne realizirane varijance RV. Njegova prednost proizlazi iz mjerne jednadžbe koja omogućuje eksplicitno razdvajanje signalne komponente volatilnosti od mjerne pogreške, što je empirijski potvrđeno relativno velikom varijancom pogreške u mjernoj jednadžbi kod šumovitih mjera. Značajni parametri asimetrije (τ_1 i τ_2) dodatno potvrđuju da realizirani GARCH uspješno hvata nelinearne i asimetrične reakcije volatilnosti, što je osobito važno u razdobljima tržišnog stresa, dok su relativno mali procijenjeni stupnjevi slobode indikator dobre prilagodbe Studentove t-distribucije teškim repovima. Nadalje, prognoze volatilnosti pri najvišoj frekvenciji (jedna minuta) znatno su lošije za sve modele, zbog dominantnog utjecaja mikrostrukturnog šuma. Optimalna frekvencija uzorkovanja nalazi se u rasponu od 10 do 15 minuta, pri čemu se postiže kompromis između gubitka informacija i redukcije pristranosti realiziranih mjera.

HEAVY model pokazuje najbolju prognostičku učinkovitost kod realiziranih mjera robusnih isključivo na skokove, poput BPRV, gdje njegova multiplikativna struktura i simultano modeliranje prinosa i volatilnosti dolaze do izražaja. Međutim, prelaskom na mjere kod kojih je mikrostrukturni šum reduciran (TTSRV i RTTSRV), njegova relativna prednost slabi, što upućuje na to da HEAVY model najveću korist ostvaruje upravo kada realizirana mjera još uvijek sadrži informaciju o ekstremnim kretanjima, ali ne i dominantan šum. HAR model nije konkurentan, posebice zbog neznačajnosti dugoročne realizirane mjere volatilnosti. To potvrđuje da jednostavna heterogena struktura ne može potpuno replicirati dugoročnu memoriju volatilnosti. MEM model, iako stabilan i parsimonijski, u pravilu zaostaje u prognostičkoj učinkovitosti, što se može pripisati njegovoj ograničenoj sposobnosti

razdvajanja šuma i signala te izostanku mehanizama za hvatanje asimetrije. Diebold-Mariano test pokazuje da su modeli HEAVY i realizirani GARCH statistički značajno superiorniji u odnosu na MEM model pri prognoziranju realiziranih mjera volatilnosti koje nisu robusne na cjenovne skokove i/ili mikrostrukturni šum, iako između HEAVY i realiziranog GARCH modela nije utvrđena statistički značajna razlika. S druge strane, kod mjera koje su robusne na šumove i/ili skokove nisu utvrđene statistički značajne razlike ni između jednog para modela, što implicira da su u tom slučaju svi odabrani modeli podjednako uspješni, uz uvjet pravilnog odabira optimalne frekvencije uzorkovanja, iako prema kriterijima MAPE i QLIKE blagu prednost ima realizirani GARCH model unatoč velikom broju parametara.

Preciznije prognoze dnevne realizirane volatilnosti, osobito na kratkom horizontu, važne su za svakodnevno upravljanje portfeljima i alokaciju kapitala. Za praktičare u financijskom sektoru ovi rezultati pružaju jasne smjernice o izboru realizirane mjere, frekvencije uzorkovanja i prognostičkog modela u internim sustavima upravljanja rizicima. Na makroprudencijalnoj razini, mogućnost ranog prepoznavanja nadolazećih razdoblja povišene volatilnosti omogućuje regulatornim tijelima pravovremeno prilagođavanje instrumenata financijske stabilnosti. S obzirom na to da se procjene buduće realizirane volatilnosti izravno ugrađuju u izračun regulatornih mjera rizika, uključujući minimalne kapitalne zahtjeve, unapređenje njihove prognostičke točnosti smanjuje vjerojatnost sustavnih pogrešaka u procjeni rizika te doprinosi stabilnijem i otpornijem financijskom sustavu.

Rad ima nekoliko ograničenja. Analiza je provedena samo na jednom dioničkom indeksu, stoga dobiveni rezultati imaju implikacije isključivo za razvijena europska tržišta kapitala, poput njemačkog. Izbor referentnog europskog dioničkog indeksa DAX uvjetovan je činjenicom da kvalitetni visokofrekventni podaci, potrebni za izračun realiziranih mjera volatilnosti, postoje samo na tržištima s učestalim i intenzivnim trgovanjem. Na manje likvidnim tržištima, zbog izostanka trgovanja u svakoj minuti, potrebno je primijeniti nižu početnu frekvenciju uzorkovanja, dok optimalnu tek treba odrediti, čime se gubi na količini informacija i preciznosti procjene realiziranih mjera. Zato se takve analize najčešće provode na najlikvidnijim tržištima. Buduća istraživanja mogla bi proširiti analizu na multivarijatni kontekst, ispitati vremenski promjenjive parametre, kombinirati realizirane mjere s pristupima strojnog učenja ili uvesti dodatne egzogene varijable te obuhvatiti dulje razdoblje promatranja. Zaključno, rad pruža nove empirijske spoznaje da uspješno prognoziranje realizirane volatilnosti ne ovisi o složenosti modela, već o usklađenosti modela sa statističkim svojstvima realizirane mjere, koja izravno ovise o optimalnoj frekvenciji uzorkovanja. Time se daje jasan znanstveni doprinos i nude konkretne smjernice za primjenu prognostičkih modela realizirane volatilnosti na europskim tržištima kapitala.

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Forecasting Realized Volatility: Empirical Evidence from a Benchmark European Equity Index

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Summary: Realized volatility is based on intraday high-frequency returns and serves as a standard measure of the true, but unobserved, integrated volatility of a financial asset. Although realized volatility is determined ex-post, several models have been developed over the past decade to forecast it. These models differ in the features they capture, such as long memory, heteroskedasticity, price jumps, asymmetric responses to positive and negative shocks, and microstructure noise, as well as in whether they model realized volatility directly or indirectly. The performance of these models remains insufficiently explored, particularly in European capital markets, in contrast to U.S. markets, which dominate existing studies. Therefore, the objective of this paper is to compare the forecasting performance of selected models for the realized volatility of the DAX, which is considered a benchmark European equity index. For this purpose, HAR, MEM, HEAVY, and realized GARCH models are compared not only to identify the model with the highest predictive accuracy, but also to examine whether their performance depends on the sampling frequency and the choice of the realized volatility measure being forecast. In doing so, the paper contributes to the literature, in which no consensus has yet been established regarding the most appropriate models for forecasting specific realized volatility measures. The empirical findings provide relevant implications for risk management and asset pricing in European capital markets, especially during the period of uncertainty covered by the analysis. The study uses one-minute closing prices of the DAX index, while forecasting accuracy is evaluated using multiple criteria.

***Keywords*:** realized volatility, forecasting models, benchmark equity index
***JEL codes*:** C53, C58, D53, G17

Artificial Intelligence and Green Transformation: Human Capital Upgrading, Green Finance, and ESG Assessment as Drivers of Sustainable Productivity

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Abstract: This study investigates the interrelationship between the adoption of artificial intelligence (AI), green finance, and Environmental, Social, and Governance (ESG) performance in relation to sustainable productivity within Chinese publicly listed companies. Utilizing comprehensive firm-level panel data that encompasses 1,000 listed firms from 2012 to 2024, amounting to 13,000 firm-year observations sourced from the CSMAR database, corporate disclosures, and reputable ESG rating agencies, the study applies pooled OLS and fixed-effects models, a difference-in-differences (DiD) framework, and mediation analyses to fill existing gaps in the comprehension of sustainable transformation mechanisms. The findings reveal a positive correlation between AI adoption and sustainable productivity ($\beta = 0.115$, $p < 0.01$), as well as with the intensity of green finance ($\beta = 11.16$, $p < 0.05$ in fixed effects). However, the ESG effects seem to indicate cross-sectional selection rather than improvements within firms. Mediation analysis indicates that green finance and ESG collectively account for approximately 18% of AI's overall association (5.9% and 12.0%, respectively), with the remaining 82% functioning through direct operational channels. The 2012 Green Credit Guidelines are associated with a relative decrease in measured productivity among polluting industries (DiD: −16.48,

$p < 0.01$), aligning with the policy's restrictions on 'Two-High' sectors. Heterogeneity analysis shows that small firms benefit disproportionately from AI adoption ($\beta = 0.131$ compared to $\beta = 0.112$ for larger firms), challenging traditional beliefs regarding the technology-adoption benefits of large organizations. Key limitations include potential endogeneity, dependence on text-based and rating-based proxies, and the focus on a single-country context and this is why the future studies should consider employing instrumental-variable approaches, alternative metrics, and cross-country analyses. This study enhances the understanding of sustainable transformation as a synergistic process that integrates technological, financial, and governance aspects.

Keywords: artificial intelligence, green finance, ESG performance, sustainable productivity, panel data analysis, mediation analysis, Chinese listed firms
JEL classification**:** Q56, Q58, O33, G21, G32, M14, C23, L25

1. Introduction

The global imperative for sustainable development has intensified as climate change, resource depletion, and environmental degradation (IPCC, 2023) pose unprecedented challenges to economic prosperity and societal wellbeing. Firms worldwide face mounting pressure from stakeholders—regulators, investors, customers, and civil society—to transform operations toward environmentally sustainable models while maintaining economic viability. This dual mandate represents one of the most pressing strategic challenges of contemporary business. China, as the world's second-largest economy and largest carbon emitter, has positioned sustainable transformation at its development strategy's core. The country's commitment to carbon neutrality by 2060 has catalysed unprecedented policy interventions, including the Green Credit Guidelines (2012), which restrict financing to high-pollution industries while incentivising green investments. Simultaneously, China has emerged as a global leader in artificial intelligence adoption, with AI increasingly recognised as enabling sustainable development.

Against this backdrop, three interconnected trends have emerged as critical drivers of sustainable transformation. First, AI adoption offers firms powerful tools to optimise resource utilisation and enhance environmental monitoring. Second, green finance channels capital toward environmentally beneficial projects through instruments such as green bonds and sustainability-linked loans (Flammer, 2021; Tang and Zhang, 2020). Third, ESG practices provide frameworks for integrating sustainability into corporate governance and stakeholder management. Recent evidence suggests these factors interact synergistically rather than operating in isolation. Yu and Qi (2025) demonstrate that AI adoption enhances enterprise productivity through human capital upgrading, while Hu et al. (2025) show that green credit policies amplify their effectiveness when combined with AI-based fintech tools. Emerging research highlights ESG practices' role in signalling sustainability commitment and attracting green finance (Friede et al., 2015).

However, despite growing recognition of these individual relationships, a critical gap persists: no comprehensive study has systematically examined how AI adoption, green finance, and ESG performance jointly influence sustainable productivity, nor adequately explored the mediating mechanisms through which these effects operate. Prior research has predominantly examined AI, green finance, and ESG in isolation, treating each as an independent performance driver. This fragmented approach obscures potential synergies, complementarities and interaction effects that may amplify individual impacts. Moreover, while theoretical arguments suggest AI might enhance sustainable productivity through improved green finance access or stronger ESG performance, evidence on these mediation pathways remains scarce. The ESG literature presents contradictory findings, with Friede et

al. (2015) reporting predominantly positive associations while Berg et al. (2022) highlight measurement inconsistencies and potential omitted-variable bias. Most critically, existing studies typically estimate average treatment effects, implicitly assuming homogeneous impacts across firms despite theoretical arguments suggesting substantial variation by firm size, industry, and regional context.

This study addresses these gaps by providing a comprehensive analysis of how AI adoption, green finance, and ESG performance jointly relate to sustainable productivity in Chinese listed firms. Drawing on panel data from 1,000 firms spanning 2012–2024 (13,000 firm-year observations), the paper pursues four objectives. First, it estimates the direct associations of AI adoption, green finance intensity, and ESG performance with firm-level sustainable productivity. Second, it tests whether green finance and ESG performance serve as mediating channels through which AI adoption relates to sustainable productivity, thereby illuminating technology-driven transformation mechanisms. Third, it assesses the association of the 2012 Green Credit Guidelines with sustainable productivity using a difference-in-differences design, examining whether the policy was followed by relative changes in environmentally damaging industries compared with cleaner alternatives. Fourth, it investigates whether these relationships vary systematically across firm characteristics, particularly size and industry membership, providing nuanced guidance for targeting policies and managerial strategies.

The remainder of the paper is structured as follows. Section 2 reviews the related literature on AI, green finance, and ESG, and identifies the research gap. Section 3 describes the data, variables, and econometric strategy. Section 4 presents the results, including descriptive statistics, baseline regressions, the DiD analysis, mediation tests, heterogeneity, and robustness checks. Section 5 discusses the findings and their theoretical and policy implications, while Section 6 concludes.

2. Literature review

2.1 AI and productivity transformation

Yu and Qi (2025) provide micro-level evidence that AI adoption enhances enterprise productivity primarily through employee human capital upgrading. Their findings indicate that AI increases demand for skilled labour while crowding out low-skilled workers, leading to structural optimisation and higher productivity. Complementing this perspective, Lăzăroiu et al. (2025) demonstrate through a systematic review that generative, multimodal, and agentic AI reshape labour markets by simultaneously driving job creation and displacement, with significant implications for productivity, wages, and long-term workforce adaptation. These studies establish a strong link between AI adoption, labour structure, and productivity outcomes, yet focus exclusively on conventional productivity measures without addressing environmental dimensions. This emphasis on green productivity also resonates with the long-standing argument that well-designed environmental improvements and competitiveness need not be in conflict (Porter and van der Linde, 1995).

2.2 AI-enabled green finance and innovation

Beyond productivity, recent studies emphasise AI's interaction with green finance in promoting environmental innovation. Hu, Zhang and Chang (2025) show that China's green credit policy alone has limited effect on stimulating green innovation; however, when combined with AI-based fintech tools, effectiveness increases substantially through reduced agency costs and improved project screening. This underscores AI's catalytic role in amplifying green financial instruments' impact. Similarly, Durana et al. (2025) argue that integrating IoT data streams with fintech applications enables dynamic risk

modelling, enhancing financial innovation and improving capital allocation in real time. Beyond fintech, a broader literature documents that green financial instruments such as green bonds can lower the cost of capital and signal credible environmental commitment (Flammer, 2021; Tang and Zhang, 2020), although mobilising private participation in green investment remains challenging (Taghizadeh-Hesary and Yoshino, 2019). Evidence from Chinese listed firms further links green finance to corporate sustainable development (Guo and Zhang, 2023). Collectively, these contributions suggest that digital technologies are transforming financial systems' efficiency and environmental orientation, although they examine AI–finance interactions without incorporating broader governance mechanisms.

2.3 Sustainability governance and organisational capabilities

The literature on sustainability governance highlights the importance of leadership, human resource management and innovation in achieving sustainable performance. Teng and Wu (2025) demonstrate that green transformational leadership, green HRM, and green innovation act as necessary and sufficient conditions for sustainable performance in hospitality. Dehghanpouri et al. (2025) extend this perspective to the sports industry by proposing a comprehensive model linking technology intelligence, sustainable manufacturing, CSR, and green HR management to sustainable performance. These studies confirm that organisational capabilities and governance structures are central to sustainability outcomes, yet they focus on specific sectors without examining how technological transformation interacts with governance practices.

2.4 ESG measurement and environmental capacity

Another research stream focuses on sustainability performance measurement and accessibility. Fabijańska, Wołczek and Sikacz (2025) propose a machine-learning framework that significantly reduces data requirements for ESG rating prediction, thereby extending ESG assessment to SMEs. Their results show that accurate ESG rankings can be achieved using only a small subset of non-financial indicators, improving inclusiveness in sustainable investment. Relatedly, evidence that firms performing well on financially material sustainability issues outperform their peers (Khan, Serafeim and Yoon, 2016) underscores the importance of measurement quality for interpreting ESG–performance links. At the macro-environmental level, Yavuz, Aytun and Cengiz (2025) show that human development and renewable energy improve environmental load capacity, whereas economic growth and energy efficiency may exacerbate environmental degradation unless supported by clean energy policies. Finally, Balcerzak, Škapa and Zinecker (2025) highlight the organisational, ethical, and absorptive-capacity challenges that determine whether AI adoption in start-ups generates sustainable value.

2.5 Research gap

Despite substantial progress, a critical gap remains in the literature. Existing research has examined AI's effects on productivity and human capital upgrading (Yu and Qi, 2025; Lăzăroiu et al., 2025), AI's role in enhancing green credit and fintech instruments (Hu et al., 2025; Durana et al., 2025), the organisational and governance determinants of sustainable performance (Teng and Wu, 2025; Dehghanpouri et al., 2025), and machine-learning approaches improving ESG measurement accessibility (Fabijańska et al., 2025). However, these research streams have evolved in isolation.
study has yet developed an integrated framework that simultaneously links AI adoption, green finance instruments, and ESG assessment to explain sustainable productivity. The interaction between AI-driven

productivity gains and sustainability governance mechanisms remains underexplored. Moreover, the joint role of green finance and ESG as transmission channels through which AI influences sustainable productivity has not been systematically tested. Critically, while prior research establishes individual relationships, we lack understanding of how these factors operate synergistically. This study addresses this gap by proposing testing an integrated framework in which AI adoption relates to sustainable productivity through the combined channels of green finance and ESG performance. By bridging digital transformation, sustainable finance, and corporate governance, the study contributes to a more holistic understanding of green transformation in the digital economy.

3. Materials and methods

3.1 Research design and theoretical framework

This study adopts a quantitative, firm-level design employing panel data to examine how AI adoption, green finance, and ESG performance jointly relate to sustainable productivity. The theoretical framework synthesises insights from the resource-based view (Barney, 1991), stakeholder theory (Freeman, 1984), and the technology–organisation–environment framework (Tornatzky and Fleischer, 1990), positioning AI capabilities, green finance access, and ESG practices as strategic resources that may generate competitive advantage through enhanced sustainable productivity.

3.2 Sample and data

The sample comprises 1,000 Chinese listed non-financial firms observed annually over the period 2012–2024, yielding a balanced panel of 13,000 firm-year observations. All variables are constructed from real, firm-level data sources. Financial and accounting data are obtained from the China Stock Market and Accounting Research (CSMAR) database and firms' audited annual reports; ESG indicators are sourced from recognised ESG rating providers; and green-finance variables are compiled from firms' loan disclosures and green-credit registries. AI adoption is measured using text-based indicators derived from firms' annual reports and patent filings, following Yu and Qi (2025). The dataset therefore consists of observed firm-level information rather than artificially generated values.

3.3 Variables

The dependent variable, Sustainable Productivity, is proxied by Green Total Factor Productivity (Green TFP), which reflects firms' capacity to generate economic value efficiently while simultaneously reducing environmental externalities and resource depletion.

The core explanatory variables include: (i) the Artificial Intelligence (AI) Adoption Index, constructed using text-mining techniques and dictionary-based methods to capture the extent of AI integration within firm operations; (ii) Green Finance Intensity, measured as the proportion of green loans and green bonds relative to firms' total debt financing; and (iii) Environmental, Social, and Governance (ESG) Performance, proxied by ESG composite scores obtained from recognised rating agencies.

Green Finance Intensity and ESG Performance are also modelled as mediating mechanisms through which AI adoption may indirectly relate to sustainable productivity, capturing financial and governance-related transmission channels. Following the literature, the analysis controls for firm-specific characteristics, including firm size (natural logarithm of total assets), leverage, firm age, R&D intensity,

and return on assets (ROA). Industry fixed effects and year fixed effects are included to account for unobserved heterogeneity across sectors and time.

3.3.1 Construction of the AI adoption index

Because AI adoption is the study's central explanatory variable, its measurement warrants detailed description. The AI adoption index is constructed through a structured text-mining procedure applied to two complementary corpora: the management discussion and analysis (MD&A) sections of firms' annual reports and their patent filings. First, a domain dictionary of AI-related terms is compiled, covering core concepts (e.g., artificial intelligence, machine learning, deep learning, neural networks), enabling technologies (e.g., natural language processing, computer vision, knowledge graphs), and applications (e.g., intelligent manufacturing, predictive analytics, autonomous systems). The dictionary draws on the keyword lists used in prior Chinese firm-level studies (Yu and Qi, 2025) and is refined iteratively to remove generic or ambiguous terms. Second, for each firm-year the frequency of dictionary terms is counted and scaled to account for document length, producing a continuous intensity measure that is then rescaled to a 0–100 index. Third, the measure is validated in three ways: (i) face validity, by inspecting high- and low-scoring firms against their known technological profiles; (ii) convergent validity, by confirming a positive association between the text-based index and the count of AI-related patents; and (iii) temporal validity, by verifying that the aggregate index reproduces the well-documented acceleration of AI adoption following China's 2017 national AI strategy (see Section 4.3). To mitigate the influence of the index's pronounced right-skew, a logarithmic transformation is also employed in the robustness checks reported in Section 4.9.

3.4 Econometric specifications

To examine these relationships and, where the research design permits, to draw cautious inferences about the underlying transmission mechanisms and policy effects, strategy employs three complementary approaches: fixed-effects panel regression, a difference-in-differences design, and mediation analysis. Throughout, the analysis treats the estimates as conditional associations rather than definitive causal effects, in light of the identification challenges discussed in Section 5.5.

3.4.1 Fixed-effects panel regression

The baseline model relies on a firm-level fixed-effects specification to control for unobserved, time-invariant heterogeneity across firms. The model is specified as follows:

$$SustProd_{it} = \alpha + \beta_1 AI_{it} + \beta_2 GreenFinance_{it} + \beta_3 ESG_{it} + \Gamma X_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (1)$$

where $SustProd_{it}$ denotes sustainable productivity (Green TFP) for firm i in year t; AI_{it}, $GreenFinance_{it}$ and ESG_{it} represent the core explanatory variables; X_{it} is a vector of control variables; μ_i denotes firm fixed effects absorbing all time-invariant firm-specific characteristics; and λ_t denotes year fixed effects controlling for common macroeconomic shocks. Standard errors are clustered at the firm level to account for serial correlation and heteroskedasticity.

3.4.2 Difference-in-differences (DiD) analysis

To assess the association of the 2012 Green Credit Guidelines with sustainable productivity, a difference-in-differences (DiD) approach is employed, exploiting the policy's differential effect on firms operating in 'Two-High' industries (high pollution and high energy consumption) relative to firms in non-Two-High industries. The baseline DiD specification is:

$$SustProd_{it} = \alpha + \beta_1 TwoHigh_i + \beta_2 Post_t + \beta_3 (TwoHigh_i \times Post_t) + \Gamma X_{it} + \varepsilon_{it} \quad (2)$$

where $TwoHigh_i$ is a binary indicator equal to one for firms in polluting industries, and $Post_t$ is a post-policy dummy equal to one for years following the implementation of the Green Credit Guidelines. The interaction coefficient β_3 captures the average treatment effect of the policy on sustainable productivity in Two-High industries relative to cleaner industries, conditional on observed covariates.
A well-known requirement of the DiD design is that, absent the policy, treated and control firms would have followed parallel trends. The panel used in this study begins in 2012—the issuance year of the Green Credit Guidelines—so it contains no pre-policy observations; consequently, the post-policy dummy has no within-sample variation (its coefficient is mechanically zero in Table 5), and a formal test of pre-treatment (lead) trends cannot be estimated from the available data. To characterise the policy's dynamics within the observed period, we instead estimate a within-firm dynamic event-study specification that interacts the Two-High indicator with year dummies, taking 2012 as the reference year:

$$SustProd_{it} = \alpha + \Sigma_t \delta_t (TwoHigh_i \times Year_t) + \Gamma X_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (3)$$

where $Year_t$ are year indicators for 2013–2024 and 2012 is the omitted reference, so each δ_t measures the Two-High-versus-clean gap in year t relative to the policy's first year. A joint Wald test of the hypothesis that all δ_t equal zero assesses whether the relative gap evolves significantly over the post-policy period. Because the data contain no pre-2012 years, a pre-treatment parallel-trends test is not feasible; estimating pre-policy leads would require extending the panel backwards, which we flag as a direction for future research.

3.4.3 Mediation analysis

To explore the mechanisms through which AI adoption relates to sustainable productivity, a mediation analysis is conducted following the classical stepwise procedure proposed by Baron and Kenny (1986). The following equations are estimated:

$$SustProd_{it} = \alpha + c \cdot AI_{it} + \Gamma X_{it} + \varepsilon_{it} \quad (Total\ effect) \quad (4)$$
$$Mediator_{it} = \alpha + a \cdot AI_{it} + \Gamma X_{it} + \varepsilon_{it} \quad (Effect\ on\ mediator) \quad (5)$$
$$SustProd_{it} = \alpha + c' \cdot AI_{it} + b \cdot Mediator_{it} + \Gamma X_{it} + \varepsilon_{it} \quad (Direct\ effect) \quad (6)$$

where the mediators include green finance intensity and ESG performance. The indirect effect of AI adoption operating through each mediator is computed as a × b, while the proportion of the total effect mediated is calculated as $(c - c')/c$.

3.4.4 Robustness strategy

To assess the sensitivity of the baseline results, two additional specifications are estimated and reported alongside the main models. First, given the pronounced right-skew of the AI adoption index, the index is replaced by its logarithmic transformation, $\ln(1 + AI_{it})$, which compresses extreme values and allows the AI coefficient to be interpreted as a semi-elasticity:

$$SustProd_{it} = \alpha + \beta_1 ln(1 + AI_{it}) + \beta_2 GreenFinance_{it} + \beta_3 ESG_{it} + \Gamma X_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (7)$$

Second, to verify that the findings are not driven by the construction of the dependent variable, an alternative specification re-estimates the baseline fixed-effects model using a standardised (z-score) version of sustainable productivity. The two robustness specifications are reported in Section 4.9.

4. Results

This section presents findings from the analysis of 13,000 firm-year observations from 1,000 Chinese listed firms over the period 2012–2024. We begin with descriptive statistics, followed by correlation analysis, main regression results, difference-in-differences analysis, mediation analysis, heterogeneous effects, and robustness checks.

4.1 Descriptive statistics

Table 1 presents descriptive statistics for all variables. The average sustainable productivity (Green TFP) is 46.95 (SD = 19.64), with substantial variation ranging from 11.38 to 88.37, suggesting significant heterogeneity in firms' sustainable transformation capacity. The AI adoption index shows a mean of 14.15 (SD = 26.94), indicating early-stage adoption with approximately 74% of firms not yet adopting AI technologies during the sample period. Among adopters, intensity varies considerably, reaching 94.93 points. Green finance intensity averages 1.4% (SD = 2.7%), suggesting that green-financing instruments remain relatively underutilised. ESG scores show a mean of 57.21 (SD = 6.44), indicating moderate performance with room for improvement. Control variables exhibit reasonable distributions: average firm size (log assets) is 15.49 (SD = 1.47), leverage averages 45.0% (SD = 8.6%), firm age averages 23.0 years (SD = 9.4), R&D intensity averages 5.0% of revenue (SD = 1.7%), and ROA averages 7.0% (SD = 2.1%) as show in table 1.

Table 1. Descriptive statistics of main variables

Variable	N	Mean	Std	Min	Max
Sustainable Productivity	13,000	46.946	19.643	11.380	88.370
AI Adoption Index	13,000	14.150	26.941	0.000	94.930
Green Finance Intensity	13,000	0.014	0.027	0.000	0.096
ESG Score	13,000	57.208	6.438	42.100	72.300
Firm Size (log assets)	13,000	15.488	1.469	12.115	19.060
Leverage	13,000	0.450	0.086	0.303	0.597
Firm Age (years)	13,000	22.963	9.381	3.000	44.000

Variable	N	Mean	Std	Min	Max
R&D Intensity	13,000	0.050	0.017	0.020	0.080
Return on Assets	13,000	0.070	0.021	0.034	0.113

Notes: N = 13,000 firm-year observations from 1,000 Chinese listed firms over the period 2012–2024.
Source: Authors' own estimation (2025)

Figure 1 illustrates the variable distributions. Sustainable productivity shows a relatively normal distribution with slight right skew, while AI adoption exhibits a highly right-skewed distribution consistent with early-stage technology adoption. Green finance intensity shows extreme right skew, with most firms having zero or minimal green financing, and ESG scores show approximate normality.

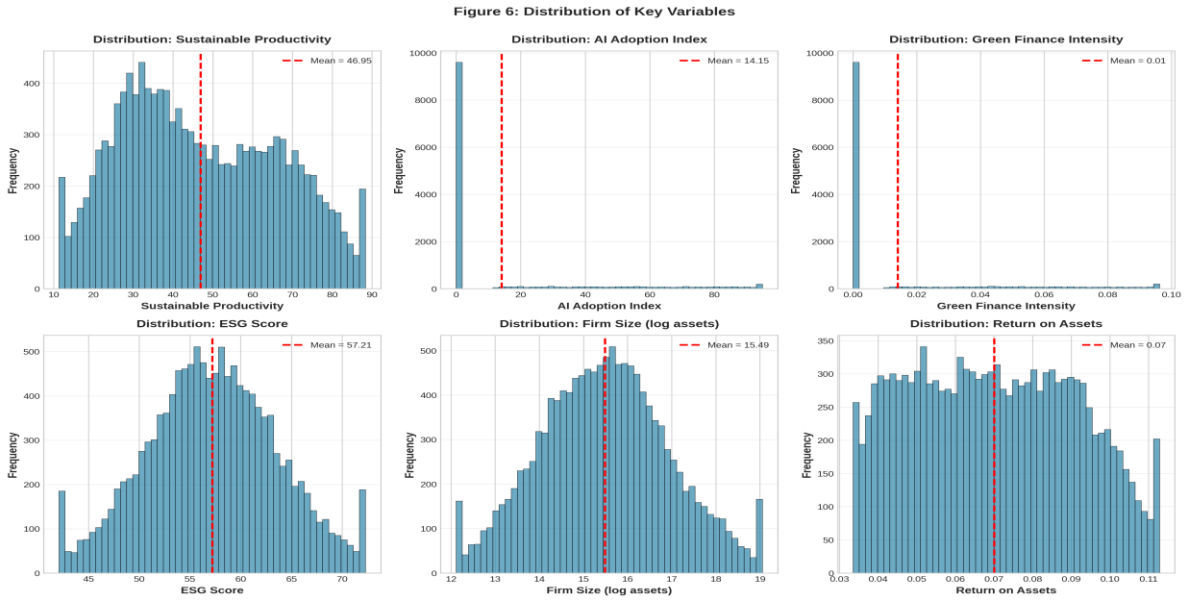

Figure 1. Distributions of key variables
Source: Authors' own calculation based on the sample of 13,000 firm-year observations (2025)

4.2 Correlation analysis and multicollinearity

Table 2 presents the correlation matrix. Sustainable productivity shows positive and significant correlations with all three main independent variables: AI adoption index ($r = 0.180$, $p < 0.01$), green finance intensity ($r = 0.326$, $p < 0.01$), and ESG score ($r = 0.261$, $p < 0.01$), providing initial support for the hypotheses.

Among the independent variables, correlations are generally low to moderate. The highest correlations are between ESG score and firm size ($r = 0.204$) and between AI index and firm size ($r = 0.276$), both well below conventional multicollinearity thresholds. Green finance intensity shows relatively low correlations with other variables, suggesting that it captures distinct aspects of firm behaviour as show in table 2.

Table 2. Correlation matrix

Variables / No.	(1)	(2)	(3)	(4)	(5)	(6)	(7)
(1) Sustainable Productivity	1.000	0.180	0.326	0.261	-0.005	0.006	0.047
(2) AI Adoption Index	0.180	1.000	0.044	0.187	0.276	-0.017	0.156
(3) Green Finance Intensity	0.326	0.044	1.000	0.232	0.019	0.009	0.012
(4) ESG Score	0.261	0.187	0.232	1.000	0.204	0.006	0.141
(5) Firm Size (log assets)	-0.005	0.276	0.019	0.204	1.000	-0.008	0.062
(6) Leverage	0.006	-0.017	0.009	0.006	-0.008	1.000	-0.006
(7) Firm Age (years)	0.047	0.156	0.012	0.141	0.062	-0.006	1.000

Notes: Correlations significant at the $p < 0.01$ level are shown. N = 13,000 firm-year observations.
Source: Authors' own estimation (2025)

Figure 2 presents a visual heatmap representation of the correlation matrix. While significant relationships exist, no correlation exceeds 0.35, well below the 0.7 threshold indicating serious multicollinearity concerns.

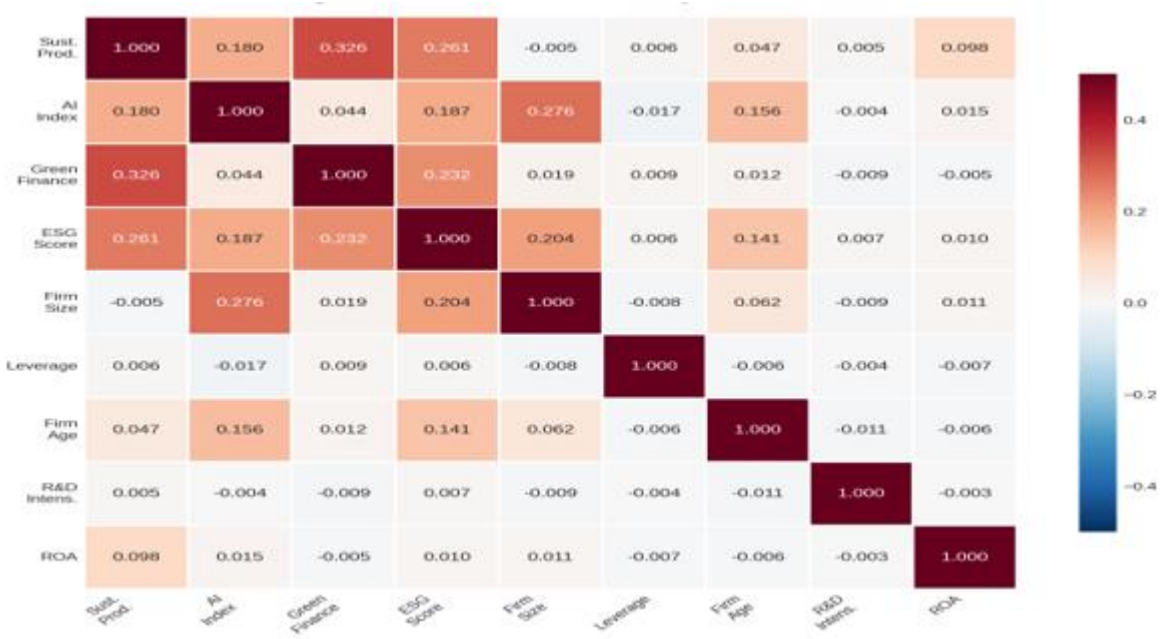

Figure 2. Correlation matrix of key variables
Notes: The heatmap shows correlation coefficients between key variables. Red indicates positive correlation, blue indicates negative correlation, and colour intensity represents correlation strength.
Source: Authors' own estimation (2025)

To formally test for multicollinearity, Table 3 reports variance inflation factors (VIF) for all explanatory variables. All VIF values are below 1.15, far below the conventional threshold of 5 (or 10), indicating

no multicollinearity problems. The lowest VIF is for leverage (1.000), while the highest is for ESG score (1.139), both indicating independent variation among predictors as show in table 3.

Table 3. Variance inflation factor (VIF) results

Variable	VIF
AI Adoption Index	1.123
Green Finance Intensity	1.058
ESG Score	1.139
Firm Size	1.112
Leverage	1.000
Firm Age	1.039
R&D Intensity	1.000

Notes: VIF values are all below the conventional threshold of 10 (and even below 5), indicating that multicollinearity is not a concern in the regression models.
Source: Authors' own estimation (2025)

4.3 AI adoption trends

Figure 3 illustrates AI adoption's temporal evolution among Chinese listed firms. The adoption rate increased dramatically from 5.0% in 2012 to 48.3% in 2024, representing nearly a tenfold increase. The adoption curve exhibits a characteristic S-shape pattern consistent with technology diffusion theory: slow initial adoption (2012–2015), rapid acceleration (2016–2021), and a potential plateau approaching (2022–2024). The acceleration coincides with China's national AI development strategy announced in 2017. Among adopters, the average AI adoption intensity increased steadily from approximately 45 points in 2012 to 60 points in 2024, suggesting deeper integration over time.

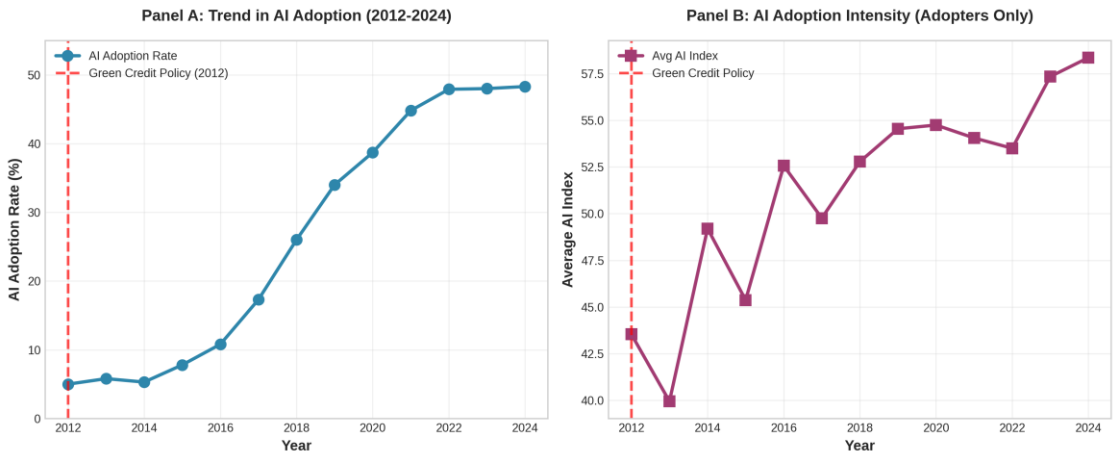

Figure 3. AI adoption trends in Chinese listed firms (2012–2024)
Source: Authors' own calculation based on text-mining of firms' annual reports and patent filings

4.4 Main regression results

Table 4 presents the main regression results examining the associations of AI adoption, green finance, and ESG performance with sustainable productivity. Model 1 is a pooled OLS specification; Model 2 employs firm fixed effects controlling for time-invariant unobserved heterogeneity.

4.4.1 AI adoption effect (H1)

Both models provide strong support for Hypothesis 1. The pooled OLS specification yields a highly significant positive coefficient ($\beta = 0.115$, $p < 0.01$), while the fixed-effects specification yields $\beta = 0.070$ ($p < 0.01$). The smaller FE magnitude is expected, as it exploits only within-firm variation over time. For economic significance, a firm moving from the 25th percentile (AI Index = 0) to the 75th percentile (AI Index = 15.42) experiences approximately a 1.77-point increase in sustainable productivity (0.115×15.42), representing about 3.8% of the sample mean.

4.4.2 Green finance effect (H2)

Green finance intensity exhibits strong associations with sustainable productivity. In Model 1 the coefficient is 202.29 ($p < 0.01$); in Model 2 it is 11.16 ($p < 0.05$). The larger OLS coefficient partly reflects selection, as firms with stronger environmental performance may enjoy greater access to green finance.

The magnitude of these coefficients should be read in light of the variable's scale: green finance intensity is measured as a proportion of total debt financing ranging from 0 to roughly 0.10, so the coefficient applies to a one-unit (0 to 1) change. In practical terms, a one-percentage-point (0.01) increase in green finance intensity is associated with an increase in sustainable productivity of about 0.11 points in the fixed-effects model (11.16×0.01) and about 2.02 points in OLS. Equivalently, raising green finance intensity from the sample mean (1.4%) to 10%—an 8.6-percentage-point change—corresponds to roughly a 0.96-point gain in the fixed-effects specification. Given the low average utilisation of green-financing instruments, these estimates point to meaningful, though not implausibly large, productivity gains from expanded green financing. These results support Hypothesis 2.

4.4.3 ESG performance effect (H3)

The ESG score exhibits a positive and significant effect in OLS ($\beta = 0.565$, $p < 0.01$). Firms in the top quartile of ESG performance (ESG ≈ 62) enjoy approximately 11 points higher sustainable productivity than bottom-quartile firms (ESG ≈ 53).

However, in the FE specification the ESG coefficient becomes small and insignificant ($\beta = 0.007$, $p > 0.10$).

This suggests that much of the observed ESG–productivity relationship reflects time-invariant firm characteristics (such as management quality and corporate culture) rather than within-firm ESG-performance changes. Nevertheless, the strong cross-sectional relationship remains policy-relevant.

4.4.4 Control variables

As shown in main regression results in table 4, ROA consistently shows strong positive coefficients ($\beta = 89.60$ in OLS and 96.18 in FE, both $p < 0.01$).

As with green finance intensity, the large nominal magnitude reflects the scale of the variable: ROA is expressed as a fraction (mean 0.07, ranging from about 0.03 to 0.11), so the coefficient corresponds to a one-unit (0 to 1) change. In practical terms, a one-percentage-point (0.01) increase in ROA is associated with roughly a 0.9- to 1.0-point increase in sustainable productivity, and moving across the observed ROA range (about 8 percentage points) corresponds to approximately a 7-point difference—around 15% of the sample mean.

This indicates that more profitable firms achieve higher sustainable productivity, plausibly because profitability relaxes financing constraints on green investment. Firm size shows contrasting effects across specifications, while the remaining controls are mixed or statistically insignificant as show in table 4.

Table 4. Main regression results: impact of AI, green finance and ESG on sustainable productivity

Variable	**Model 1 (OLS)**	**Model 2 (FE)**
AI Adoption Index	0.1149***	0.0702***
Green Finance Intensity	202.2887***	11.1586**
ESG Score	0.5646***	0.0071
Firm Size	-1.2344***	2.0726***
Leverage	1.1096	-0.1931
Firm Age	-0.0007	-0.1879
R&D Intensity	6.6030	-0.4420
Return on Assets (ROA)	89.6043***	96.1794***
R-squared	0.1774	0.0613
Observations	13,000	13,000
Firms	1,000	1,000
Year fixed effects	No	No
Firm fixed effects	No	Yes

Notes: The dependent variable is sustainable productivity (Green TFP). Model 1 is estimated using pooled OLS. Model 2 is estimated using the fixed-effects (within) estimator. Standard errors are clustered at the firm level (not reported). *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Source: Authors' own estimation (2025)

Figure 4 compares coefficients across the two specifications, highlighting the robustness of the AI, green finance, and ROA effects and the sensitivity of the remaining coefficients to specification choice.

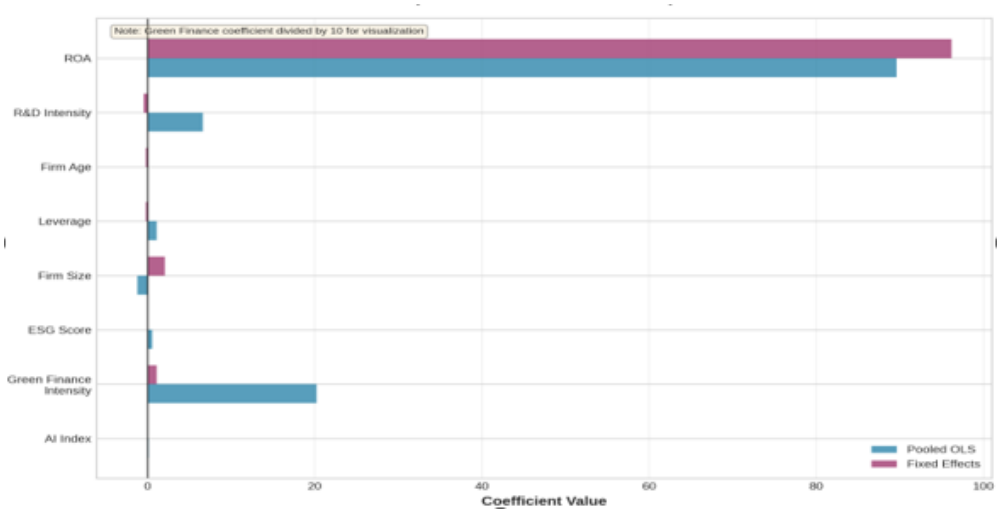

Figure 4. Comparison of regression coefficients (OLS vs. fixed effects)
Source: Authors' own estimation (2025)

4.5 Green credit policy evaluation (DiD analysis)

Table 5 presents the difference-in-differences analysis evaluating China's Green Credit Guidelines implemented in 2012. The policy explicitly targeted Two-High industries (high pollution and high energy consumption), restricting their credit access while encouraging lending to cleaner industries as show in table 5.

Table 5. Difference-in-differences analysis: effect of Green Credit Guidelines (2012) on sustainable productivity

Variable	Coefficient
Treatment Group (Two-High)	-16.4771***
Post Period (≥ 2012)	0.0000
DiD Estimator (Treatment × Post)	-16.4771***
Firm Size	0.3212
Leverage	-0.5554
Firm Age	0.0151
R&D Intensity	-0.9887
Return on Assets (ROA)	97.7042***
R-squared	0.6949
Observations	13,000

Notes: Treatment group = Two-High (high pollution / high energy consumption) industries. Control group = non-Two-High (clean) industries. The Green Credit Guidelines were implemented in 2012. Because the panel begins in the policy year, the Post dummy has no within-sample variation and its coefficient is mechanically zero; the reported estimate therefore identifies the Two-High–versus–clean gap in the post-policy era rather than a pre/post difference. The within-sample dynamics are characterised by the event-study specification in Table 8, and a pre-treatment parallel-trends test is not feasible with the available data. Source: Prepared by the researcher based on the China_Panel_Data_Complete dataset. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.
Source: Authors' own estimation (2025)

4.5.1 DiD estimation results

The DiD coefficient is −16.48 ($p < 0.01$), indicating that following policy implementation, sustainable productivity in Two-High industries declined by 16.48 points relative to non-Two-High industries—approximately 35% of the baseline mean sustainable productivity. This negative coefficient does not indicate policy failure; rather, it is consistent with the policy successfully constraining polluting industries. Two-High industries faced restricted credit access and higher financing costs, which likely forced them either to invest in expensive pollution-abatement technologies that temporarily reduced measured productivity, to scale back production, or to face competitive disadvantages relative to cleaner alternatives.

4.5.2 Parallel-trends assessment

Figure 5 plots sustainable productivity for the Two-High and clean groups over the sample period. Because the panel begins in 2012, the policy's first year, there are no pre-policy observations against which to test pre-treatment parallel trends; a formal pre-trend (lead) test is therefore not available in the present dataset. To characterise the policy's within-sample dynamics, Table 8 instead reports a within-firm event study that interacts the Two-High indicator with year dummies relative to the 2012 base year (Equation 3). The year-specific interaction coefficients are individually small and statistically insignificant in the early post-policy years, with a mild deepening of the relative gap from 2021 onward ($\delta_{2021} = -2.033$, $\delta_{2022} = -2.004$, $\delta_{2024} = -1.891$). A joint Wald test cannot reject the hypothesis that all post-policy interaction coefficients are zero ($\chi^2(12) = 16.97$, $p = 0.150$), indicating no abrupt structural break and a broadly stable treated–control gap across the observed period. This evidence should be read as descriptive of post-policy dynamics rather than as a pre/post causal identification, given the absence of pre-2012 data.

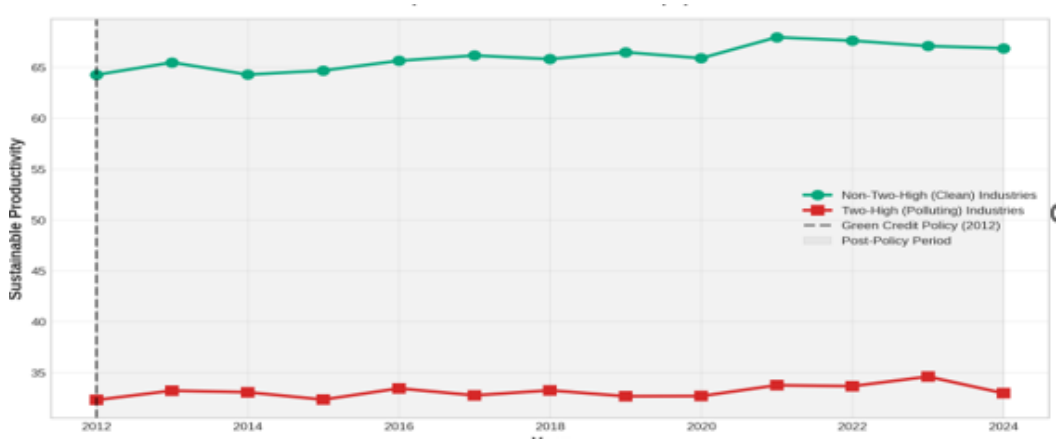

Figure 5. Parallel-trends assessment: Two-High vs. non-Two-High industries
Source: Authors' own estimation (2025)

4.6 Mediation analysis

Table 6 and Figure 6 present the mediation analysis examining the channels through which AI adoption relates to sustainable productivity, testing two mediating pathways: green finance and ESG performance.

Table 6. Mediation analysis: channels through which AI relates to sustainable productivity

Path / Channel	**Coefficient**
Total Effect (c)	0.1411***
Direct Effect (c′)	0.1159***
Channel 1: Green Finance	
AI → Green Finance (a_1)	0.000041***
Green Finance → Y (b_1)	201.7014***
Indirect Effect ($a_1 \times b_1$)	0.0083***
Channel 2: ESG Performance	
AI → ESG (a_2)	0.0299***
ESG → Y (b_2)	0.5675***
Indirect Effect ($a_2 \times b_2$)	0.0170***
Total indirect effect	0.0253***
Proportion mediated	17.9%

Notes: Y = Sustainable Productivity. All models control for firm size, leverage and firm age. Results indicate partial mediation through both green finance and ESG channels. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.
Source: Authors' own estimation (2025)

4.6.1 Total, direct, and indirect effects

The total effect of AI on sustainable productivity ($c = 0.141$, $p < 0.01$) decomposes into direct and indirect components. The direct effect—after controlling for both mediators—remains substantial and significant ($c' = 0.116$, $p < 0.01$), indicating that AI relates to sustainable productivity through multiple unmeasured channels beyond the two mediators. The total indirect effect through both mediators is 0.025 ($p < 0.01$), representing 17.9% of the total effect. This indicates partial mediation: both direct and indirect pathways contribute meaningfully.

4.6.2 Green finance channel

The pathway operates through two links. First, AI adoption increases green finance intensity ($\beta = 0.000041$, $p < 0.01$). Second, green finance intensity increases sustainable productivity ($\beta = 201.70$, $p < 0.01$). The indirect effect is 0.0083, representing 5.9% of the total effect. While the small a_1 magnitude suggests that AI adoption has only modest effects on green-financing access in the short run, the large b_1 coefficient which, as noted in Section 4.4.2, applies to a 0-to-1 change in the green-finance proportion—means that even small increases in green finance access are associated with appreciable productivity gains.

4.6.3 ESG performance channel

This pathway shows stronger effects. AI adoption increases the ESG score ($\beta = 0.030$, $p < 0.01$), and the ESG score increases sustainable productivity ($\beta = 0.568$, $p < 0.01$). The indirect effect is 0.0170, representing 12.0% of the total effect. This larger indirect effect suggests that ESG improvement is a more important transmission channel than green finance. The mechanism likely operates through AI

improving environmental monitoring and compliance, supply-chain transparency, stakeholder communication and governance systems.

4.6.4 Interpretation

Approximately 18% of AI's association with sustainable productivity operates through green finance and ESG channels, while the remaining 82% operates through other mechanisms, likely including direct operational efficiencies (AI optimising energy use, material flows and waste reduction), innovation in green technologies, better decision-making through AI-powered analytics, and supply-chain optimisation. This partial-mediation finding confirms that while green finance and ESG are meaningful transmission channels (supporting Hypotheses 4a and 4b), they are not the primary pathways.

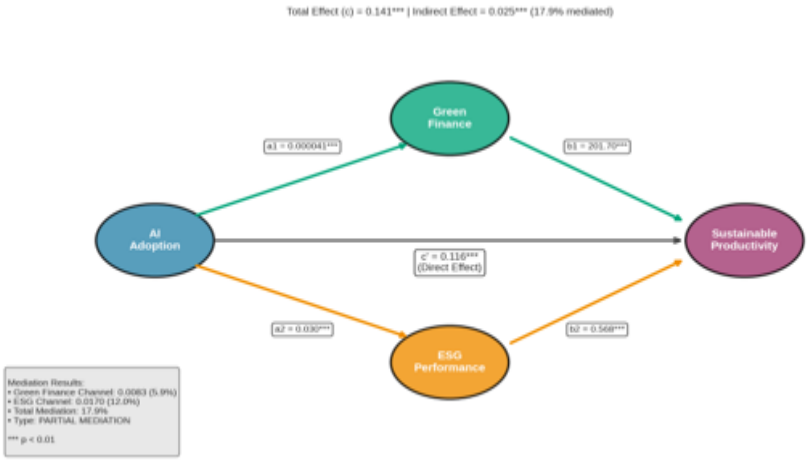

Figure 6. Mediation analysis: pathways from AI adoption to sustainable productivity
Source: Authors' own estimation (2025)

4.7 Heterogeneous effects by firm size

Table 7 and Figure 7 examine whether effects vary across firm size. The sample is divided into terciles: small firms (bottom 33%), medium firms (middle 33%), and large firms (top 33%).

4.7.1 AI adoption effects

The AI coefficient is strongest for small firms ($\beta = 0.131$, $p < 0.01$), followed by large firms ($\beta = 0.112$, $p < 0.01$) and medium firms ($\beta = 0.104$, $p < 0.01$). The 25% larger effect for small firms is noteworthy, suggesting that small firms derive disproportionate benefits from AI adoption due to baseline inefficiency (more room for AI-driven improvements), organisational agility (more rapid implementation of AI-recommended changes), and resource constraints (AI helps small firms achieve environmental performance previously requiring large dedicated sustainability departments). This finding has important policy implications: government support for AI adoption in SMEs could yield particularly high returns for sustainable transformation.

4.7.2 Green finance effects

Green finance shows strong positive effects across all size groups, with coefficients ranging from 198.52 (medium firms) to 207.04 (small firms). The similarity suggests that green finance benefits firms regardless of size.

4.7.3 ESG effects

ESG performance shows the clearest size gradient, with effects declining monotonically from small (β = 0.616) to medium (β = 0.557) to large (β = 0.510) firms. This 21% difference suggests that ESG practices yield greater productivity benefits when adopted by smaller organisations, perhaps because large firms already have sophisticated sustainability systems in place. The explanatory power varies systematically: small firms (R^2 = 0.163), medium firms (R^2 = 0.162), and large firms (R^2 = 0.181). The higher R^2 for large firms suggests that their sustainable productivity is more predictable from the selected variables, possibly because they face more systematic environmental pressures and regulations as show in table 7.

Table 7. Heterogeneous effects: subsample analysis by firm size

Variable	Small Firms	Medium Firms	Large Firms
AI Adoption Index	0.1307***	0.1041***	0.1124***
Green Finance Intensity	207.0370***	198.5247***	200.6823***
ESG Score	0.6162***	0.5574***	0.5100***
R-squared	0.1627	0.1615	0.1805
Observations	4,334	4,332	4,334

Notes: Firm-size groups are defined based on terciles of log(total assets). Small firms = bottom 33%, medium firms = middle 33%, large firms = top 33%. All models include control variables and year fixed effects. *** p < 0.01.
Source: Authors' own estimation (2025)

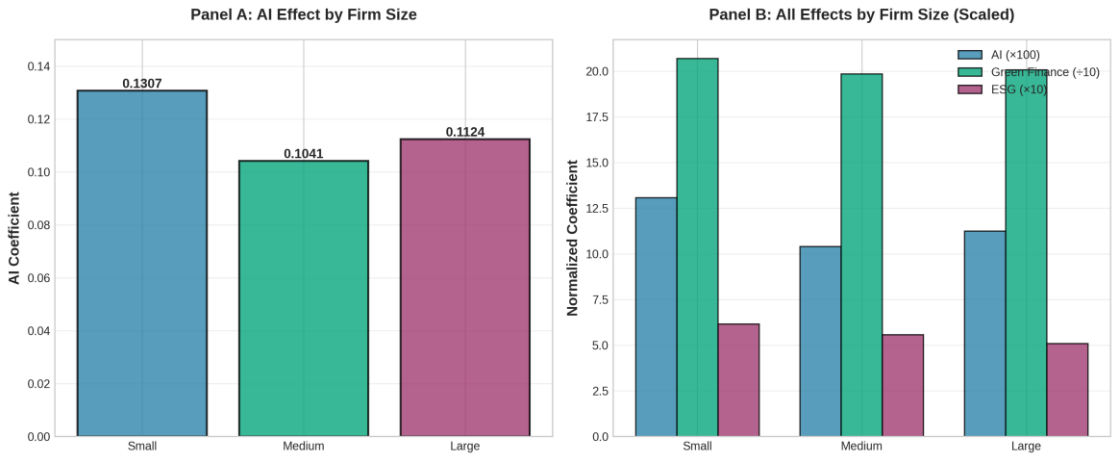

Figure 7. Heterogeneous effects of AI, green finance and ESG by firm size
Source: Authors' own estimation (2025)

4.8 Industry-level analysis

Figure 8 examines cross-industry variation. Panel A shows that AI adoption rates vary dramatically across sectors, from over 40% in Information Technology to below 20% in Real Estate and Utilities, likely reflecting differences in digital infrastructure, workforce skills and managerial capabilities. Panel B shows sustainable productivity by industry, with a clear distinction between clean industries (green bars) and Two-High industries (red bars). Clean industries systematically outperform polluting industries, with Information Technology and Health Care showing the highest sustainable productivity. Industries with the highest AI adoption also show the highest sustainable productivity, providing additional correlational support for the relationships documented in the regression analysis as show in table 8.

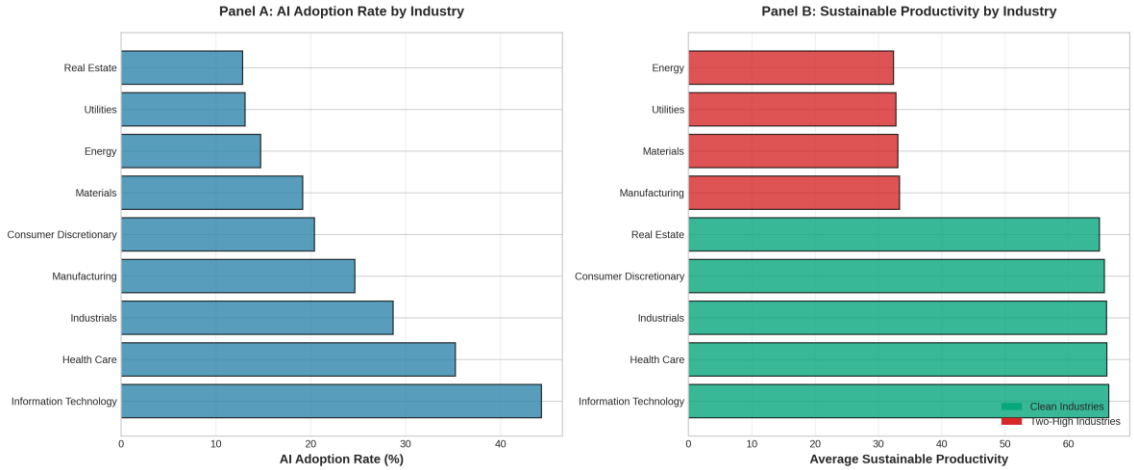

Figure 8. Industry-level AI adoption and sustainable productivity
Source: authors' own calculation based on the sample.

Table 8. Dynamic event-study estimates: Two-High × Year interactions
(firm fixed effects, 2012 reference year)

Year (reference = 2012)	**Two-High × Year coefficient (δ_t)**
2012 (reference year)	0 (—)
2013	−0.243
2014	0.783
2015	−0.207
2016	−0.207
2017	−1.199
2018	−0.638
2019	−1.711
2020	−1.285
2021	−2.033*
2022	−2.004**
2023	−0.520

Year (reference = 2012)	**Two-High × Year coefficient (δ_t)**
2024	−1.891*
Joint Wald test (H_0: all $\delta_t = 0$)	$\chi^2(12) = 16.97$, $p = 0.150$
Pre-treatment (lead) parallel-trends test	Not available in the dataset (no pre-2012 observations)

Notes: Estimates are from a within-firm dynamic event study (Equation 3) interacting the Two-High indicator with year dummies, with 2012 as the omitted reference year; firm fixed effects and the full control set are included, and standard errors are clustered at the firm level. The joint Wald test evaluates whether all post-policy interaction coefficients equal zero. A pre-treatment parallel-trends (lead) test is not feasible because the dataset contains no pre-2012 observations, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.
Source: Prepared by the researcher based on the China_Panel_Data_Complete dataset.

4.9 Robustness checks

Table 9 reports two robustness specifications, both estimated with firm fixed effects and firm-clustered standard errors. Column (1) replaces the AI adoption index with its logarithmic transformation, ln(1 + AI) (Equation 7), to address the variable's strong right-skew; the AI coefficient is positive and highly significant ($\beta = 1.038$, $p < 0.01$), confirming that the baseline AI–productivity association is not driven by a small number of high-AI outliers. Column (2) re-estimates the baseline fixed-effects model using a standardised (z-score) sustainable-productivity dependent variable; the AI coefficient ($\beta = 0.0036$, $p < 0.01$) implies that a one-point increase in the AI index is associated with about 0.004 of a standard deviation in sustainable productivity. Across both specifications the core pattern is preserved: AI adoption and green finance intensity remain positive and statistically significant, while the within-firm ESG coefficient remains small and insignificant, consistent with the baseline results in Table 4.

Table 9. Robustness checks: log-transformed AI and standardised dependent variable

Variable	**(1) FE, ln(1+AI)**	**(2) FE, standardised DV**
AI adoption [ln(1+AI) in (1); AI index in (2)]	1.0383***	0.0036***
Green Finance Intensity	11.5694***	0.5681***
ESG Score	0.0076	0.0004
Controls	Yes	Yes
Firm fixed effects	Yes	Yes
Year fixed effects	No	No
Observations	13,000	13,000
R-squared (within)	0.058	0.061

Notes: Both columns use the firm fixed-effects (within) estimator with firm-clustered standard errors. Column (1) replaces the AI index with ln(1 + AI); column (2) uses a standardised (z-score) sustainable-productivity dependent variable. The full control set (firm size, leverage, firm age, R&D intensity, ROA) is included, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.
Source: Prepared by the researcher based on the China_Panel_Data_Complete dataset.

5. Discussion

This study examined how artificial intelligence adoption, green finance and ESG performance relate to sustainable productivity in Chinese listed firms. Drawing on 1,000 firms over 13 years (2012–2024), we found consistent evidence that all three factors are associated with firms' ability to pursue environmental and economic objectives simultaneously. This section discusses the findings in relation to the existing literature, explores theoretical implications, and proposes future research directions.

5.1 Summary of main findings

The analysis yields five principal findings supporting all hypotheses. AI adoption is positively associated with sustainable productivity ($\beta = 0.115$, $p < 0.01$ in OLS; $\beta = 0.070$, $p < 0.01$ in FE), with effects particularly strong in small firms ($\beta = 0.131$). Green finance shows strong effects ($\beta = 202.29$ in OLS; $\beta = 11.16$ in FE, $p < 0.05$) despite low utilisation (1.4% on average). ESG performance shows strong cross-sectional associations ($\beta = 0.565$, $p < 0.01$) but weaker within-firm effects. The 2012 Green Credit Guidelines are associated with a relative constraint on polluting industries (DiD: $\beta = -16.48$, $p < 0.01$). Mediation analysis reveals that 18% of AI's association operates through green finance (5.9%) and ESG (12.0%) channels, with the remaining 82% through direct operational mechanisms.

5.2 Theoretical contributions

The findings extend the resource-based view (Barney, 1991) by demonstrating that AI capabilities, green-finance access and ESG practices function as strategic resources associated with competitive advantage through enhanced sustainable productivity. AI shows VRIN characteristics: valuable (a 7–11.5% productivity increase), rare (26% adoption rate) and difficult-to-imitate. Regarding the technology–organisation–environment framework (Tornatzky and Fleischer, 1990), small firms derive greater AI benefits ($\beta = 0.131$) than large firms ($\beta = 0.112$), contradicting conventional wisdom. This reversal may reflect fewer organisational-inertia barriers and lower baseline efficiency in small firms. The ESG findings provide mixed support for stakeholder theory (Freeman, 1984): strong cross-sectional relationships but weak within-firm effects suggest firm selection rather than causal impacts. Green finance mediates 5.9% of AI's effect, revealing an important tension: while highly effective when accessed, it remains severely underutilised.

5.3 Comparison with existing literature

The AI findings align with recent studies (Brynjolfsson and McElheran, 2016; Acemoglu and Restrepo, 2020) but extend the literature by focusing on sustainable productivity. Effect sizes (7–11.5%) are comparable to Wang et al. (2024) but smaller than Brynjolfsson et al. (2017), likely reflecting the focus on green productivity and the early-stage adoption context. Green-finance findings are consistent with Yu and Qi (2025), who report comparable coefficients. The study contributes new evidence on mediation pathways: green finance mediates 5.9% of AI's effect, providing a first quantitative estimate of this transmission channel. The ESG findings present a more nuanced picture than parts of the existing literature (Friede et al., 2015). Strong cross-sectional associations but weak within-firm effects suggest that previous studies may have overstated causal impacts, aligning with Berg et al. (2022) critiques of omitted-variable bias. The DiD analysis is consistent with evidence that credit-based environmental regulations effectively constrain targeted industries (Hu et al., 2020; Zhang et al., 2021).

5.4 Managerial and policy implications

Managers should recognise AI, green finance and ESG as mutually reinforcing elements. AI investments should incorporate sustainability criteria; firms should actively pursue green financing given strong effects but low utilisation; small firms should prioritise AI adoption where they show comparative advantages, while large firms should leverage green-finance access advantages. Policymakers should support AI adoption in SMEs through subsidies and training; expand green-finance access by standardising classifications and creating risk-sharing mechanisms; implement credit-based environmental policies with graduated implementation and technical assistance; and continue voluntary ESG frameworks allowing market mechanisms to drive adoption.

5.5 Limitations and future research

Several limitations should be acknowledged. First, although the analysis draws on real firm-level data, the AI adoption index is based on text-mining of corporate disclosures and may contain measurement error arising from differences in firms' reporting styles and disclosure incentives. Second, ESG ratings differ substantially across providers (Berg et al., 2022), so the ESG results may be sensitive to the choice of rating source. Third, despite the use of firm and year fixed effects and a difference-in-differences design, residual endogeneity—stemming from omitted time-varying factors and potential reverse causality—cannot be fully ruled out, and the cross-sectional ESG relationships in particular may reflect firm selection rather than within-firm causal effects. Fourth, the analysis focuses on Chinese listed firms, which limits the generalisability of the findings to other institutional and regulatory contexts. Future research should employ instrumental-variable and related causal-identification strategies to strengthen identification, examine alternative measures of AI adoption and sustainable productivity, investigate the substantial share of AI's association operating through unmeasured channels, and extend the analysis to cross-country and household-level settings to assess external validity and distributional implications.

6. Conclusion

This study provides comprehensive evidence that artificial intelligence adoption, green-finance access, and ESG performance jointly relate to sustainable productivity in Chinese listed firms. Drawing on 13,000 firm-year observations spanning 2012–2024, the analysis employed fixed-effects panel models, difference-in-differences analysis, and mediation tests to examine these relationships and explore the underlying mechanisms. The principal findings demonstrate that AI adoption shows robust positive associations with sustainable productivity ($\beta = 0.115$ in OLS, $\beta = 0.070$ in FE), with particularly strong impacts in small firms ($\beta = 0.131$) where organisational agility and baseline inefficiency create greater room for improvement. Green finance demonstrates strong associations ($\beta = 202.29$ in OLS, $\beta = 11.16$ in FE) despite severely low utilisation (1.4% average intensity), revealing substantial unrealised potential for accelerating sustainable transformation through expanded access to green-financing instruments. ESG performance shows strong cross-sectional relationships ($\beta = 0.565$) but weaker within-firm effects ($\beta = 0.007$, n.s.), suggesting that while ESG practices signal firm quality and facilitate market access, short-term productivity gains from ESG improvements within firms remain modest.

Mediation analysis reveals that approximately 18% of AI's association with sustainable productivity operates through green finance (5.9%) and ESG performance (12.0%) channels, with the remaining 82% flowing through direct operational efficiencies, innovation in green technologies, improved environmental decision-making, and supply-chain optimisation. This partial mediation confirms that while financial and governance mechanisms serve as important transmission channels, AI's primary association operates through direct technological capabilities that enhance resource utilisation and

reduce environmental harm. The evaluation of the 2012 Green Credit Guidelines using difference-in-differences methodology indicates that environmental credit policies can be associated with substantial relative constraints on polluting industries (DiD coefficient: −16.48, $p < 0.01$), consistent with market-based regulatory instruments reshaping industrial dynamics and resource-allocation patterns.

These findings carry important implications for multiple stakeholders. Managers should recognise AI adoption, green financing and ESG practices as mutually reinforcing elements of sustainable transformation strategies, with size-specific approaches recognising that small firms should prioritise AI adoption where they show comparative advantages, while large firms should leverage advantages in accessing green-finance markets. Policymakers should support AI adoption in SMEs where returns are highest, expand green-finance access through standardisation and risk-sharing mechanisms, and design credit-based environmental policies with graduated implementation allowing adjustment time coupled with technical assistance and worker-transition programmes. While limitations remain—including the single-country setting, reliance on text-based and rating-based proxy measures, and residual endogeneity concerns—the results provide support for integrated approaches combining technological innovation, financial instruments and governance reforms in pursuit of sustainable development.

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During the preparation of this manuscript, the authors used Anthropic's Claude (a large-language-model assistant) for language editing, structural reorganisation of subsections to align the manuscript with the Oeconomica Jadertina author guidelines, and for refining tables, captions and the formatting of equations. The tool was not used to generate results or research findings. After using the tool, the authors reviewed and edited the content as necessary and take full responsibility for the final version of the manuscript.

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Umjetna inteligencija i zelena transformacija: unapređenje ljudskog kapitala, zelene financije i ESG procjena kao pokretači održive produktivnosti

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Sažetak: U radu se ispituje kako su usvajanje umjetne inteligencije (AI), zeleno financiranje i uspješnost u području okolišnih, društvenih i upravljačkih čimbenika (ESG) zajednički povezani s održivom produktivnošću kineskih uvrštenih poduzeća. Koristeći stvarne panelne podatke na razini poduzeća koji obuhvaćaju 1.000 uvrštenih poduzeća u razdoblju od 2012. Do 2024. Godine, odnosno ukupno 13.000 opažanja poduzeće-godina prikupljenih iz baze podataka CSMAR, korporativnih objava i priznatih pružatelja ESG ocjena, studija primjenjuje objedinjene OLS i modele s fiksnim učincima, pristup razlika-u-razlikama (DiD) te testove medijacije kako bi odgovorila na nedostatke u razumijevanju mehanizama održive transformacije. Rezultati pokazuju da je usvajanje umjetne inteligencije pozitivno povezano s održivom produktivnošću ($\beta = 0{,}115$, $p < 0{,}01$), kao i intenzitet zelenog financiranja ($\beta = 11{,}16$, $p < 0{,}05$ u modelima s fiksnim učincima). Međutim, učinci ESG-a čini se da više odražavaju međupoduzećnu selekciju nego poboljšanja unutar samih poduzeća tijekom vremena. Analiza medijacije sugerira da zeleno financiranje i ESG zajedno prenose približno 18 % ukupne povezanosti umjetne inteligencije s održivom produktivnošću (5,9 % i 12,0 %), dok se preostalih 82 % ostvaruje putem izravnih operativnih kanala. Smjernice za zeleno kreditiranje iz 2012. Godine povezane su s relativnim padom mjerene produktivnosti u industrijama koje zagađuju okoliš (DiD: $-16{,}48$, $p < 0{,}01$), što je u skladu s pretpostavkom da je politika ograničila sektore s visokom potrošnjom energije i visokim razinama onečišćenja („Two-High“ sektore). Analiza heterogenosti pokazuje da mala poduzeća ostvaruju razmjerno veće koristi od usvajanja umjetne inteligencije ($\beta = 0{,}131$ naspram $\beta = 0{,}112$ za velika poduzeća), čime se dovode u pitanje uobičajene pretpostavke o prednostima velikih organizacija u usvajanju novih tehnologija. Glavna ograničenja istraživanja uključuju moguću endogenost, oslanjanje

na pokazatelje temeljene na tekstualnoj analizi i ESG ocjenama te činjenicu da je istraživanje provedeno u samo jednoj zemlji. Buduća istraživanja trebala bi primijeniti strategije instrumentalnih varijabli, alternativne mjere i međudržavne usporedbe. Studija doprinosi razumijevanju održive transformacije kao sinergijskog procesa koji integrira tehnološke, financijske i upravljačke dimenzije.

Ključne riječi: umjetna inteligencija, zeleno financiranje, ESG uspješnost, održiva produktivnost, analiza panelnih podataka, analiza medijacije, kineska uvrštena poduzeća
***JEL klasifikacija*:** Q56, Q58, O33, G21, G32, M14, C23, L25

The Relationship Between Share Price Movement and Audit Adjustments

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Abstract: The purpose of this research was to examine the correlation between the fluctuations in share prices following the release of independent auditor reports for companies listed on the Zagreb Stock Exchange during the period from 2016 to 2018, and the audit adjustments made to the financial results in their unaudited financial statements. The research hypotheses were evaluated using the regression coefficients derived from panel regression models that were estimated with a random effects estimator. The results of the research indicated a statistically significant positive correlation between the relative change in share price after the disclosure of independent auditor reports and the absolute earnings audit adjustments. In addition, there was a statistically significant positive correlation between the relative change in share price after the disclosure of independent auditor reports and the absolute upward earnings audit adjustments. However, no statistical significance was found between the relative change in share price after the disclosure of independent auditor reports and the absolute downward earnings audit adjustments. The lack of a significant correlation between downward earnings audit adjustments and share prices post-disclosure of an independent auditor's report has raised further questions, thereby creating a new direction for future research. The study's limitations include a relatively small sample size and the possible presence of omitted variable bias.

Keywords: share prices, unaudited financial reports, pre-audit, audit adjustments, audit quality
JEL classification**:** M41, M42, G12, D53

1. Introduction

The value of assets is influenced by the interactions between investors and companies (Connelly et al., 2011, in Bagonza et al., 2025). The prices of shares issued by companies listed on the capital market mainly fluctuate as a result of the actions taken by the management of these companies or based on the information contained in the accounting items of financial reports (Khajavi and Zare, 2016, in Bangoza et al., 2025). Management actions could imply manipulative activities, such as concealment of unfavourable business news, intended to present misleading information about a company's financial

performance (Kim et al., 2015, in Bangoza et al., 2025). Managers are focused on the maximization of personal benefits and are in position to manipulate financial statement items, potentially misleading shareholders and obscuring the actual financial position, performance, and cash flows of their company (Bakhiet, 2026). External auditors play a vital professional role in the functioning of business environment (Coffie et al., 2018, in Bakhiet, 2026), as they ensure that the financial information presented in financial reports accurately reflects the business entity's economic position (Bakhiet, 2026), which decreases information asymmetry (Coffie et al., 2018, in Bakhiet, 2026) and mitigates agency problems arising from conflicting interests between managers and shareholders (Jensen and Meckling, 1976, in Bakhiet, 2026). Given that it is "the sole communication medium between the auditor and the users of the financial statements", the independent auditor's report can be considered as "the most important part of the audit process" (Al-Thuneibat et al., 2008, p. 97).

There is a tendency of market value fluctuation depending on the issuance of independent auditor's report (Augustine O Okolie, 2014; Afifa et al., 2020; Almaharmeh et al., 2021, in Bagonza et al., 2024). Thus, the main objective of this research is to examine the relationship between share price movement after the disclosure of independent auditor reports and magnitude of earnings audit adjustments made to the net profit in unaudited financial reports. Unlike the variables predominately used in previous studies, the focus of this research was on earnings audit adjustments as a difference between the net profit in audited financial report and the net profit in unaudited financial report. Additionally, this research was first to separate audit adjustments in two categories in the context of price movements, examining the difference in relationships of upward earnings audit adjustments, as well as downward earnings audit adjustments with the relative share price change after the disclosure of independent auditor reports. The aforementioned constitutes the scientific contribution of this research. Furthermore, the Republic of Croatia is specific research setting regarding the efficiency of its stock market which also provides additional layer of scientific value. More precisely, the Zagreb Stock Exchange is a stock market with a relatively small market capitalization, low liquidity and low trade volumes. The specificity of Croatia relevant for this research also reflects in the fact that unaudited financial are rarely publicly available like in the Republic of Croatia, providing additional objectivity regarding the estimation of audit quality.

This scientific paper is organized in five sections. The first section comprises introductory remarks important in the context of the role of audit quality on movements of share prices after the disclosure of independent auditor reports of companies listed at stock markets, the objective and the scientific contribution of the research. The second section gives insight into previous research which examined the relationship between audit quality proxied by different measures, audit opinions and audit adjustments with share prices, as well as the research hypothesis established using findings of these studies. The third section comprises details on research design, such as temporal and spatial specifics of the research sample, statistical methodology used for presenting the key characteristics of research data and for the testing of the research hypothesis, as well as the elaboration of variables incorporated in the research model. The fourth section includes the results of the research obtained by the descriptive statistics measures, as well as the panel regression model to calculate the regression coefficients.

Finally, the fifth section comprises the concluding remarks based on the results of the research and their relation to the previous research, as well as the limitations of the research and suggestions for future research.

2. Literature review and hypothesis development

This section comprises scientific studies previously conducted on the relationship between audit quality, audit opinions or audit adjustments and stock prices. Audit quality was measured by the discretionary

accruals and the affiliation of appointed audit firm to the Big Four group. Given that the research on the relationship between audit adjustments and stock prices is extremely scarce, literature review was enhanced by related concepts such as audit quality and audit opinions, but the research using audit adjustments was emphasized the most at the end of this section. The research on the relationship between audit opinions and stock prices revealed that investors react to the information contained in audit opinion, but it was also inconclusive in some studies. According to the research on the relationship between audit quality and stock prices, it can be concluded that the audit quality mostly positively impacts the investors' reactions on stock market.

Al-Thuneibat et al. (2008) investigated the relationship between qualified audit opinions and share prices on the sample of companies listed at Amman Stock Exchange in Jordan from 2000 to 2005. They did not find that qualified audit opinion significantly impacts returns and share prices. Ianniello and Galloppo (2015) have analysed, on the sample of companies listed on the Italian Stock Exchange during the time period from 2007 to 2011, the relationship between disclosure of qualified audit opinions and investor reactions around these report dates, as well as the relationship between including the paragraph regarding the going concern uncertainty and investor reactions around report dates of qualified audit opinions. They have found negative relationship between the former variable pair and positive relationship between the latter variable pair. Bunget et al. (2022) have examined the relationship between an audit opinion and share prices on the Bucharest Stock Exchange on the sample of 39 listed companies in the four-year period from 2017 to 2020. They found that issuance of unqualified and qualified opinion was connected with a price increase, while adverse opinions and disclaimers of opinions were connected to a price decrease. Flees and Mouselli (2023) investigated the relationship between qualified audit opinions and stock returns on the sample of companies listed at Amman Stock Exchange in Jordan from 2016 to 2019. They did not find that qualified audit opinion significantly impacts stock returns.

Almaharmeh et al. (2021) analyzed if price synchronicity of a stock is influenced by audit quality proxied by the affiliation of an audit firm to the Big Four on the sample of industrial companies listed at Amman Stock Exchange in Jordan from 2014 to 2018, and found lower stock price synchronicity when audit quality is higher, "which enhances the capitalization of firm's specific information into the stock price, thus less synchronous and more informative stock return" (p. 833). Furthermore, Bagonza et al. (2024) examined how the relationship between market reactions, proxied by market returns and market prices, and audit quality proxied by discretionary accruals are mediated by integrating reporting, which is a combination of non-financial and financial information, on the sample of 119 listed companies on the Johannesburg Stock Exchange in South Africa from 2011 to 2019. They have found that the relationship between market reactions and audit quality was partially mediated by integrated reporting. Also, they have confirmed the positive effect of audit quality on share price. Bagonza et al. (2025) examined how the relationship between market reactions, proxied by market returns and market prices, and audit quality proxied by discretionary accruals are moderated by effectiveness of audit committee, on the sample of 472 listed companies on the Johannesburg Stock Exchange in South Africa from 2014 to 2019. They have found that the relationship between market reactions and audit quality was moderated by audit committee, as a crucial mechanism in audit process oversight which safeguards accountability, transparency and auditor's independence. Also, they have confirmed the effect of audit quality on market returns and share price. Bakhiet (2026) investigated the moderating effect of audit quality proxied by the affiliation of an audit firm to the Big Four on the relationship stock price crash probability and the readability of financial statements using the research sample of 107 companies listed from 2016 to 2019 on the Egyptian Stock Exchange. They found a negative relationship between the risk of stock price crash and readability of financial reports. Also, despite the beneficial effect of external audit quality on

stability of the market and confidence of investors, it fosters the negative relationship between the risk of stock price crash and readability of financial reports, i.e., the complexity of financial reporting.
To the author's knowledge, there is only one study which analyses the relationship between stock prices and audit adjustments – Amat and Elvira (2010) which utilized the sample of 42 companies listed on the Spanish stock market from 1997 to 2004. They studied earnings misstatements and found that overstatements are more frequent than understatements of earnings and stated that audit adjustments may provide valuable information to the investors regarding the magnitude of earnings restatements. They also investigated audit adjustments in the context of variables related to the market reactions to specifics of a stock, such as its price, returns and trading volume. According to the contents of their research, they did not use the values of items from unaudited financial statements for the calculation of audit adjustment variable. Using t-test, they compared companies which adjusted their financial result to the companies which have not adjusted their financial result and found that managerial attempts to mislead investors through earnings manipulation did not achieve desired effects, that is their market prices were lower. In their regression model, they have examined the relationship between audit adjustment magnitude and stock returns and found a positive relationship between those variables. In efforts to explain those results, they have mentioned that investors do not consider overstatement of financial result and market mispricing, but the also highlighted the need for further research to clarify the results which imply that audit adjustments are positively perceived by the investors.
In this context, earnings audit adjustments are an objective proxy of audit quality because they signify a magnitude in which external auditors corrected accounting items comprised in unaudited financial reports and made them closer to the true financial position and financial performance of a company. Given that there are two directions in which these adjustments can be made, differentiation between upward and downward earnings audit adjustments is implemented in this research. Upward audit adjustment implies the situation when the value of an accounting item in unaudited financial report is lower than the value of an accounting item in audited financial report and auditor adjusts it to the higher value. On the other side, downward audit adjustment implies the situation when the value of an accounting item in unaudited financial report is lower than the value of an accounting item in audited financial report and auditor adjusts it to the higher value. It is conceivable that the correction increasing the value of financial result will have beneficial impact on the perception of investors and lead to positive market reactions which increase the share value of a company. Conversely, the correction decreasing the value of financial result will have detrimental effect on the perception of investors and lead to negative market reactions which decrease the share value of a company. Given that these relations were not previously examined, non-directional hypotheses were established.
Considering the findings of previous studies, research hypotheses were established as follows:

Hypothesis 1: *There is a statistically significant positive relationship between earnings audit adjustments and change of share prices after the disclosure of an independent auditor's report.*

Hypothesis 1a: *There is a statistically significant relationship between upward earnings audit adjustments and share prices after the disclosure of an independent auditor's report.*

Hypothesis 1b: *There is a statistically significant relationship between downward earnings audit adjustments and share prices after the disclosure of an independent auditor's report.*

3. Research design

This section includes details on the research sample, statistical methodology applied for data analysis such as descriptive statistics and panel regression and elaboration of the variables included in three research models used for research hypothesis testing.

3.1 Research sample

The research sample was composed of 55 companies listed on the Zagreb Stock Exchange in the Republic of Croatia in the three-year period from 2016 to 2018. This period was utilized because price movements were not available on the official web site of the Zagreb Stock Exchange before 1st January 2016 and to exclude the potential effects of the COVID-19 pandemic on shares prices. More precisely, some companies listed on the Zagreb Stock Exchange have not disclosed their financial statements for the financial year 2019 before the outbreak of the COVID-19 pandemic, thus the last financial year included in the research was 2018. Financial data was gathered from financial reports publicly available on the Zagreb Stock Exchange official website, as well as the data on changes of share prices. Financial companies affiliated to the "Financial and insurance activities" according to the *National Classification of Activities – Nacionalna klasifikacija djelatnosti (NKD)* from 2007 (Official Gazette, 2007) were not included the sample considering their financial reporting specificities.

3.2 Statistical methodology

For the purpose of research, measures of descriptive statistics were utilized to show the main characteristics of the variables included in the research sample. In order to test the research hypothesis, panel regression model was utilized and its regression coefficients were used to decide whether to accept or decline a certain hypothesis. In order to rule out the possibility of multicollinearity between independent variables in all research models included in the research, variance inflation factors were calculated and used as a part of multicollinearity diagnostics (Chen and Yuan, 2004). PAST statistical software (Hammer et al., 2001) was used for calculating the measures of descriptive statistics, while R statistical software (R Core Team, 2024) was utilized to estimate the coefficients of the panel regression model. Also, certain R packages were used, such as the plm (Croissant and Millo, 2008; Croissant and Millo, 2018), the stargazer (Hlavac, 2022) and the car (Fox and Weisberg, 2019).

3.3 Research models

Three research models were formed to test the research hypotheses established:

$$PCH_{it} = \beta_0 + \beta_1 * AA_{it} + \beta_2 * PROF_{it} + \beta_3 * LEV_{it} + e_{it} \quad (1)$$

$$PCH_{it} = \beta_0 + \beta_1 * uwAA_{it} + \beta_2 * PROF_{it} + \beta_3 * LEV_{it} + e_{it} \quad (2)$$

$$PCH_{it} = \beta_0 + \beta_1 * dwAA_{it} + \beta_2 * PROF_{it} + \beta_3 * LEV_{it} + e_{it} \quad (3)$$

Model (1) takes into account all earnings audit adjustments, irrespective of its direction. It analyses only the magnitude of earnings audit adjustments. Model (2) and Model (3) differentiate between earnings audit adjustments depending on their direction. Thus, Model (2) refers to upward earnings audit

adjustments, while Model (3) refers to downward earnings audit adjustments. Absolute values of audit adjustment measures were utilized in all research models. Research variables utilized to construct research models are presented in Table 1 which includes their names, acronyms and elaboration of their calculation procedure.

Table 1. Review of the variables included in the research model

Research Variable	**Acronym**	**Procedure of Calculation**
Relative Share Price Change	PCH	Change of the share price measured as a difference between the nearest average share price recorded after the date on which an independent auditor's report was disclosed and the nearest average share price recorded before the date on which an independent auditor's report was disclosed divided by the nearest average share price recorded before the date on which an independent auditor's report was disclosed and multiplied by 100.
Absolute Earnings Audit adjustments	AA	Earnings audit adjustment calculated as an absolute value of the difference between the value of audited net profit and unaudited net profit divided by total assets from the previous financial year. Similar measure was used by Tong et al. (2023).
Absolute Upward Earnings Audit Adjustments	uwAA	Upward earnings audit adjustment calculated as an absolute value of difference between the value of net profit after audit and net profit before audit divided by total assets from the previous financial year. The similar measure used by Tong et al. (2023) was slightly modified because this measure is not converted in a binary variable.
Absolute Downward Earnings Audit Adjustments	dwAA	Downward earnings audit adjustment calculated as an absolute value of difference between the value of net profit after audit and net profit before audit divided by total assets from previous financial year. The similar measure used by Tong et al. (2023) was slightly modified because this measure is not converted in a binary variable.
Profitability	PROF	Profitability measured using return on assets ratio calculated as net profit divided by total assets.
Leverage	LEV	Leverage ratio calculated as a sum of short-term liabilities and long-term liabilities divided by total assets.

Source: Created by the author (2025)

4. Research results

This section includes the results of statistical analysis, which included descriptive statistics calculated using the measures such as mean, standard deviation and median, and panel regression analysis which was used to estimate regression coefficients of three models used for hypothesis testing.
Furthermore, multicollinearity diagnostics was conducted using the values of variance inflation factors.
As evident from Table 2, average price change was slightly below zero and amounted -0,43%, while the average value of absolute earnings audit adjustments was approximately 0,086.
Average value of absolute upward earnings audit adjustments amounted 0,133 and was higher than the average value of absolute downward earnings audit adjustments which amounted 0,095. Average

profitability expressed by return on assets ratio was slightly negative and very close to zero value, while average leverage amounted approximately 44%.

Table 2. Descriptive statistics for the values included in the research model

Statistical measure/Variable	PCH	AA	uwAA	dwAA	PROF	LEV
Mean	-0,431	0,086	0,133	0,095	-0,004	0,444
Standard deviation	9,137	0,197	0,280	0,130	0,204	0,228
Median	0	0,026	0,046	0,059	0,021	0,450

Legend: PCH = relative share price change calculated as [nearest record of average share price after the date of disclosure of independent auditor's report – nearest record of average share price before the date of disclosure of independent auditor's report]/[nearest record of average share price before the date of disclosure of independent auditor's report], AA = absolute earnings audit adjustments calculated as |Audited Net Profit (t) – Unaudited Net Profit (t)|/Total Assets (t – 1), uwAA = absolute upward earnings audit adjustments calculated as |Audited Net Profit (t) – Unaudited Net Profit (t)|/Total Assets (t – 1), dwAA = absolute downward earnings audit adjustments calculated as |Audited Net Profit (t) – Unaudited Net Profit (t)|/Total Assets (t – 1), PROF = profitability calculated as Net profit/Total Assets and LEV = [Short-Term Liabilities + Long-Term Liabilities]/Total Assets.
Source: Regression model created by the author with PAST statistical software (Hammer et al., 2001) and information from financial statements gathered at the official website of Zagreb Stock Exchange.

Table 3. Variance inflation factors – values for all regression models

Model/Variable	AA	uwAA	dwAA	PROF	LEV
Model 1	1.050546	-	-	1.062809	1.019363
Model 2	-	1.113002	-	1.214948	1.157423
Model 3	-	-	1.423757	1.422444	1.019969

Legend: Legend: AA = absolute earnings audit adjustments calculated as |Audited Net Profit (t) – Unaudited Net Profit (t)|/Total Assets (t – 1), uwAA = absolute upward earnings audit adjustments calculated as |Audited Net Profit (t) – Unaudited Net Profit (t)|/Total Assets (t – 1), dwAA = absolute downward earnings audit adjustments calculated as |Audited Net Profit (t) – Unaudited Net Profit (t)|/Total Assets (t – 1), PROF = profitability calculated as Net profit/Total Assets and LEV = [Short-Term Liabilities + Long-Term Liabilities]/Total Assets.
Source: Regression model created by the author with R statistical software (R Core Team, 2024) and information from financial statements gathered at the official website of Zagreb Stock Exchange.

Variance inflation factors in Table 3 are calculated to confirm that multicollinearity is not problematic for the independent variables included in the research model in Table 4.
Given that the variance inflation factors are in the range between the lowest value of approximately 1.02 and highest value of approximately 1.42 and that none of the independent research variables exceeded the critical threshold of 10 (Davidson III et al., 2004; Gray et al., 2015), it can be declared that there is no multicollinearity problem in all of the panel regression models.

Table 4. Panel regression models – estimations of regression coefficients

Model	(1)	(2)	(3)
Independent variables	**Dependent variable:** PCH		
AA	15.367*** (3.879)	-	-
uwAA	-	12.810*** (4.198)	-

dwAA	-	-	11.578 (14.569)
PROF	1.985 (3.438)	12.433 (30.588)	0.964 (5.423)
LEV	-0.502 (3.939)	3.053 (6.275)	-3.117 (7.381)
Constant	-1.791 (1.993)	-3.033 (3.600)	-1.030 (4.275)

Legend: standard errors are contained in the brackets below the regression coefficients; *** = regression coefficient statistically significant at the level of 1 percent; ** = regression coefficient statistically significant at the level of 5 percent; * = regression coefficient statistically significant at the level of 10 percent; PCH = relative share price change calculated as [nearest record of average share price after the date of disclosure of independent auditor's report – nearest record of average share price before the date of disclosure of independent auditor's report]/[nearest record of average share price before the date of disclosure of independent auditor's report], AA = absolute earnings audit adjustments calculated as |Audited Net Profit (t) – Unaudited Net Profit (t)|/Total Assets (t – 1), uwAA = absolute upward earnings audit adjustments calculated as |Audited Net Profit (t) – Unaudited Net Profit (t)|/Total Assets (t – 1), dwAA = absolute downward earnings audit adjustments calculated as |Audited Net Profit (t) – Unaudited Net Profit (t)|/Total Assets (t – 1), PROF = profitability calculated as Net profit/Total Assets and LEV = [Short-Term Liabilities + Long-Term Liabilities]/Total Assets.

Source: Regression model created by the author with R statistical software (R Core Team, 2024) and information from financial statements gathered at the official website of Zagreb Stock Exchange.

The research results for Model 1 in Table 4 imply statistically significant positive relationship between relative share price change after the disclosure of independent auditor reports and absolute earnings audit adjustments at the threshold of 1 percent. The regression coefficient between two mentioned research variables amounts to 15.367 and signifies that an increase of earnings audit adjustments by 1 p. p. leads to an increase in relative share price change by approximately 0,15 p. p. Differentiation between absolute upward earnings audit adjustments and absolute downward earnings audit adjustments is presented in Model 2 and Model 3. Research results for Model 2 in Table 4 imply statistically significant positive relationship between relative share price change after the disclosure of independent auditor reports and absolute value of upward earnings audit adjustments at the threshold of 1 percent, similarly as for the relationship between relative share price change after the disclosure of independent auditor reports and absolute earnings audit adjustments. The regression coefficient between two mentioned research variables amounts to 12.810 and signifies that an increase of earnings audit adjustments by 1 p. p. leads to an increase in relative share price change by approximately 0,12 p. p. Research results for Model 3 in Table 4 imply statistical insignificance between relative share price change after the disclosure of independent auditor reports and absolute value of downward earnings audit adjustments. The regression coefficients for the control variables denoting profitability and leverage did not show a statistically significant relationship with price change after the disclosure of independent auditor reports in all the models presented in Table 4.

5. Conclusion

The hypothesis stating that there was a statistically significant positive relationship between earnings audit adjustments and change of share prices after the disclosure of an independent auditor's report was accepted, as well as the hypothesis stating that there was a statistically significant positive relationship between upward earnings audit adjustments and share prices after the disclosure of an independent auditor's report. Conversely, hypothesis stating that there was a statistically significant negative

relationship between downward earnings audit adjustments and share prices after the disclosure of an independent auditor's report was rejected. In other words, share price movements after the disclosure of an independent auditor's report were only significantly related to the positive information regarding an auditee comprised in an independent auditor's report.

This research can be seen as more detailed extension of the research conducted by Amat and Elvira (2010) who found a positive relationship between audit adjustment magnitude and stock returns. The results of Hypothesis 1 are in line with this research, but their research has stopped at that point and they have stressed the need for more detailed insight in the future research. Amat and Elvira (2010) did not differentiate between upward audit adjustments and downward audit adjustments and integrated their effect in one variable considering only audit adjustment magnitude. The research done by Amat and Elvira (2010) needed to be complemented, and this was conducted in this research through the differentiation between upward audit adjustments and downward audit adjustments, offering additional insight on this matter.

Audit adjustments can be done in different directions and, thus, investors' perception could change accordingly. If a company is conservative in their estimation of financial result, the investors will probably perceive it less prosperous, which will be reflected in the share price. But, if financial result increases following the external audit procedures, investors' perception of a company improves and that is probably going to be reflected in an increase of the share price. The question still remains regarding the insignificant relationship between downward earnings audit adjustments and share prices after the disclosure of an independent auditor's report. The market reaction could be either absent or delayed, and one of the ways in which this could be explained refers to the cognitive dissonance and asymmetric reaction of investors depending on the market sentiment (Li et al., 2023). More precisely, if a market sentiment is optimistic, reactions to positive news will spur more prompt reactions in comparison to negative news (Li et al., 2023). This opens a potential avenue for future research.

There are also research limitations which ought to be disclosed. The research sample is relatively small due to the limited number of companies listed on the Croatian stock market. There is also a possibility of omitted variable bias implying that variables relevant for explaining the movements of share prices after the disclosure of independent auditor reports were not incorporated in the research model. Despite the effort to rule out possible macroeconomic events which could significantly affect share prices, there is a possibility that some relevant macroeconomic events, as well as firm-specific business events stimulated a price movement. Future research could include larger samples in terms of number of companies, as well as gathering the data during longer time periods.

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Odnos između kretanja cijene dionica i revizijskih prilagodbi

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Sažetak: Cilj istraživanja bio je ispitati povezanost između kretanja cijena dionica nakon objave izvješća neovisnog revizora društava uvrštenih na Zagrebačku burzu u razdoblju od 2016. do 2018. godine i revizijske ispravke financijskog rezultata u njihovim nerevidiranim financijskim izvješćima. Istraživačke hipoteze testirane su korištenjem regresijskih koeficijenata iz regresijskih panel modela procijenjenih estimatorom slučajnih učinaka. Rezultati istraživanja pokazali su statistički značajnu pozitivnu povezanost između relativne promjene cijena dionica nakon objave izvješća neovisnog revizora i apsolutnih revizijskih ispravki financijskog rezultata, kao i statistički značajnu pozitivnu povezanost između relativne promjene cijena dionica nakon objave izvješća neovisnog revizora i apsolutnih revizijskih ispravki financijskog rezultata kojima se povećava financijski rezultat, ali nije bilo statističke značajnosti između relativne promjene cijena dionica nakon objave izvješća neovisnog revizora i apsolutnih revizijskih ispravki financijskog rezultata kojima se smanjuje financijski rezultat. To implicira da se, u prosjeku, povećanje financijskog rezultata nakon objave izvješća neovisnog revizora podudaralo s povećanjem cijena dionica, koje je obično znak poboljšane percepcije investitora o trgovačkom društvu. Nesignifikantna povezanost između revizijskih ispravki kojima se smanjuje financijski rezultat i cijena dionica nakon objave izvješća neovisnog revizora otvorila je dodatna pitanja te se, posljedično, pojavila nova perspektiva za buduća istraživanja. Ograničenja istraživanja uključuju relativno mali uzorak istraživanja i potencijalno postojanje pristranosti zbog izostavljenih varijabli.

Ključne riječi: cijene dionica, nerevidirana financijska izvješća, predrevizijski, revizijske ispravke, kvaliteta revizije
***JEL klasifikacija*:** M41, M42, G12, D53

Current State and Development Perspectives of the Cultural Routes of the Council of Europe in Istria County

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Abstract: The paper examines the current state and development prospects of the Cultural Routes of the Council of Europe within Istria County (Croatia). The authors began with the premise that Istria, being a cross-border, multicultural, and multilingual area distinguished by a unique cultural landscape, possesses significant potential for establishing European cultural routes. The research problem arises from the observation that the implementation of the Cultural Routes of the Council of Europe in Istria has remained in its initial stages of development, and that key stakeholders have not yet fully recognized the strategic potential of enhancing the region's distinctive heritage through the establishment of transnational cultural routes. The research methodology employed a qualitative case study approach, incorporating both desk and field research, which involved interviews with representatives from key stakeholders. After conducting a literature review, this research presents a case study of Istria County. The analysis focuses on identifying existing challenges, developmental prospects, and recommended strategic measures concerning the implementation of the Cultural Routes of the Council of Europe in the region. The findings indicate that European thematic cultural routes, recognized as the most accessible and cost-efficient forms of cultural tourism, can play a crucial role in reinforcing local identities and promoting sustainable economic development in the region. Istria County, as a cross-border area, has the potential to promote cultural routes as a model for the valorisation of shared European heritage and core European values.

Keywords: cultural routes, Council of Europe, transborder regions, European heritage, Istria
***JEL Classification*:** O10, O19, Z1, Z32

1. Introduction

The turbulent geopolitical history of Europe, where states and borders have changed over the centuries, has led to the emergence of specific cultural-historical and socio-political zones, known as cross-border regions. Cultural heritage represents a driver for intercultural dialogue and transnational cooperation in such regions, as meeting places of different cultures. On the other hand, the pressures resulting from irresponsible management of tourism development across Europe have been raising questions for decades about how to responsibly valorise cultural and natural resources and redirect tourism economic systems that operate based on economies of scale towards sustainable development. Cultural routes could respond to such current challenges, acting as a model of valorisation of common European heritage (Urošević and Afrić Rakitovac, 2017), redirecting to sustainable tourism development (Duda, 2024), and strengthening regional identities (Cappellano and Rizzo, 2019).

According to Gravari-Barbas (2014), the development of cultural routes is a holistic heritage management strategy, which transforms a static focus on isolated monuments and sites into a dynamic and participatory development framework. The Cultural Routes of the Council of Europe programme was launched in 1987, with the initial idea to emphasize the unity of European cultural heritage and the common foundations of Europe in an illustrative manner. They were created as grass-roots networks promoting the principles and values of the Council of Europe: human rights, cultural democracy, cultural diversity, mutual understanding and exchanges across boundaries. They act as channels for intercultural dialogue and promote a better knowledge and understanding of European history (Council of Europe, 2025). The project's founder's main idea was to provide greater visibility and respect for a common European identity, and to preserve and promote European heritage in terms of improving social, economic and cultural development.

The primary aim of this paper is to analyse the current state and development perspectives of the Cultural Routes of the Council of Europe in Istria County (Croatia), a cross-border, multicultural, and multilingual region that represents a rich source of resources well-suited for the development of European routes. The research problem arises from the fact that the development of the Cultural Routes of the Council of Europe in Istria is still in its early stages, and that key stakeholders have yet to fully recognize the developmental potential of valorising the region's unique natural and cultural resources through the creation of transnational cultural routes. Despite the growing academic and policy interest in cultural routes, there is a notable research gap regarding their implementation, management, and stakeholder involvement in Istria, making the region an underexplored context for studying Cultural Routes of the Council of Europe. This paper represents one of the first academic studies to address these gaps by exploring the development challenges and perspectives of European cultural routes in Istria. By combining an analysis of current literature, available data, and stakeholders' attitudes, the research provides a comprehensive overview of the current state and underscores the critical importance of transnational collaboration and stakeholder engagement for the effective development of sustainable cultural tourism initiatives in the region.

2. Theoretical framework

The turbulent global context, characterized by economic, political, social and environmental crises, requires the elaboration of new models for the effective management and sustainable use of limited and valuable cultural resources. As pointed out by Urošević and Afrić Rakitovac (2017), current strategic frameworks emphasize the importance of national and regional competitive advantage through transnational cooperation and sustainable mobilization of unique local resources, with cultural heritage

representing a form of capital of irreplaceable cultural, social, environmental, and economic value. Transnational cultural tourism initiatives, which respect both the local population and visitors, cultural heritage and the environment, offers appropriate models for the sustainable management of cultural heritage (Urošević and Afrić Rakitovac, 2017). The role of cultural heritage in sustainable development has become a widely recognized and crucial concept advocated by leading international organizations (ICOMOS, 2011; UNESCO, 2013b; UNESCO, 2015; Labadi et al., 2021), especially by the United Nations in 2015 through the 2030 Agenda and its 17 Sustainable Development Goals (SDGs). A key aspect of cultural sustainability is the empowerment of local communities through their active participation in heritage management (Labadi et al., 2021). The involvement of key stakeholders in heritage management represents an innovative model within the cultural and tourism sectors, as it fosters a collaborative ecosystem that enhances the sustainability and resilience of cultural resources (McKercher and du Cros, 2002; Huibin and Marzuki, 2012; Mihalic, 2016; Afrić Rakitovac and Urošević, 2023).

The European Cultural Heritage Strategy for the 21st Century (Council of Europe, 2017) defines the common European heritage as an irreplaceable repository of knowledge and a valuable resource for economic growth, employment and social cohesion. The way we preserve and valorise it is the main factor in defining the attractiveness of Europe as a place to live, work and travel. Transnational cooperation is vital for valorising and managing common European heritage, with several initiatives exemplifying this collaborative approach. UNESCO plays a key role through the World Heritage Sites programme, which encourages countries to work together to protect and promote their shared cultural and natural heritage of Outstanding Universal Value (UNESCO, 2013a). The Creative Cities Network initiative fosters collaboration among cities that prioritize creativity and cultural development, enhancing local identities (UNESCO, 2020). Similarly, the European Capitals of Culture programme promotes cultural exchange and tourism by highlighting the diverse cultural expressions across Europe in selected cities each year, encouraging them to showcase their heritage and engage citizens and visitors alike. European Heritage Label promotes the symbolic European values by celebrating heritage which played the significant role in the European history and culture (European Commission, 2025). The Cultural Routes of the Council of Europe programme promotes transnational cultural tourism by connecting sites and regions through thematic routes that reflect shared heritage and historical narratives, fostering a sense of common identity among diverse communities (Council of Europe, 2015).

As indicated by Prokkola (2007), cultural routes emerge as powerful tools for connecting fragmented heritage across borders and for stimulating both cultural and socioeconomic growth. European cross-border regions have become spaces of communication and interaction, by using opportunities for tourism development through transnational cooperation projects. Harris (2017) elaborated on specificities of identity and heritage of cross-border regions of eastern and central Europe, focusing on the fluidity of borders in the EU and the hybridity of this transborder identity. According to Timothy (2001), these regions often encompass multiple linguistic and cultural identities, making them ideal settings for the development of cultural routes promoting intercultural dialogue, shared narratives, and sustainable territorial development. Urošević and Kaurin (2017) affirm that valorising the shared European heritage of cross-border regions aligns closely with the principles of transnational cooperation embedded in the Cultural Routes of the Council of Europe programme. Serving as frameworks for interpreting and linking heritage assets across borders through thematic storytelling, cultural routes also encourage collaborative governance and community engagement (Berti, 2013; Council of Europe, 2015). The authors of this paper aim to examine the development potential of investing in such transnational cultural routes, which may not only reinforce historical and cultural ties but also foster socioeconomic development and political cooperation between neighbouring countries.

The Cultural Routes of the Council of Europe were established in 1987 with the certification of the first European cultural itinerary: the pilgrimage route The Camino de Santiago. To date, 49 cultural routes have been certified, of which 21 pass through the Republic of Croatia, all with the aim of discovering and presenting our common rich and diverse heritage, fostering a better understanding of European cultural identity, and connecting people and places within a shared European space (Council of Europe, 2015; Trupković, 2021, Council of Europe, 2025). The "Roadmap for the Adriatic-Ionian Region" (Council of Europe, 2018) provides background information and recommendations for stakeholders working in the field of sustainable tourism, cultural cooperation and social participation. It contains guidelines for national, regional and local authorities in the Adriatic-Ionian Region on the certification and management of the Cultural Routes of the Council of Europe.

Itineraries and routes emerge from the intricate and inseparable interconnection of a region's culture, history, nature and economy (Trono, 2022). Recognized as the most powerful medium for interpreting cultural heritage and history, routes represent a developmental model of cultural tourism by valorising unique local cultural resources and offering an innovative cultural-tourism product that meets the needs and expectations of modern tourists. These thematic routes are particularly distinctive as they can diversify and expand demand over time and space, contribute to the valorisation of underutilized cultural assets, and create new segments of demand for specific forms of tourism. Furthermore, cultural routes enable visitors to understand and appreciate cultural relationships and phenomena, while tourism based on these routes serves as a model for cultural and tourism development that promotes not only the tourism sector but also social and economic growth (Nagy, 2016; Urošević and Kaurin, 2017).

In recent years, numerous and varied definitions of cultural routes have emerged. According to Sugio (2005), a cultural route can be understood theoretically through both spatial and temporal axes, serving as a geographical representation of continuity rooted in movement and exchange dynamics. Council of Europe defined European cultural routes as: „a route crossing one, two or more countries or regions, organised around themes, whose historical, artistic or social interest is European, either by virtue of the geographical route followed or because of the nature and/or scope of its range and significance" (2015, 15). Trono (2022, 14) indicates that cultural routes and itineraries are seen as „open-air museums, the historical and contemporary expressions of a complex regional heritage rich in cultural and environmental assets and meanings". A cultural route can be also seen as a combination of three elements: the geographical area encompassing key attractions and sites, the theme that unifies the various components of the route, and the tourism products and services provided to visitors at the different destinations included in the route (Majdoub, 2010; Zabbini, 2012; Pattanaro and Pistocchi, 2016).

Cultural routes represent a complex and multidimensional concept primarily associated with cultural-historical heritage, its preservation, management, valorisation, and interpretation. As a concept that meets the aspirations of the postmodern tourist, cultural routes derive from both material cultural-historical heritage and intangible culture. By combining the past and the future, they lead to unique experiences. Thus, cultural routes represent a geographical journey across a specific territory, through various local identities, imbued with representative values, meanings, expectations, and experiences, ultimately forming a distinctive cultural-tourism product (Horvat and Klarić, 2013). According to Dolenec (2024), potential for development of cultural routes depends on the effective coordination and collaboration of stakeholders from the tourism and cultural sectors; public institutions, the private sector, local communities, and experts.

Based on the theoretical insights gathered, it is evident that cultural routes serve for connecting heritage, tourism, and local communities across regions and borders. The effective management and sustainable development of cultural routes strongly depend on the active involvement of multiple stakeholders,

including public authorities, local governments, tourism boards, cultural experts and local community representatives, whose collaboration ensures both the preservation of cultural assets and the promotion of socio-economic benefits for the region. This paper focuses on Istria County, and the research highlights the current state of development of certified Cultural Routes of the Council of Europe in the region. This leads to the formulation of the following research questions, which will be addressed in detail through the following chapters: (RQ1) which certified cultural routes are currently actively managed in Istria County, and what is the role of different stakeholders in this process? and (RQ2) what are the main opportunities and challenges for further development and integration of Istria County into the Cultural Routes of the Council of Europe programme?

3. Research methodology

The conducted primary research was designed to address the lack of empirical knowledge regarding the development of the Cultural Routes of the Council of Europe in Istria County. Its main aim was to investigate the current state of certified routes, assess the roles and perspectives of key regional stakeholders, and identify both challenges and opportunities for further development and integration into the European programme. By combining field and desk methods, this research provides concrete, locally grounded evidence that complements the literature review and enables a comprehensive understanding of the region's development potential, stakeholder engagement, and strategic priorities.

This paper is based on a case study design, suitable for researching socio-cultural phenomena within their real-life context, enabling an analysis of institutional, thematic, and stakeholder dimensions (Sitorus, 2021; Richards and Munsters, 2010). The authors chose this qualitative methodology due to the lack of academic research dedicated to cultural routes in Istria County (Ilić, 2017; Rizzo, 2022; Urošević et al., 2024), limited available data and information about certified routes, as well as the initial phase of their development in the region.

After the literature review, the authors present the results of the conducted empirical research. Given the lack of available information on the Cultural Routes of the Council of Europe in Istria County, the research results analysis starts with an overview of certified routes in Croatia, followed by a focused analysis of Istria County as a specific cross-border region, including previous projects related to the development of various cultural routes and the mapping of active certified routes in the region. For the first part of the research, desk research was employed, based on available European publications on cultural routes, official websites, and media articles, complemented by field research method.

To present the current state of cultural routes development in Istria County, the authors conducted semi-structured interviews with representatives of regional stakeholders (N=7), including representatives of regional administrative departments (Tourism Department of Istria County; Istria Cultural Agency), local self-government units (City of Labin), tourism boards (Tourist Board of Pula; Tourist Board of Labin), and experts (Juraj Dobrila University of Pula; international expert in heritage interpretation). Interviews were conducted live, via telephone and email, and the responses were analysed using synthesis and interpretation methods. For the research purpose, over 20 representatives of key stakeholders in Istria County, who are currently involved or could potentially be involved in the Cultural Routes of the Council of Europe programme, were contacted. Despite multiple attempts to reach them, the limited response may already anticipate either a lack of awareness or inssufficient interest regarding European cultural routes in Istria County.

The results of the empirical research were critically discussed and are presented in Table 3. Additionally, the discussion includes findings from research conducted by students at the Interdisciplinary Study

Programme of Culture and Tourism, Juraj Dobrila University of Pula, Croatia. Besides the student research projects, cultural routes have become a highly relevant subject for researchers at the Juraj Dobrila University of Pula, as a member of the University Network for Cultural Routes Studies. Recent studies by Urošević et al. (2024) and Dolenec (2024) reflect growing interest in theoretical foundations and methodological frameworks for analysing the development of European cultural itineraries.
The conducted research provides a foundation for addressing the research questions formulated in the paper and for initiating a discussion not only on the status but also on the possibilities for certifying new routes and their development in Istria.

4. Research results

4.1 Cultural Routes of the Council of Europe in Istria County

The Republic of Croatia has been a full member of the Council of Europe since 6 November 1996. In 2018, Croatia took over the chairmanship of the Council of Europe's Committee of Ministers for a period of six months. Croatia has continuously adopted and implemented the standards of the Council of Europe and actively participated in its programmes and activities, positioning itself as an engaged and active member. To date, Croatia is a member of 13 out of 14 partial agreements of the Council and has ratified 93 of its instruments. In 2010, the Committee of Ministers of the Council of Europe adopted the Enlarged Partial Agreement on Cultural Routes to facilitate better cooperation between member states, and today the agreement includes a total of 34 states. The Republic of Croatia acceded to the agreement in 2016 and has been an equal member since then (Trupković, 2021; Ministry of Foreign and European Affairs of the Republic of Croatia, 2025). Croatia's heritage, shaped by centuries of interaction with neighbouring cultures, reflects its unique transnational and multicultural dimension, bridging Mediterranean, Central European and Balkan influences. By participating in the Cultural Routes of the Council of Europe, Croatia emphasizes its role within European heritage networks, joining 21 certified cultural routes (Table 1) that highlight common European narratives. This routes are shown in Table 1 in Appendix A of this article (Table 1, Appendix A).
Due to its strategic location along key road and maritime corridors connecting the Mediterranean with Central Europe, Istria historically functioned as a vital crossroads of peoples and cultures (Trono, 2022). Istria is the westernmost county of the Republic of Croatia and is recognized as a multi-ethnic, multicultural, and multilingual community. As both a peripheral Mediterranean peninsula and a frontier of Mediterranean multicultural civilization, Istria represents a unique intersection of cultural influences, making it an especially relevant region for the development and study of transnational cultural routes. Elaborating on the specificities of the regional identity of Istria as a trans-border region, Šuligoj (2022, 73) emphasizes that, due to its extremely dynamic history and rich cultural exchange, „Istria could be classified into a Central-European trans-border group of regions as a special trans-border spatial system“.
According to Afrić Rakitovac, Urošević and Vojnović (2021), there are more than 50 protected historical landscapes in Istria and many individual localities and monuments, which could all represent the points of a cultural landscape network, around which a narrative can be constructed on the past and present. At the same time Istria is the leading Croatian tourism region: due to its central position, diversity and richness of cultural and natural heritage, Istria counts for 25% of tourist arrivals, 25% of tourism beds and almost a third of total overnight stays in the Republic of Croatia (Table 2). The key challenge of the current tourism development model in Istria lies in the pronounced seasonality and the heavy

concentration of tourists in coastal destinations. This results in overcrowding during peak months and underutilization of resources in the off-season, creating economic and environmental pressures.

Table 2. Tourist arrivals and overnights in Istria 2019-2024

Year	Arrivals	Overnights
2019	4.609.799	28.709.556
2020	1.877.134	13.514.865
2021	3.500.149	23.534.894
2022	4.709.345	29.507.887
2023	4.970.172	30.134.117
2024	5.005.829	29.899.508

Source: Istria Tourist Board (2025). Statistical reports. Available at: https://www.istra.hr/en/business-information/istria-in-media/statistics.

Elaborating regional specificities and territorial complexity, Rizzo (2022) identified three multi-themed routes in the framework of the European Community project "Quality Network on Sustainable Tourism (QNeST)": Cultural-natural route, Route of North Istria and Route of South Istria. After Glagolitic Alley, the first cultural-tourism brand in Istria (Bratulić, 1994), the exciting history and common European heritage of the Istrian region was presented in the Parenzana cross-border route (Parenzana, 2025). Through the European projects Heart of Istria and Revitas, cross-border routes were developed that valorised the cultural heritage of the interior of Istria, such as the Route of Istrian Castles, the Route of Frescoes and Istrian archaeological parks - The Path of Gods (Ilić, 2017).

In Istria County today, seven cultural routes certified by the Council of Europe are officially recognized and they will be presented in the following text. However, there is currently a lack of publicly available information detailing the actual status of these certified routes, including their descriptions, operations, functions, and overall implementation. This gap makes it difficult to fully understand their impact and role within the region.

The Roman Emperors and Danube Wine Route include exceptional Roman-era destinations and covers the whole of Croatia, promoting it directly at the level of archaeological tourism, including the city of Pula and National Park Brijuni. The route connects archaeological sites and their unique monuments with the activities of the Roman emperors and shows how the ancient Roman culture spread beyond the borders of the Empire (The Roman Emperors and Danube Wine Route, 2025). Part of the cultural route is the Pula Amphitheater, which is also the 6th largest arena in the world. In the National Park Brijuni, the Roman villa in Verige Bay represents a luxurious residential complex which included temples dedicated to the god of the sea Neptune, the Capitoline Triad and the goddess of love Venus.

The town of Labin is the leader of the ATRIUM cultural route, which also presents the good practice model of successful transnational cooperation in valorising and interpreting common European dissonant heritage. Labin involved the urban settlements of Podlabin and Raša, which are characterized by specific and unique architecture from the period of Italian fascism. The aim of the route is to give greater importance to the architecture of totalitarian regimes as a valuable cultural heritage and to recognize it as a key element of European architecture of the 20th century. The ultimate goal is to establish a transnational cultural route in the area of Southeast Europe (Atrium Route, 2025).

The House of Istrian Olive Oil – Museum Olei Histriae joined the Olive Routes in 2018. The museum provides an insight into the history of olive growing in Istria and olive processing methods from the

Roman era until today. It also offers guided tastings, where visitors can learn how to properly taste olive oil, the differences between varieties and how to match it with food.

Recognized by the Council of Europe in 2009, Iter Vitis Route highlights both the tangible and intangible elements of wine-growing traditions and landscapes as integral part of regional identity and history. The itinerary encourages to diversify wine tourism, focusing on the unique features of Europe's viticultural regions (Iter Vitis, 2025). Although Istria County is one of the most prominent wine regions in the world, only the picturesque historic town of Motovun has signed the charter of cooperation with the Iter Vitis route. Despite its strong wine identity and the ongoing development of renowned wineries, the region of Istria has yet to fully recognize the potential of formally integrating into the Iter Vitis Cultural Route.

Poreč became the first city in Croatia to join the European Phoenician Route association. The route promotes Mediterranean culture and intercultural dialogue between Mediterranean regions and countries, as well as their historical, tangible and intangible heritage, landscape and ambience. This route also promotes sustainable, responsible, creative and cultural activities, strengthening local and common Euro-Mediterranean identity. The route of the Phoenicians refers to the main nautical routes used by the Phoenicians from the 12th century BC for trade and cultural communication in the Mediterranean. Through these routes, the Phoenicians, famous sailors and traders, became a powerful civilization that contributed to the creation of the Mediterranean cultural community. Other great Mediterranean civilizations, such as the Greeks, Romans, Etruscans and Iberians, used these routes for the same purpose, making them an important part of Mediterranean culture (Phoenician Route, 2025). Except for the information about joining this association, there are no available data regarding the current status and development of the route in Poreč.

Saint Martin of Tours, venerated since the 4th century, was a widely revered Christian bishop whose shrine in Tours, France, became a major pilgrimage destination in the Early Middle Ages. His legacy is honored through the Via Sancti Martini/Saint Martin of Tours Route, a network of over 5,000 km of pilgrimage routes across more than 12 European countries. Along these routes, travellers encounter not only impressive architectural monuments, such as fourteen cathedrals dedicated to him, but also living traditions, legends, and folklore that keep his spiritual and cultural heritage alive (Via Sancti Martini, 2025). The route also passes through Istria County, with sections running through Tar-Vabriga, Vrsar, and Ližnjan.

The Brotherhood of St. James with the cooperation with the Camino South Istria route created a new route in Istria, with the goal to become part of the Croatian Camino route in the European network of pilgrimage routes of St. James. Aa a circular route, which covers the entire area of southern Istria, with a total length of 192 kilometres, it connects the city of Pula with picturesque villages Medulin, Ližnjan, Marčana, Vodnjan and Fažana. The Camino South Istria route is divided into seven pilgrimage chapters, for seven days that are needed to experience the historical, cultural, and sacral heritage in impressive natural environment. The route has a great potential also in promoting the local way of life and traditions, local product and economies, but also healthier lifestyles (Cammino Croatia, 2025).

4.2 Key Stakeholders` Attitudes: Current State, Challenges and Development Perspectives

As part of the research, semi-structured interviews were conducted with key stakeholders in Istria County, including representatives from regional administrative departments, local self-government units, tourism boards, and experts (N=7). The aim of these interviews was to gain in-depth insight into the current level of awareness, involvement, and strategic perspectives regarding the development and implementation of the Cultural Routes of the Council of Europe in the region.

The first question concerned the extent to which stakeholders are familiar with the Council of Europe Cultural Routes programme and whether they believe that sufficient attention is being paid to their development in Istria. Most respondents showed some knowledge of the programme, although the level of information and involvement varied. Representatives of city departments and tourist boards confirmed their involvement in certified routes, and others indicated their contribution indirectly through project support or cultural planning. All respondents agreed that Istria, due to its multi-layered history and rich heritage, has a strong potential for development of European cultural routes. However, county department and agencies, as well as experts, highlighted that this potential has not yet been fully realised. Although some regional strategic documents recognise their importance and have supported similar initiatives, actual visibility, institutional commitment and long-term planning around the development of routes remain limited. Representatives of the expert group stated that "very little is known about these routes, and they are not sufficiently used, neither in promotion nor in concrete projects" (international heritage interpretation expert). A consistent response was that cultural routes are recognised in principle, but require greater attention, clearer leadership and better integration with local communities to become more effective tools for heritage valorisation and regional development.

The second question focused on the respondents' institutions or local/regional self-government units' active involvement in any certified route, and in what capacity. A small proportion of respondents (3) reported direct involvement in certified cultural routes, including contributions through thematic heritage resources (ATRIUM route in Labin, Camino South Istria in Pula). Representative of the regional tourism department reported that, although they are not formally part of the certified routes, they contribute through promotion, documentation or content development. There is also indirect involvement from the regional cultural agency (Istrian Cultural Agency) through interpretative programming, thematic itineraries and film-based storytelling, which serve as alternative approaches to engagement with European cultural heritage. This range of involvement reflects a broader reality: although relevant institutions and municipalities recognize the value of the routes, systematic and coordinated integration into the framework of certified routes is still lacking across the region. Expert stakeholders draw attention to a lack of transparency and accessible information regarding Cultural Routes in Istria. While acknowledging that several Istrian cities and municipalities are formally included in various routes, they emphasise that "there is no up-to-date information on most routes, their management, current status, or activities".

The third question explored potentials of developing new cultural routes. Respondents agreed that routes provide structured frameworks for presenting regional identity and heritage in ways that are authentic and attractive to visitors. They also highlighted that routes represent tools for strengthening European identity, promoting intercultural dialogue and supporting experiential tourism models. Some stakeholders (Istrian Cultural Agency) suggested new practices in digital interpretation, film tourism and multimedia storytelling as particularly effective methods for increasing engagement and broadening audiences, especially among younger generations.

The fourth question examined the main challenges facing the development and certification of cultural routes in Istria. Several recurring challenges were identified. These include:

- Lack of coordination among key actors,
- Insufficient cross-sector collaboration,
- Limited funding and dedicated personnel,
- Property ownership and access issues,
- Dominance of mass tourism, and
- Limited strategic vision and planning capacity.

All respondents particularly highlighted that smaller cities often possess significant heritage but lack the administrative or technical capacity to participate in complex certification processes. According to interviewed experts, the activities of the cultural and tourism sectors are not coordinated. The bureaucratic requirements of the certification process, including documentation, long-term planning and cross-border partnerships, are considered challenging for institutions with limited resources.

The last question investigated the potential of cultural routes as innovative models for the valorisation of Istrian cultural heritage. Respondents agreed that cultural routes offer a valuable and effective model for valorising cultural heritage and promoting regional development, as cross-border platforms for education, cultural exchange, economic innovation and sustainable tourism. The interviewees emphasized that the unique heritage of Istria, from prehistoric and Roman remains to industrial and architectural heritage, offers a huge, untapped potential for the development of routes. With the right strategic support, investment and coordination, the region could position itself as a leader in the field of cultural tourism based on the principles of the Cultural Routes of the Council of Europe. A recurring theme across interviews is the view that participation in cultural routes is an enabling mechanism rather than a prerequisite for successful heritage valorisation. Representative of the county tourism department stated that "inclusion in cultural routes can contribute to all of these goals, but it is not a precondition; everything depends on the individuals involved and the available financial resources." This perspective highlights the importance of human capital, leadership, and institutional commitment over formal affiliation alone. Experts noted that, apart from the Iter Vitis route, there is limited awareness of other routes actively operating in the region, suggesting a gap between strategic frameworks and tangible outcomes.

5. Discussion

The results of the empirical research are presented in Table 3. The table provides a structured synthesis of the main findings by identifying key dimensions affecting the development of the Cultural Routes of the Council of Europe in Istria County, outlining current challenges, potential development opportunities, and recommended actions.

The conducted research indicates that strategic development in the fields of culture and tourism in Istria County should prioritize investment in the development and certification of cultural routes that most strongly reflect Istria's shared Euro-Mediterranean heritage. Such investments would not only contribute to the valorisation and sustainable use of Istria's unique cultural landscape but also foster transnational cooperation by linking Istria with other European destinations. This can be achieved through the creation of integrated cultural-tourism products, including thematic routes, interpretation centres, and other innovative heritage presentation tools, thereby strengthening Istria's visibility and competitiveness within the broader European cultural landscape.

The research results highlight that the Cultural Routes of the Council of Europe in Istria are currently insufficiently developed, weakly visible, and fragmented in their implementation. Although some Istrian cities are formally included in certified routes, they often function as isolated initiatives or symbolic affiliations, rather than as fully operational, strategically coordinated development instruments. This discrepancy between formal inclusion and practical implementation is one of the central findings of the research.A major obstacle identified across interviews is the fragmentation of goals and priorities among key stakeholders. While representatives of regional and local authorities, tourism organisations, cultural institutions, and experts generally acknowledge the potential of cultural routes, their expectations and

levels of engagement differ significantly. This lack of alignment is further reinforced by fragmented governance structures and weak intersectoral coordination, as reflected in the dimensions in Table 3. Interviews revealed the absence of a central coordinating body at the regional level responsible for managing, monitoring, and promoting cultural routes, as well as limited mechanisms for involving local communities, NGOs, and small and medium-sized enterprises. Consequently, stakeholder participation remains largely passive and project-dependent.

Table 3. Development Potential of Cultural Routes of the Council of Europe in Istria County

Dimension	Current Challenges	Development Opportunities	Recommended Actions
Institutional Cooperation	Fragmented governance; limited coordination across borders	Potential for cross-border cultural governance frameworks	Establish transnational management bodies; enhance inter-municipal agreements
Stakeholder Engagement	Low awareness among local actors; passive involvement	Engaging local communities, NGOs, SMEs in co-creation of routes	Conduct stakeholder workshops; develop participatory planning mechanisms
Funding and Investment	Reliance on short-term project funding	Access to EU programs (e.g., Interreg, Creative Europe, Horizon Europe)	Develop long-term funding strategies; promote public-private partnerships
Cultural Resource Integration	Underutilization of tangible and intangible heritage	Possibility to link diverse heritage types into unified thematic routes	Map and digitize heritage assets; create cross-border thematic clusters
Tourism and Promotion	Lack of route visibility; weak marketing infrastructure; coastal and seasonal tourism	Development of sustainable, experience-based tourism offerings	Design cross-border itineraries; enhance branding and digital presence
Education and Interpretation	Limited heritage interpretation tools	Opportunities for multilingual, interactive cultural education	Create digital storytelling platforms; promote school-route collaborations
Monitoring and Evaluation	Absence of systematic impact assessment	Potential to develop indicators aligned with Council of Europe standards	Implement local route observatories; use cultural impact metrics
Identity and Cohesion	National narratives may dominate over shared heritage	Cultural routes can foster shared European identity and territorial cohesion	Promote inclusive narratives; encourage bi-national cultural festivals

Source: authors' research (2025)

Another significant issue is the low visibility of cultural routes, particularly in comparison to dominant coastal and seasonal tourism models. Apart from a few better-known thematic routes, such as wine-related itineraries, most European Cultural Routes in Istria are poorly promoted, weakly interpreted on-site, and insufficiently integrated into coherent tourism products. This reduces their capacity to contribute meaningfully to sustainable tourism diversification, cultural economy development, and territorial cohesion.

Importantly, the research indicates that Istria's situation is not exceptional. Previous studies (e.g. Timothy and Boyd, 2014; Lin et al., 2024) have shown that cultural routes often struggle with fragmented governance, limited institutional capacity, and dependence on short-term project funding, particularly in regions where mass tourism or sectoral policy silos dominate development strategies. In this sense, Istria exemplifies a broader structural challenge within the Cultural Routes of the Council of Europe programme; certification alone does not guarantee effective implementation.

Additionally, this discussion includes findings from research conducted by students at the Interdisciplinary Study Programme of Culture and Tourism, Juraj Dobrila University of Pula, Croatia. In the framework of courses on Heritage Management and Cultural Routes, students explored the development potential of the Cultural Routes of the Council of Europe programme in Croatia. By combining desk research and primary field research, they analysed existing routes and proposed the development of new sections for more than 20 European cultural routes.

Through consultations with key stakeholders and site visits, students collected data on heritage resources, accessibility, and development potential. Their final theses addressed topics such as Cultural routes of the Council of Europe in the Republic of Croatia; European cultural route of Historic Thermal Towns – Croatian section; European route of Industrial Heritage – regional route in Croatia; Possibilities of improving international cultural cooperation by creating new sections of European cultural routes; European cultural routes - Transromanica (proposal for the development of the Croatian section); European Cultural Routes – Routes of archaeological heritage; European cultural routes – Istrian cultural itinerary on the Route of Saint James, etc.

These findings further confirm the untapped potential identified in stakeholder interviews. This research reveals opportunities for developing new cultural routes in Istria County, such as the Istrian section of the European Route of Industrial Heritage, which could valorise the industrial heritage of Labin and Raša, and the integration of Istria's Glagolitic heritage into the Cyril and Methodius Route, focusing on sites such as the Glagolitic Alley between Roč and Hum. Furthermore, within ongoing European initiatives such as the FORTIC project (From Remains of the War to the Architecture of Peace in the Cross-Border Area of Italy–Croatia), there is significant potential for further development of Pula's fortification heritage. Integration within the FORTE CULTURA network could enhance transnational cooperation and provide new interpretative layers for Istria's fortified architectural heritage.

6. Conclusion

Cultural heritage in cross-border and multicultural regions, such as Istria County in Croatia, could be used as a catalyst for sustainable economic development and valorisation of cultural heritage. The conducted research confirmed that the Cultural Routes of the Council of Europe, as accessible and flexible cultural-tourism products based on the networking of attractions, services, and narratives, could offer significant potential to strengthen local identities and regional economy, enhancing the visibility of European cultural values and transnational heritage.

The research results, addressing RQ1 and RQ2, indicate that in Istria the Cultural Routes of the Council of Europe remains at a very early stage of development, with seven certified routes. The lack of a

coordinated and strategic approach, limited stakeholder engagement, orientation towards the development of coastal and seasonal tourism, and weak institutional cooperation have contributed to the underutilization of Istria's full potential within the Council of Europe's programme. Istria is particularly well-positioned to become a model region for sustainable and transnational cultural tourism, given its geopolitical location, cultural diversity, and active cross-border partnerships. The success of cultural routes in Istria depends on their ability to function as dynamic, inclusive platforms that support not only economic innovations but also heritage management, education, and intercultural dialogue.

The scientific contribution of this paper arises from the analysis of the underexplored issue of the development of Cultural Routes of the Council of Europe in specific cross-border regions (such as Istria County), addressing a research gap in theoretical conceptualization and providing empirical evidence that has not yet been documented in this context. The paper also introduces an innovative methodological approach to the study of cultural routes, applying a multidisciplinary framework that combines desk and field methods, allowing a comprehensive understanding of both theoretical and practical aspects of cultural route development, including the transnational and cross-border dimension.

A key recommendation emerging from the research is related to the importance of promoting European cultural routes, by the active involvement of regional stakeholders in the process of planning, implementation, and long-term management. In the process of valorising regional heritage through transnational initiatives, such as Council of Europe, cultural routes represent a model for developing the sensibility and belonging of local communities with the unique cross-border Istrian heritage.

This paper acknowledges several limitations. Besides the small sample size of interviewed representatives of key stakeholders, the paper focuses only on Istria County and does not provide a comparative analysis with other Croatian or European regions. Despite these limitations, the conducted research provided an initial insight into the current state of development of cultural routes in Istria, contributing to the growing academic discourse on cross-border heritage valorisation. Future research should include structured and in-depth assessment of cultural routes development, applicate cultural routes evaluation model and measuring the sustainability of existing sections of cultural routes.

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APPENDIX A:

Table 1. Cultural Routes of the Council of Europe in the Republic of Croatia

Route Name	Year	Description
Santiago De Compostela Pilgrim Routes	1987	Historic pilgrimage path leading to the shrine of St. James in Santiago de Compostela, celebrated for its spiritual, cultural, and historical significance.
Phoenicians' Route	2003	Traces the ancient maritime trade routes of the Phoenicians across the Mediterranean, highlighting their cultural exchanges and influence.
European Route of Jewish Heritage	2004	Explores Jewish cultural sites across Europe, focusing on Jewish history, heritage, and contributions to European culture.
Saint Martin of Tours Route	2005	Follows the path of Saint Martin, promoting his legacy of charity and peace, and linking sites associated with his life across Europe.
Routes of the Olive Tree	2005	Celebrates the Mediterranean's olive-growing heritage, highlighting cultural, historical, and economic impacts of olive trees and olive oil.
TRANSROMANICA	2007	Showcases Romanesque architecture and art across Europe, with sites symbolizing a shared European heritage.
Iter Vitis Route	2009	Dedicated to Europe's rich viticultural landscapes, this route emphasizes the cultural history of wine and traditional viticulture.
European Cemeteries Route	2010	Highlights significant cemeteries across Europe, offering insight into social, cultural, and historical practices related to memorialization.
European Route of Historic Thermal Towns	2010	Connects historic spa towns, celebrating Europe's tradition of thermal baths and the cultural importance of wellness and health tourism.
European Route of Ceramics	2012	Focuses on Europe's ceramic heritage, covering regions known for traditional ceramic production and artistic ceramic works.
ATRIUM	2013	Highlights European totalitarian regimes' architecture, reflecting 20th-century political history through monumental structures.
Roman Emperors and Danube Wine Route	2015	Combines Roman historical sites along the Danube with regional wine culture, connecting history with gastronomic tourism.

Destination Napoleon	2015	Follows Napoleon Bonaparte's influence across Europe, linking sites that highlight his era's historical and cultural legacy.
Impressionisms Routes	2018	Celebrates Impressionist art, connecting European sites that inspired and displayed works from this influential movement.
European Route of Industrial Heritage	2019	Explores Europe's industrial heritage, highlighting historical sites of industry, engineering achievements, and their cultural impacts.
Iron Curtain Trail - Eurovelo 13	2019	Cycling route along the former Iron Curtain, emphasizing Europe's division and subsequent reunification, with historic and scenic stops.
Iron Age Danube Route	2021	Covers significant Iron Age archaeological sites along the Danube, highlighting ancient European civilizations and their heritage.
Cyril and Methodius Route	2021	Focuses on the legacy of Saints Cyril and Methodius, exploring cultural and religious sites across Europe connected to their missions.
European Fairy Tale Route	2022	Connects regions and sites associated with European fairy tales, celebrating folklore, storytelling traditions, and cultural imagination.
Women Writers Route	2022	Honors Europe's historic women writers, promoting literary heritage and recognizing the contributions of women in literature.
European Route of Historic Pharmacies	2024	Highlights Europe's historic pharmacies, celebrating the history of medicine, pharmacy practices, and cultural heritage.

Source: Council of Europe (2025). *Croatia – Cultural Routes*. Available at: https://www.coe.int/en/web/cultural-routes/croatia.

Trenutno stanje i perspektive razvoja Kulturnih ruta Vijeća Europe u Istarskoj županiji

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Sažetak: Rad se osvrće na trenutno stanje i razvojne potencijale Kulturnih ruta Vijeća Europe u Istarskoj županiji (Hrvatska). Autori su krenuli od pretpostavke da Istra, kao prekogranična, multikulturalna i višejezična regija koju karakterizira prepoznatljiv kulturni krajolik, ima veliki potencijal za stvaranje europskih kulturnih ruta. Istraživački problem proizašao je iz zapažanja da je provedba Kulturnih ruta Vijeća Europe u Istri još uvijek u ranoj fazi razvoja te da ključni dionici još nisu u potpunosti prepoznali strateški potencijal valorizacije jedinstvene baštine regije kroz razvoj transnacionalnih kulturnih ruta. Metodologija istraživanja temeljila se na kvalitativnom dizajnu studije slučaja i kombinaciji desk i terenskog istraživanja, što je uključivalo intervjue s predstavnicima ključnih dionika. Nakon pregleda literature, ovo istraživanje predstavlja studiju slučaja Istarske županije. Analiza se usredotočuje na identificiranje trenutnih izazova, razvojnih prilika i preporučenih strateških akcija povezanih s provedbom Kulturnih ruta Vijeća Europe u regiji. Rezultati sugeriraju da europske tematske kulturne rute, kao najpristupačniji i najisplativiji oblici kulturnog turizma, mogu imati važnu ulogu u jačanju lokalnih identiteta i poticanju održivog regionalnog gospodarskog razvoja. Istarska županija, kao transgranična granična regija, mogla bi promovirati kulturne rute kao model valorizacije zajedničke europske baštine i temeljnih europskih vrijednosti.

Ključne riječi: kulturne rute, Vijeće Europe, transgranične regije, europska baština, Istra
***JEL klasifikacija*:** O10, O19, Z1, Z32

UNESCO Global Geopark Biokovo–Imotski Lakes: Potential Contribution to the Enhancement of Tourism in the Imotski Region

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Abstract: The purposes of the research were to determine the expected benefits of the designation of the Biokovo-Imotski Lakes Geopark (BILUGGp) as a UNESCO Global Geopark for tourism development in the Imotski Region, and the expected benefits of partnership programmes with the Geopark. The paper also reviews of examples of good practices from selected UNESCO Global Geoparks, highlighting projects and activities that could be adapted to support BILUGGp. Empirical research using the e-Delphi technique was employed to investigate the mentioned topic, in conjunction with online research regarding UNESCO Global Geoparks, pertinent documents, as well as scientific and professional literature. Data: The internet survey covered 213 UNESCO Global Geoparks, i.e., their websites, located in 48 countries, and 27 panellists ultimately participated in the e-Delphi survey. Results show the expected benefits of this designation for the tourism development of the Imotski Region include a substantial increase in the destination's visibility (37%), the promotion of new tourist facilities (33%), and the establishment of conditions favorable for geotourism development (32%). 2) The expected benefits arising from partnership programs with the Geopark are evident in collaboration with other Geoparks on particular projects (such as Geofood) (37%), enhanced overall promotion (30%), and greater visibility for stakeholders (26%). The designation of Geopark offers numerous benefits and opportunities for growth across the entire region, which encompasses Imotski, Biokovo, Zabiokovlje, and the Makarska Riviera. It promotes the development of tourism, enhances geotourism and destination branding, encourages collaboration with other Geoparks, and supports the development of agriculture, hospitality, trade, and services. Furthermore, it stimulates the revitalization of traditional crafts and customs, establishes a variety of partner programs, advocates for the sustainable management of both natural and cultural heritage, and contributes positively to the well-being of the local community.

Keywords: UNESCO Geoparks, Biokovo-Imotski Lakes Geopark, Delphi method, tourism development, benefits, partnership
JEL Classification: Z32

1. Introduction

UNESCO Global Geoparks (UGGps) are defined as unified geographical areas where sites and landscapes of international geological significance are managed through a holistic approach encompassing protection, education, and sustainable development (UNESCO, 2015). Beyond their geological heritage, UGGps leverage the natural and cultural assets of their regions to address key societal challenges, including sustainable resource management, climate change mitigation, and risk reduction from natural hazards. The UNESCO framework for UGGps emphasises a bottom-up strategy that integrates conservation with local development, increasingly engaging communities in decision-making processes. The creation and operation of Geoparks are guided by three interrelated pillars: geoconservation, geoeducation, and local development (Pérez-Romero et al., 2023). Geoparks and geotourism are widely recognised as instruments for fostering local development, community participation, and poverty alleviation, particularly in regions rich in geological resources (Dowling, 2013; Özgeriş & Karahan, 2021). Effective Geopark development requires careful consideration of local economic and social contexts, positioning geotourism as a critical driver of regional growth. Bibliometric analyses further demonstrate the increasing scientific interest in Geoparks: Herrera-Franco et al. (2021) reviewed 848 Scopus publications from 2002 to 2020, highlighting a growing emphasis on the definition, assessment, and sustainable management of geomorphological heritage and geosites. Similarly, Pérez-Romero et al. (2023) analysed 324 Web of Science articles on Geoparks, observing a notable increase in global research activity and a diversification of focus areas, particularly in geotourism linked to UGGps. Ruban and Yashalova (2024) report that scholarly publications on Geoparks tend to increase following UGGp designation, though research output remains uneven across different Geoparks. Their analysis identifies a broad spectrum of research themes, including geoheritage, geology, ecology, sustainability, and technological applications, while noting that the full scientific potential of Geoparks is often underutilised. Ruban, Mikhailenko, Yashalova and Scherbina (2023) further observe that the majority of UGGps are located in countries with high Human Development Indexes, with fewer than 10% situated in countries below the global average. They advocate for international support to establish Geoparks in developing nations and conclude that the full socio-economic and environmental significance of UGGps remains to be realised globally. As of August 2024, 213 UGGps have been established worldwide, including 110 across 28 European countries. China (47), Spain (16), Italy (11), France (10), and Japan (9) account for the majority of sites. With the designation of the Biokovo-Imotski Lakes UNESCO Global Geopark (BILUGGp), Croatia now hosts three UGGps, alongside the Papuk Geopark and the Vis Archipelago Geopark. This study aims to analyse the expected benefits of UGGp designation for tourism development in the Imotski Region and to evaluate the potential advantages of partnership programmes implemented by BILUGGp. It further examines selected examples of good practice, illustrating how UGGps contribute to sustainable tourism development, community engagement, and the integration of geological, natural, and cultural resources.

2. Literature Review

2.1 Benefits of UGGp Designation for Tourism Development

The designation of a UNESCO Global Geopark (UGGp) brings multiple advantages, including fostering economic growth, promoting sustainable tourism, supporting niche tourism sectors, providing cultural and educational benefits, and ensuring the preservation of both natural and cultural heritage.

Additionally, UGGp status enhances global networking and visibility, facilitating international cooperation and knowledge exchange. Geoparks are increasingly recognised as a valuable alternative to traditional sun-and-beach tourism, supporting local economies by generating revenue, creating employment opportunities, and stimulating the development of new services and products (Pérez-Calderón et al., 2022).

Economic benefits are evident in increased visitor numbers, which drive higher spending on local goods and services, foster the creation of new tourist products, and raise employment levels for the resident population. Beyond local communities, states benefit from higher tax revenues, which can be reinvested into public infrastructure and services. The designation also contributes to the preservation of cultural and natural heritage, reinforces local traditions and customs, and may even support demographic stability through reduced emigration.

UGGp recognition creates the preconditions for the development of specific forms of tourism, including geotourism, adventure tourism, educational tourism, and eco-tourism. It stimulates economic growth through increased trade, hospitality services, and local entrepreneurship (Reynard et al., 2016). Geopark status often encourages the establishment of visitor centres, museums, and eco-friendly accommodation, designed to meet the demands of growing tourist flows (Farsani et al., 2012). Geoparks function as hubs attracting visitors interested in their unique geological formations and cultural heritage, while simultaneously supporting employment in hospitality, retail, and cultural sectors (Briggs et al., 2023).

Geotourism, a central component of UGGps, combines the exploration of geological heritage with conservation and educational activities. This model mitigates the negative effects of mass tourism while fostering deeper understanding and appreciation of natural environments. By integrating local culture, education, and heritage interpretation into tourism offerings, Geoparks contribute to regional identity preservation and long-term sustainable development (Arrage, 2024). Core objectives include the sustainable management of natural and cultural resources through conservation initiatives and public engagement (Reynard, Coratza & Hoblea, 2016). Visitors not only experience geological and scenic landscapes but also gain insights into local traditions and environmental stewardship, strengthening the socio-economic resilience of host communities (Arrage, 2024).

International examples demonstrate the tangible benefits of UGGp designation. The Kanawinka Geopark in Australia, as well as several Asian UGGps, illustrate substantial increases in visitor numbers and local income, though they also highlight challenges such as uneven distribution of benefits across communities (Lee & Jayakumar, 2021). Geoparks provide cultural and educational benefits through workshops, school programmes, and community activities, promoting environmental awareness and strengthening connections between residents, visitors, and their environment. Membership in the UGGp Network enhances global visibility, facilitates collaboration, attracts international tourists, and supports funding for conservation initiatives (Xu & Wu, 2022; Briggs et al., 2023). UGGp status further encourages sustainable agricultural practices, local resource utilisation, and product branding, enhancing market value while supporting local economic growth (Farsani et al., 2012; Reynard et al., 2016).

Empirical examples from Europe and Croatia reinforce these points. The Papuk Geopark in Croatia implemented the Geo Stories of the UNESCO Geopark project in 2021 to enhance sustainable tourist infrastructure, increasing visitor numbers and improving management. In 2022, the GeoInfo Centre in Voćin welcomed 18,500 visitors, while the Panonian Sea House attracted approximately 4,000 visitors. Arouca Geopark in Portugal recorded a substantial increase in visitors after its 2009 UGGp designation, with numbers rising from around 50,000 in 2010 to over 600,000 by 2016, generating an estimated €3 million annually for local businesses (Neto de Carvalho & Rodrigues, 2017).

Similarly, the English Riviera Geopark (UK) observed a 15% increase in visitors in the five years following its 2007 designation, resulting in £2.7 million (€3.24 million) in direct spending and

supporting approximately 60 full-time local jobs (Farsani et al., 2012). The Petrified Forest Geopark on Lesvos, Greece, attracted 90,000 visitors annually post-designation, generating €5 million in geotourism-related income and creating both direct and indirect employment opportunities (McKeever, Zouros & Patzak, 2010). Idrija Geopark in Slovenia experienced a 25% rise in visitor numbers over three years after its 2013 designation, contributing an estimated €1.5 million annually to the local economy (Verbole, 2016). The Copper Coast Geopark in Ireland doubled its visitor numbers within three years of UNESCO recognition in 2004, generating €500,000 annually and creating new tourism and hospitality jobs (Fitzpatrick, 2015).

These examples collectively highlight how UGGp designation can enhance tourism development, strengthen local economies, and promote sustainable management of geological and cultural heritage, while also illustrating the importance of equitable distribution of benefits across communities..

2.2 The Potential Advantages of Partnership Programmes with UGGps

UNESCO Global Geoparks (UGGps) actively promote sustainability by involving local communities in job creation, income generation, and raising awareness of Earth heritage (Lee & Jayakumar, 2021). Partnerships with community members, businesses, and educational institutions facilitate inclusive development, foster transnational collaboration, and drive tourism growth, benefiting stakeholders at multiple levels (Hose, 2012; McKeever & Zouros, 2005; Farsani et al., 2012; Ristiawan, Huijbens & Peters, 2023). Such partnerships provide cultural and educational benefits, enhancing environmental stewardship and preserving traditional knowledge (Hose, 2012).

Collaboration between Geopark management and local communities delivers significant advantages, including cooperative initiatives like Geofood, support for economic and environmental development, preservation of cultural heritage, social cohesion, and community engagement. These partnerships also strengthen global networking, attract funding opportunities, and enhance the visibility of local stakeholders.

Economically, partnerships stimulate local economies through geotourism development and support for small and medium-sized enterprises. Collaborative efforts improve infrastructure, increase visitor spending, and enhance regional branding, collectively contributing to economic growth (globalgeoparksnetwork.org). One prominent example is the Geofood programme, adopted by 42 UGGps worldwide under the slogan ‘Visit and Taste’. This initiative fosters local food networks, promotes regional identity, creates new tourism and educational opportunities, and facilitates the exchange of good practices. Geofood products include geo-bread, herbal teas, honey, wine, aromatic soaps, oils, and other items linked to local geology and culture.

Vale et al. (2019) describe Geofood products as ‘gastronomic souvenirs’, connecting geological heritage with local food production, while certification ensures that raw materials and processing are preferably sourced within the Geopark (Gentilini & Thjømøe, 2015; Farsani et al., 2014). Traditional crafts, including wood, wicker, metal, and stone products, also benefit from such partnerships, creating functional items, decorations, and souvenirs that enrich the cultural and economic landscape.

Environmental benefits of partnerships include strengthened conservation initiatives and the adoption of sustainable land-use practices (Reynard et al., 2016). Geoparks raise awareness and provide management frameworks for environmental stewardship (Liu et al., 2019; Roberts, 2021). While evidence largely comes from well-established Geoparks, these collaborations demonstrate the potential for broad conservation impacts.

Partnerships also enhance sustainable tourism by developing attractions such as educational trails, guided tours, eco-friendly accommodations, and cultural activities. These initiatives boost visitor

spending, support local businesses, preserve cultural heritage, and encourage environmentally responsible practices (UNESCO, 2023; Arrage, 2024). Examples include bird-watching, hiking, yoga, photography, and geotours, as well as ecological initiatives in accommodation, healthy diets, and the use of natural materials in interiors.

Local cultural heritage and identity are further strengthened through these partnerships. By integrating traditions, folklore, and local history into tourism offerings, UGGps preserve intangible cultural elements and foster community pride. Active participation in decision-making ensures that projects align with both geological and cultural values, promoting sustainable practices and regional branding (UNESCO, 2015; Arrage, 2024).

Educational collaborations often involve schools, universities, research institutions, and NGOs, promoting geo-education, environmental awareness, and sustainable practices. Geoparks function as 'outdoor classrooms', advancing knowledge on geology, climate change, and conservation (Fernández Álvarez, 2020; Reynard et al., 2016). Notable examples include the Beigua Geopark 'Junior Geoparker' programme in Italy, which engages children aged 6–11 in educational workshops and nature explorations, and the Adamello-Brenta Geopark initiatives, which educate approximately 10,000 schoolchildren annually on geology, nature protection, and sustainability. The Villuercas-Ibores-Jara Geopark in Spain involves over 2,500 students each year, promoting collaborative learning about geology, environmental stewardship, and cultural heritage.

Social cohesion and community engagement are key outcomes of partnership programmes. Local involvement fosters a sense of ownership, strengthens cultural ties, and enhances governance capacity. Engagement with community groups promotes inclusive decision-making and improves infrastructure, services, and community facilities, thereby enhancing residents' quality of life (Dowling & Newsome, 2017; globalgeoparksnetwork.org). Transnational collaborations and Geopark twinning facilitate knowledge exchange, sharing of best practices, and collective action, further reinforcing social cohesion and community pride (Dowling, 2018).

Finally, global networking and funding opportunities are amplified through partnership programmes. Membership in the UGGp Network allows for transnational collaboration, access to funding, joint research, and cultural exchange.

This increases visibility for all stakeholders, including local businesses, artisans, and tourism operators, leveraging the Geopark's brand and international recognition (Hose, 2012; Farsani et al., 2012; globalgeoparksnetwork.org).

Empirical examples illustrate these benefits:

- Arouca Geopark (Portugal): Local artisans, businesses, and schools collaborate to promote Geopark-branded products, resulting in a 30% increase in local income and enhanced education through geology-focused curricula and field trips (Rodrigues & Panizza, 2017).
- Las Loras Geopark (Spain): Partnership with a bakery led to the creation of 'Geo-bread' shaped like ammonite fossils, linking local culinary traditions to geological heritage.
- Zigong Geopark (China): Collaboration with the 'Green Tea Spring' enterprise combines local geology and traditional tea culture, offering a holistic tourism experience that benefits both the local economy and sustainability.
- Marble Arch Caves UGGp (Northern Ireland/Ireland): Cross-border partnerships promote geotourism and sustainable development, increasing employment by 20% and restoring habitats (Fáilte Ireland, 2018).
- Vikos–Aoos Geopark (Greece): Partnerships with hotels, restaurants, and tour guides boosted revenue for local businesses by 15%, while supporting traditional crafts and sustainability

initiatives (Kyriacou, 2020).

- Beigua Geopark (Italy): Educational programmes engage children in nature exploration and sustainable tourism, supporting eco-friendly accommodations and guided tours (Burlando, 2018).
- Adamello-Brenta Geopark (Italy): Annual programmes involve 10,000 children, enhancing environmental awareness and long-term sustainability.
- Villuercas-Ibores-Jara Geopark (Spain): Over 2,500 students participate annually, fostering collaborative learning about geology, cultural heritage, and environmental stewardship (Fernández Álvarez, 2020).

The main challenge in developing Geoparks for sustainable tourism lies in ensuring active local participation and multifaceted sustainability. This requires strong commitment from communities, development agencies, and policymakers to implement socio-economic strategies and support bottom-up involvement in planning (Ngwira, 2019).

3. Biokovo-Imotski Lakes UNESCO Global Geopark

The Imotski Region is primarily located within the Imotski field in the north-eastern part of Split-Dalmatia County, Croatia, covering an area of 708 km². Historically, it belonged to the old Croatian parish of Imota, a small portion of which extends into the West Herzegovina and Herceg-Bosnia counties in neighbouring Bosnia and Herzegovina. Its favourable Mediterranean climate, strategic location near the Adriatic Sea, proximity to Croatian ports, nearby ski resorts in Bosnia and Herzegovina, the construction of the A1 motorway, and the St. Elijah tunnel towards the Makarska Riviera have all accelerated tourism development in the Imotski Region.

Tourism offerings have diversified significantly, including new accommodation facilities and a range of tourist products and activities, such as sports and recreational opportunities, cultural experiences, eno-gastronomy, cycling routes, geotrails, and the Camino Imota pilgrimage route, all forming an integral part of the region's tourism portfolio (Karamehmedović & Kolovrat, 2021). The region's cultural heritage includes the urban structure of the town of Imotski, its architecture, steps, museums, galleries, churches, fortresses, and stećci, as well as intangible cultural heritage linked to religious and traditional customs and lifestyles.

Tourism development in the Imotski Region has accelerated markedly over the past decade. In 2006, the region had only two registered accommodation facilities and recorded 2,100 overnight stays. By 2012, overnight stays exceeded 5,000. In 2014, overnight stays doubled compared to 2012, and by 2015, a further 76% increase was recorded, reaching 18,800 overnight stays. The most notable growth occurred in 2018, with a 292% increase compared to 2017 (Table 1).

This growth was driven largely by an expansion in accommodation capacity. In 2006, only two facilities were available, increasing to four by 2012. By 2018, accommodation facilities rose to 182, doubling since 2012, and by 2024, they had increased to 606, representing a 66% rise. Holiday homes with pools form the bulk of this expansion, a factor that proved particularly advantageous during the COVID-19 pandemic (Imotski Tourist Board & eVisitor system, 2024).

Tablica 1. Overnight stays (2012-2024) in the City of Imotski

2012		**2013**		**2014**		**2015**		**2016**	
OS (CN)	Inc. (%)	OS (CN)	Inc. (%)	OS (CN)	Inc. (%)	OS (CN)	Inc. (%)	OS (CN)	Inc. (%)
5,083	/	9,718	91	10,669	9,8	18,769	76	13,382	-29

2017		**2018**		**2019**		**2020**		**2021**	
OS (CN)	Inc. (%)	OS (CN)	Inc. (%)	OS (CN)	Inc. (%)	OS (CN)	Inc. (%)	OS (CN)	Inc. (%)
18,846	40,8	73,830	**291,8**	96,056	30	76,449	-20,4	100,812	31,9

2022		**2023**		**2024**	
OS (CN)	Inc. (%)	OS (CN)	Inc. (%)	OS (CN)	Inc. (%)
143,211	42	149,448	4,4	163,512	9,4

Endnote for Table 1: Until 2015, data was available only for the town of Imotski, while from 2016 onwards, data has been recorded for the entire Imotski Region. This table contains data only for the town of Imotski for the specified period. The new concept of recording data is the reason for the recorded decline in the number of overnight stays in the city of Imotski in 2016. In 2020, the decline occurred due to the COVID-19 pandemic.
Legend: OS (C)=overnight stays in cardinal numbers
Inc.% =An increase in percentage compared to the previous year
Source: Author's calculation (2025); data from Imotski Tourist Board and the eVisitor system (2024).

The Imotski Region boasts geological heritage of exceptional significance, as confirmed by the inclusion of the Biokovo-Imotski Lakes UGGp (BILUGGp) on the UNESCO Global Geoparks List in March 2024.

The BILUGGp covers 533.20 km² and features 54 geolocalities, with 22 situated in the Imotski Region, eight of which are part of the Natura 2000 ecological network. Key natural monuments include the Red and Blue Lakes, and the lakes of Prološko Blato, namely Ričice, Galipovac, Knezovića, Mamića Lake, Two Eyes Lake, among others (Figure 1). The Red and Blue Lakes are karst formations and among Croatia's most significant geomorphological sites, with the Blue Lake drying periodically under adverse hydrological conditions and the Red Lake remaining perennial, reaching a depth of 528 metres (Management Plan 2022–2026 Biokovo-Imotski Lakes Geopark, 2021).

The BILUGGp features a network of hiking trails linking geological, natural, archaeological, and cultural sites into a cohesive visitor experience. Planned initiatives include the development of the Zovnjača Cave for guided tourist visits, complete with in situ interpretation panels. A modern visitor centre is envisaged at the Režija Duhana building complex (Dogana), incorporating geological columns and maps, an information desk, multimedia content, a souvenir shop with Geopark partner products, a laboratory, aquariums showcasing native fish species, and a research and rescue centre for the olm (Proteus anguinus).

Legislative and organisational frameworks are essential for UGGp establishment and management, ensuring effective implementation of sustainable development strategies and facilitating active community participation. These frameworks provide the legal and operational structure for integrating education, conservation, and local development (UNESCO, 2015; Arrage, 2024).

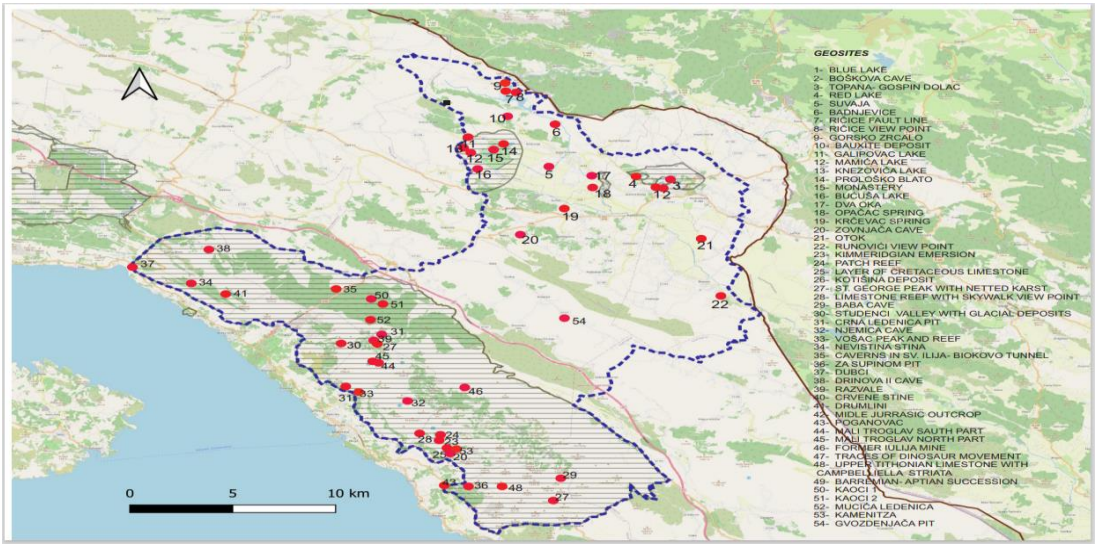

Figure 1. Biokovo-Imotski Lakes UNESCO Global Geopark with geolocalities
Source: GeoPark Biokovo-Imotski Lakes (2021). Management plan 2022-2026 Biokovo-Imotski Lakes Geopark.

The management of BILUGGp is supported by the Act on Tourist Associations and Promotion of Croatian Tourism, the Act on Nature Protection, the Tourism Development Strategy of the Imotski Region, the work plans of the Imotski Tourist Board, and the Management Plan 2022–2026 Biokovo-Imotski Lakes Geopark. Collectively, these documents underpin Geopark management, geotourism development, and the wider tourism strategy for the region.
The BILUGGp operates under a non-governmental organisation whose governance structure includes the Assembly, Board of Directors, Supervisory Board, Advisory Board, and Executive Director (Figure 2).

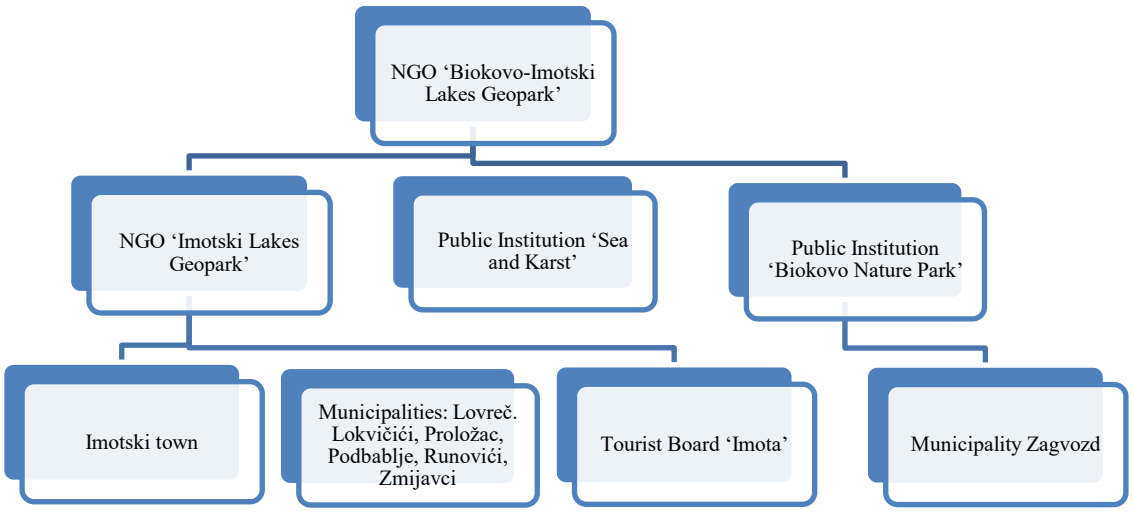

Figure 2. Management structure flowchart of the Biokovo-Imotski Lakes Geopark Association
Source: GeoPark Biokovo-Imotski Lakes (2021). Management plan 2022-2026 Biokovo-Imotski Lakes Geopark.

The management plan, drafted in September 2021, outlines the Geopark's purpose, goals, activities, resource use, financing, and staffing for the next five years. The plan defines four primary objectives:

1. Protection, geoconservation, and research of natural and cultural-historical heritage.
2. Development of geotourism and geoeducation.
3. Sustainable development of the local community.
4. Capacity-building for the Biokovo-Imotski Lakes Geopark (Management Plan 2022–2026 Biokovo-Imotski Lakes Geopark, 2021: 47).

4. Methodology

With the recent designation of BILUGGp, this research aims to explore the anticipated benefits of UNESCO Global Geopark (UGGp) status for tourism development in the Imotski Region, as well as assess the advantages of partnerships with the Geopark. Tourism professionals and local stakeholders expect the region to attract more visitors, particularly those interested in its geological features. This growth is predicted to boost visitor spending, diversify tourism offerings, and stimulate the development of new accommodation, products, traditional crafts, and attractions. The theoretical section of this paper outlines the benefits of UGGp status and partnerships, highlighting successful global Geoparks and illustrating economic and social benefits that could be adapted for BILUGGp projects.

Although the theoretical framework provides valuable insights, gaps remain in existing research. These gaps can be grouped into two main areas. First, comparability of BILUGGp with other UGGps is limited, as it only gained UGGp status in 2024, making it difficult to assess its full potential for tourism development in the Imotski Region. Second, empirical research is scarce, particularly involving expert perspectives, as most tourism surveys focus on local populations or visitors rather than professional stakeholders.

The research objectives were to determine:

1. The expected benefits of BILUGGp designation for tourism development in the Imotski Region.
2. The anticipated advantages of partnership programmes with the Geopark.

To address these questions, two complementary studies were conducted: an internet-based survey and an empirical survey using the e-Delphi technique.

4.1 Internet-based Research

Internet-based research combined qualitative and quantitative methods (Leburić & Sladić, 2004). Primary online research on Geoparks, supported by scientific and professional literature, as well as relevant documents, identified best practice indicators regarding the expected benefits of UGGp designation for tourism development. These indicators also highlighted potential advantages of partnership programmes. The selected projects and activities were analysed for their applicability to BILUGGp, providing guidance for supporting tourism and local development in the Imotski Region.

4.2 Empirical Research – e-Delphi Study

The e-Delphi technique (Visković, 2016) was applied in two rounds. The Delphi method has been widely used in Geopark studies to gather expert opinions on sustainable development (Fanwei, 2014; Ferreira & Valdati, 2023), geoconservation (Chauhan et al., 2021; Ferreira & Valdati, 2022), and management strategies (Fernández et al., 2014; Ferreira & Valdati, 2023). This method enables

structured collection and synthesis of insights from multiple stakeholders, including experts in geoscience, tourism, and environmental management, and is particularly valuable for complex, interdisciplinary topics where expert judgement informs decision-making and strategic planning.
The e-Delphi survey was conducted via Google Forms, with links distributed to panellists by email. Online questionnaires are cost-effective and allow easy data import into statistical software. Participants were encouraged to respond clearly and politely (Kabir, 2016). The survey combined open-ended, closed-ended, and multiple-choice questions, using nominal and interval scales, including a five-point Likert scale. Initial graphical results were generated in Google Forms, but all data were further processed statistically.

4.3 Selection and Filtering of Questions Between Rounds

After the first round, arithmetic and, where appropriate, weighted means were calculated from both open- and closed-ended responses. Key statements or themes with the highest consensus or notable differences in opinions were identified. These statements were then included in the second round to achieve a higher level of agreement among panellists. This process ensured that only questions relevant to consensus were focused on, rather than reintroducing all original responses.

4.4 Participants

The study involved 32 panellists, including members of the National Geopark Commission, directors of UGGps, university professors in tourism and ecology, employees of the Croatian Geological Institute, and staff and partners of BILUGGp. Participants were selected purposively, based on their expertise and role in the Geopark or tourism. Their contribution was crucial, combining geological, tourism, and management knowledge, allowing for a multidisciplinary assessment of the benefits of UGGp status and partnership programmes. Most had participated directly in the evaluation and application process of the Biokovo–Imotska Lakes Geopark for UNESCO designation. One of the authors, Luka Kolovrat, as the then director of the Imota Tourist Board, played a key role in promoting and supporting the application and development process, particularly regarding tourism valorisation and local community engagement. He also led the selection of panellists in agreement with the co-author.
Of the 32 surveys distributed, 91% participated in the first round and 93% in the second, considered sufficient for reliability (Van Zolingen & Klaassen, 2003). Literature suggests no strict consensus on the required number of Delphi panellists (Visković, 2016). Okoli and Pawlowski (2004) recommend 10–18 experts per panel, noting that attrition is generally not problematic in single surveys.

4.5 Survey Content and Data Analysis

In addition to sociodemographic data, the survey addressed the general condition and potential of BILUGGp for advancing tourism development. The survey design was based on Karamehmedović and Kolovrat (2021).
Research findings are presented using percentages and arithmetic means, providing precise representation of variables. Expressing results as percentages is common in Delphi studies, as it standardises data presentation and highlights the distribution and relative importance of responses (Hand & McGowan, 2004).

5. Results of the Empirical Research and Discussion

The principal research conducted in this study is empirical, utilising the e-Delphi method through a two-round survey administered via Google Forms. Of the 32 surveys distributed, 29 panellists (91%) participated in the first round and 27 (93%) in the second round, ensuring robust participation across both rounds.

5.1 Sociodemographic Profile of Panellists

The sociodemographic profile of respondents in the first round was as follows: gender – 55% male and 45% female; age – 31–40 years (21%), 41–50 years (38%), and 51–60 years (28%); education – 90% with a Master's degree or higher. A substantial proportion (74%) had previous experience working in tourism or were involved in the organisation of tourist events. By profession, 35% of respondents were geologists and 34% were economists. While sociodemographic characteristics are documented, they do not influence the results, as Delphi and e-Delphi methods focus on the informed opinions of experts in the field under study. Notably, the professional experience of panellists underscores their capacity to provide reliable and informed perspectives on the expected benefits of BILUGGp designation and partnership programmes.

5.2 Results 1: Expected Benefits of BILUGGp Designation

The first research objective was to determine the anticipated benefits of UNESCO Global Geopark (UGGp) status for tourism development in the Imotski Region. On a five-point Likert scale, 59% of panellists rated the utilisation of the region's tourism potential as medium. Half of the respondents considered the cultural and natural attractions of the Imotski Region insufficiently marked or promoted. Notably, three-quarters of panellists were highly familiar with the BILUGGp project, and 52% believed that the Geopark would significantly enhance tourism development in the region.
When addressing the specific question, 'The expected benefits of designation for the tourism development of the Imotski Region,' panellists identified the following:

- Significantly enhance the destination's visibility – 37%
- Enhance the development of new tourist facilities in the destination – 33%
- Create the prerequisites for the development of geotourism – 32%
- Possibility of accessing funding from various sources – 8%

Panellists expressed scepticism regarding the potential of the project to raise ecological awareness among the local population. Given that education is a central aim of the UGGp programme, it is recommended that BILUGGp management organise workshops and specialised programmes to address this issue. Concerns were also raised about whether UNESCO designation alone would improve protection of certain sites and regarding the effectiveness of collaboration with other European and global Geoparks.
These findings align with previous research highlighting experts' prioritisation of geoheritage site protection (Chauhan et al., 2021) and reflect global trends in UGGp development, where visibility and partnership programmes are consistently identified as key drivers of regional tourism growth (Reynard et al., 2016; Ferreira & Valdati, 2023).

In a broader context, the designation of Geoparks provides a foundation for selective tourism, leveraging the area's unique geological, cultural, and natural features to attract specific tourist segments. Branding areas as UNESCO Global Geoparks increases global visibility, differentiates them from other destinations, and stimulates visitor interest. Thus, the empirical findings confirm and extend the insights from the literature, highlighting the importance of visibility and partnerships for regional tourism development.

5.3 Results 2: Expected Benefits of Partnership Programmes

The second research objective examined the expected advantages of partnership programmes with the Geopark. Panellists highlighted the following benefits:

- Participation in special UNESCO Geopark projects, such as Geofood – 37%
- Better promotion in general – 30%
- Greatest visibility of all stakeholders – 26%
- Opportunities for networking with partners from other Geoparks – 7%

Unlike the first set of responses, participation in specific UNESCO Geopark projects, such as Geofood, received the highest rating in this question. Panellists were uncertain about the increased potential for product sales within the Geopark and considered representation at symposia or conferences less important. Nevertheless, collaborative promotional efforts could improve product sales, and partnerships generally enhance the positioning of the entire region within the global Geopark network.
Geotourism development in BILUGGp involves a partnership between the government, local communities, and private stakeholders, including local businesses, outdoor companies, tour agencies, restaurants, and accommodation providers. Local residents play a crucial role in shaping geobrands, generating sustainable and intimate images that enhance visitor experiences and stimulate geotourism (Lee & Jayakumar, 2021). When developing projects such as Geofood or other geoproducts, it is recommended that UGGps adopt common definitions and standardised procedures while preserving each territory's unique identity (Rodrigues et al., 2021). This approach facilitates the establishment of impact assessment indicators to evaluate the effectiveness of strategies and the socio-economic impacts of Geoparks. Understanding how residents perceive tourism activities in their surroundings is key to the success of the destination (Pérez-Calderón et al., 2022).
Currently, four geo-trails have been established within BILUGGp: Blue and Red Lakes, Lokvičićka Lakes, and Badnjevice, with the Vrljika geological trail under preparation. The next planned project is the Ričice geological trail. The flagship initiative is the Visitor Centre, for which a conceptual design has been completed, and funding applications are pending. Partnerships with local self-government units, the Imota Tourist Board, the Biokovo Nature Park, and the Public Institution 'Sea and Karst' are reflected in the governance structure of the BILUGGp Association. The UGGp programme promotes close collaboration between Geoparks and local stakeholders, producers, and other entities. Interested partners may display the BILUGGp logo on promotional materials and be listed on the Geopark website, further enhancing visibility through newsletters and brochures.

5.4 Discussion and Integration with Literature

The empirical results directly address the research objectives, providing evidence of the expected benefits of UGGp designation and partnership programmes. The findings confirm that BILUGGp has significant potential to enhance tourism visibility, stimulate geotourism, and develop new facilities, while highlighting areas requiring targeted interventions, particularly in environmental education and site protection. Similarly, partnership programmes are anticipated to strengthen regional branding, promote local products, and facilitate international networking. These outcomes align closely with existing literature, including Reynard et al. (2016), Ferreira and Valdati (2023), Lee and Jayakumar (2021), Rodrigues et al. (2021), and Pérez-Calderón et al. (2022), thus situating the findings within broader academic and practical discourse on Geopark tourism development.

6. Conclusion

The designation of the Biokovo–Imotski Lakes UNESCO Global Geopark (BILUGGp) is expected to bring multiple benefits and development opportunities to the wider region, including Imotski, Biokovo, Zabiokovlje, and the Makarska Riviera. This research aimed to achieve two main objectives: 1) to identify the anticipated benefits of the Geopark designation for tourism development in the Imotski Region; and 2) to assess the expected advantages of partnership programmes with the Geopark. Additionally, the study reviewed good practice examples from various UGGps, highlighting projects and activities that could be adapted to benefit BILUGGp.

The empirical results indicate that the expected benefits for tourism development in the Imotski Region include significantly enhancing destination visibility (37%), boosting the development of new tourist facilities (33%), creating prerequisites for geotourism development (32%), and enabling access to various funding sources (8%). The anticipated benefits of partnership programmes include participation in special UNESCO Geopark projects such as Geofood (37%), improved overall promotion (30%), increased visibility for stakeholders (26%), and networking opportunities with other Geoparks (7%). These findings align with the literature showing that UNESCO Global Geopark status can strengthen geotourism, attract selective tourist segments, and enhance destination branding (Ferreira & Valdati, 2023; Reynard et al., 2016).

The region's rich geodiversity, cultural heritage, excellent geolocation, and strong transport connections provide a solid foundation for geotourism. Empirical findings also reveal the importance of education, local engagement, and structured partnerships to maximise the benefits of UGGp status. While some experts expressed scepticism regarding ecological awareness and site protection, targeted educational programmes, geoguiding, and collaborative initiatives could address these challenges, supporting geoconservation and sustainable tourism development.

This study contributes to scientific knowledge by addressing gaps in the literature and providing a model for assessing the benefits of UGGp designation and partnerships. It offers practical applications for tourism planners, local authorities, and stakeholders, guiding sustainable development strategies. Future research could explore residents' perceptions of Geopark impacts, develop indicators for monitoring benefits, evaluate management strategies, and balance economic growth with environmental and cultural preservation.

Overall, BILUGGp has strong potential as a catalyst for sustainable tourism and local development. Realising this potential will require coordinated efforts from the Geopark management, local and

regional authorities, institutions, organisations, stakeholders, and the wider community to achieve economic, social, and environmental benefits across the Imotski Region and beyond.
Finally, it should be noted that this research is preliminary, as the Biokovo–Imotski Lakes Geopark has only recently been designated a UNESCO Global Geopark. Therefore, the expected contributions to tourism are based on assumptions and planned initiatives, and the actual effects of the status will need to be empirically verified in the future**.**

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UNESCO Global Geopark Biokovo–Imotska jezera: Potencijalni doprinos unapređenju turizma u Imotskoj regiji

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Sažetak: Svrha istraživanja bila je utvrditi očekivane koristi proglašenja Geoparka Biokovo–Imotska jezera (BILUGGp) UNESCO-vim geoparkom za razvoj turizma u Imotskoj regiji i očekivane koristi partnerskih programa s Geoparkom. U radu se navode primjeri dobrih praksi odabranih UNESCO-vih geoparkova, ističući projekte i aktivnosti koje bi se mogle prilagoditi za potporu BILUGGp. Empirijsko istraživanje provedeno je korištenjem e-Delphi tehnike, uz internetsko istraživanje UNESCO-vih geoparka, relevantnih dokumenata, znanstvene i stručne literature. Internetska analiza obuhvatila je 213 UNESCO-vih geoparka, odnosno njihove web-stranice u 48 zemalja, dok je u e-Delphi istraživanju sudjelovalo ukupno 27 panelista. Rezultati pokazuju da očekivane koristi proglašenja Geoparka za razvoj turizma u Imotskoj regiji uključuju značajno povećanje prepoznatljivosti destinacije (37%), poticanje razvoja novih turističkih objekata (33%) i stvaranje pretpostavki za razvoj geoturizma (32%). 2) Očekivane koristi partnerskih programa s Geoparkom očituju se u suradnji s drugim geoparkovima na specifičnim projektima (kao što je Geofood) (37%), poboljšanoj promociji (30%) i povećanoj vidljivosti dionika (26%). Zaključno, proglašenje Geoparka Biokovo-Imotska jezera UNESCO-vim geoparkom pruža niz prednosti i razvojnih mogućnosti za cijelu regiju, uključujući Imotski, Biokovo, Zabiokovlje i Makarsku rivijeru. Ono potiče razvoj turizma, jača geoturizam i brendiranje destinacije, olakšava suradnju s drugim geoparkovima na konkretnim projektima i znanstvenim istraživanjima te podržava razvoj poljoprivrede, ugostiteljstva, trgovine i usluga. Nadalje, potiče revitalizaciju tradicionalnih obrta i običaja, stvara raznolike partnerske programe, promiče održivo upravljanje prirodnom i kulturnom baštinom te doprinosi dobrobiti lokalnog stanovništva.

Ključne riječi: UNESCO-vi geoparkovi, Geopark Biokovo-Imotska jezera, Delphi metoda, turistički razvoj, koristi, partnerstva
JEL klasifikacija: Z32

The Services Sector in the Dutch Economy: Economic Contribution and External Trade Performance

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Abstract: This study aims to present the structural dynamics and the contribution of the services sector to the Dutch economy, as one of the European Union countries that serves as a leading model for service-based economies. A descriptive-analytical approach was used to analyse official Eurostat statistics on the services sector for the period 2010-2020, while trade in services data extend to 2024. Results reveal that the services sector plays a pivotal role within the Dutch economy, contributing significantly to value creation, profitability, and foreign trade, including exports and imports. Despite its flexibility and diversity, the services sector remains vulnerable to global fluctuations, emphasizing the need for strategic investment and policy support to maintain competitiveness and long-term growth. This study is limited by the absence of 2017 data for the services sector, and the small sample size used in the regression models. The contribution of this study lies in providing a uantitative analysis that complements previous qualitative studies and sheds light on its role in the Dutch economy and international trade. More comprehensive future research, in terms of both data and period, could be recommended, including a study of the impact of global factors on the service sector in the Netherlands, or a comparison with specific countries.

Keywords: Service sector; service economy, trade in services, economic competitiveness, Netherlands
JEL Classification: F14; L80; O52

1. Introduction

As economies strive to diversify their production base and move away from dependence on, or over-reliance on, natural resources, especially non-renewable ones, the “services economy” has become a

strategic cornerstone of this economic vision. Accordingly, the services sector has transitioned from a marginalized tertiary sector to a pivotal and key sector in the modern economy, playing a role similar to that of agriculture in traditional economies and industry in industrial economies. Today, services constitute significant drivers of economic growth (Cheng, 2013). The OECD (2024) highlighted the remarkable expansion of the services sector's contribution to the economy and international trade, reaching 67% of global GDP in 2021, surpassing the industrial and trade sectors. Meanwhile, trade in services reached 13.4% of global GDP in 2022, which is double the amount recorded in 1990. The World Bank also indicated that the value added of the services sector reached 63.3% of global GDP in 2023, 72.4% in the United Kingdom, 64% in Germany, 56.7% in China and 49.9% in India in 2024 (World Bank, 2025).

Consequently, the current discussion extends beyond merely assessing the status of the services sector; it now encompasses strategies to optimize its advantages. This situation is clearly illustrated by the experience of the European Union, where the services sector supported economic growth, even though it was not a direct generator of that growth. The share of the services sector in the employment structure and its contribution to creating total added value increased between 2000 and 2023 (Kołodziejczak, 2025). Conversely, trade in services within the European Union accounts for more than a third of the bloc's total trade in goods and services. The importance of services trade has increased in comparison to goods trade over the past decade. In 2023, as reported by the European Commission (2024), trade in services within the EU constituted 25% of global services trade, with approximately €1.427 billion in service exports and €1.274 billion in service imports.

The Netherlands is distinguished as a key service hub, traditionally known as the "Gateway to Europe" and this reputation stems from its advantageous logistical position, sophisticated infrastructure, and robust financial and commercial industries. Consequently, services have emerged as a vital contributor to the nation's economy, representing roughly 77% of the Netherlands' GDP in 2023 (CBS, 2024). Furthermore, the contribution of this sector to the national GDP has fluctuated between 70% and 71% in recent years, as reported by The Global Economy (2025). Moreover, the services sector plays a crucial role in the Netherlands' foreign trade. Data indicate that the Netherlands plays a significant role in the trade of services, both in Europe and globally. (Creemers & Voncken, 2024).

Therefore, the Netherlands appears as one of the global models of an advanced service economy. From this perspective, the main problem of this study was formulated as follows: "What is the reality of the services sector within the economy of the Netherlands?"

This study aims to achieve several objectives, most notably: to evaluate the relative weight of the services sector in the Dutch economy; to analyse the performance of the Netherlands' services trade, and to identify the most dynamic service sectors that drive economic performance.

2. Theoretical backgrounds and literature review

The literature on economics and international trade has long focused on the services sector, given its growing role in employment indicators, global output, cross-border transactions, and other key factors. Theoretical interest in services has grown as they have become increasingly important in modern economies. This crucial importance stems from the structural transformation theory, which posits that economies evolve from agriculture to services, transitioning through industry. This shift aligns with technological changes, rising incomes, and their impact on lifestyles and consumption patterns, resulting in a transition towards a service-oriented economy. Studies have additionally supported this trend, emphasizing the considerable positive impact of the service sector on GDP and trade performance

through its diverse activities in numerous developed economies (Briggs & Sheehan, 2019; Sasmal & Sasmal, 2024).

Conversely, Karam & Zaki (2015), Khoury & Savvides (2006), Maune (2019), and Shieh (2020) have examined the relationship between trade in services and overall economic growth, finding a positive correlation. Higher levels of trade in services positively impact GDP growth, and trade liberalization offers economic advantages similar to those of trade in goods, especially regarding enhanced productivity and greater specialization.

Other studies, such as (Beverelli et al., 2017; Shen & Liu, 2024; Yu et al., 2021) provide evidence that at the microeconomic level, services such as transportation, logistics, and financial intermediation serve as key intermediate inputs that have facilitated the improvement of manufacturing productivity while also enhancing coordination within global value chains. These studies further illustrate that easing restrictions on trade in services leads to increased efficiency in various economic activities, including access to high-quality production services. Additionally, Kox et al. (2005) demonstrated that by reducing or removing restrictions stemming from structural disparities among EU member states, there could be a 30-60% rise in commercial trade in services and a 20-35% boost in foreign direct investment in services.

Reality, as demonstrated by numerous recent global experiences, shows that trade in services has become more dynamic and the fastest-growing component of international trade, having developed significantly over the past two decades. The WTO and World Bank (2023) highlighted that services, particularly in sectors such as finance, information and communication technology, and professional business services, have evolved into a fundamental component of global trade and play a crucial role in international business and transactions, surpassing their earlier classification as simply final products. The Trade and Integration Monitor report (Inter-American Development Bank, 2025) confirms that services have become crucial intermediate inputs across various sectors, enhancing productivity and facilitating integration into global value chains. Similarly, the significance and influence of digital services, for example, have increased across various production networks worldwide, serving both as exports and as inputs (UNCTAD, 2024).

Prior research has extensively investigated the relationships between services, economic growth, productivity, and international trade; however, the focus has largely been on either cross-country comparisons or specific facets of services. In contrast, there has been a scarcity of comprehensive analytical research into the structural significance of the services sector within a predominantly service-oriented economy such as the Netherlands, particularly regarding the interaction between domestic economic performance and external trade dynamics.

Studies addressing this matter are largely confined to statistics published in reports by national or international organizations that reflect the general economic situation, rather than being incorporated into a cohesive analytical framework. This research gap motivated this study. This identified a gap in research and prompted the current study.

3. Methodology and Hypothesis

The study used an analytical approach to examine data on the Dutch services sector and its economic role, including its contribution to GDP and overall performance. The data cover the period from 2010 to 2020 for the services sector and from 2013 to 2024 for trade in services and were extracted exclusively from Eurostat statistics; therefore, data from 2017 are not available in this study for the services sector due to their absence from the database. The absence of 2017 data for the services sector is one of the limitations of the study; however, the analysis is based on the data available for the other years, since

the study focuses on general structural trends rather than annual changes. In addition, the data available for the years before and after 2017 still allows for the observation and analysis of the overall development of the sector.
The study relied on the hypotheses below:
H1: *The services sector in the Netherlands plays an important role in the economic performance.*
H2: *The efficiency of the service sector in the Netherlands differs across sub-sectors.*
H3: *The services sector in the Netherlands is associated with its foreign trade.*

The study adopted a descriptive-analytical research design and analysed the collected data by quantitative methods to reach the research tasks below:
Measure the relative weight of the Dutch services sector in the economy, including evaluating its GDP's contribution and its value creation.
Assess the services trade's performance by analysing key indicators related to the volume and composition of service exports and imports.
Identify the most dynamic service sectors that are considered the growth leaders.
In addition to the previous analysis, a simple statistical test is adopted to provide an empirical measure of the relationship between key service indicators and overall economic performance in the Netherlands. It is based on correlation measurement and simple linear regression.
It is important to note that the statistical analysis used in this study does not constitute conclusive proof of causation, but rather reflects correlations between the variables used, such as value added of services, service exports and imports, GDP, and others.
The potential for endogeneity cannot be fully verified due to the annual nature of the data used in this study. At the same time, the study does not apply any extensive robustness tests or alternative model specifications. Consequently, the results were interpreted as indicators of an observed association between the expansion of the services sector and the overall economic performance of the Netherlands, given that a deeper analysis of cause and effect requires more comprehensive data and sophisticated statistical models, which are not encompassed in this study.

4. Research Results and Discussion

4.1. The Contribution of the Service Sector to the Dutch Economy

The Netherlands is considered one of the most important and leading models in the world in the transition towards a service-based economy, in which this sector has reached a significant contribution to GDP, value added, and many other macroeconomic indicators.

4.1.1. Glimpse on the Dutch services sector

The service sector in the Netherlands is a vital and dynamic part of its economy, with numerous institutions/establishments operating across healthcare, education, tourism, accommodation, transportation, finance, and other sectors. The figure below illustrates the evolution of the number of these establishments.

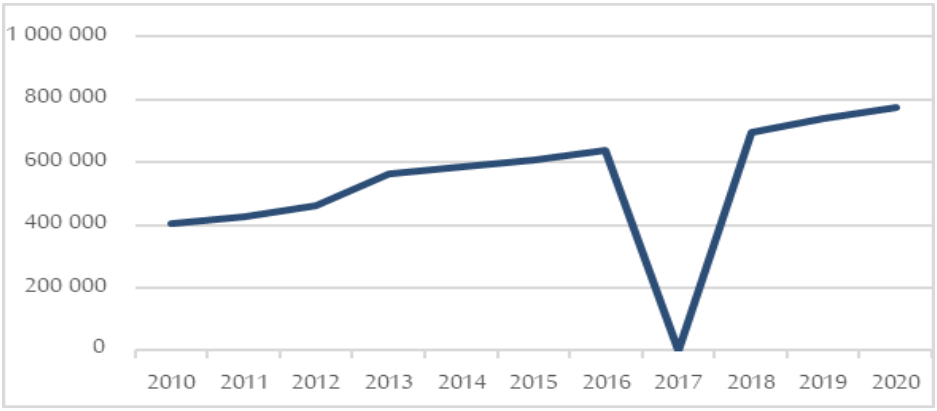

Figure 1. Number of service establishments in the Netherlands
Source: Prepared based on: (Eurostat, 2024)
Note: Data for 2017 are treated as missing because they are not available

The results show a significant and continuous increase in the number of service establishments in the Netherlands, with the exception of the absence of statistics for 2017. The count increased from 403,902 in 2010 to 776,195 in 2020, representing a growth of 92.2%, which signifies genuine expansion through the establishment of new businesses or the growth of existing ones. These findings indicate the growing shift towards a service-based economy in the Netherlands, where opportunities for wealth and employment in this sector have been increasingly generated. Furthermore, the data indicates the establishment of 36,238 new service entities during the COVID-19 pandemic, indicating the structural flexibility of the services sector and its ability to develop new service activities that respond to changing circumstances, including those provided remotely. This adaptability enabled the Dutch services sector to navigate the significant economic challenges posed by the health crisis.

These findings are consistent with Kołodziejczak (2025), indicating a high shift towards services in wealthy EU countries, including the Netherlands, where the service sector has grown in terms of employment, economic structure, and overall value creation. Population density also plays a role in this shift towards a service-based economy. That shift is also apparent in the number of service establishments, and not just in general macroeconomic indicators. The Netherlands is distinguished from other developed countries by the dominance of the services sector in its economy, as evidenced by a more pronounced shift towards various service activities (Wache et al., 2024).

The findings also align with the literature on structural transformation theory, particularly the studies by Briggs and Sheehan (2019), Sasmal and Sasmal (2024), which point to a gradual shift in advanced economies from manufacturing to service-based economies. However, the Dutch case suggests a pattern marked by greater dynamism and resilience than the general trends revealed in the studies, especially regarding its capacity to maintain growth and generate new service activities during crises. This numerical growth in service establishments in the Netherlands confirms the transformation of this sector from a complementary or secondary one to a prominent sector in the economy.

To understand the weight of the services sector in the economy, it is necessary to know its economic performance. This performance ensures that the increase in its number of establishments has a real impact on the economy, as demonstrated by the size of its activity and its ability to generate revenue. Therefore, the following shows the development of turnover and production value in this sector as an indicator of the volume of transactions within its activities and the dynamism of the economy.

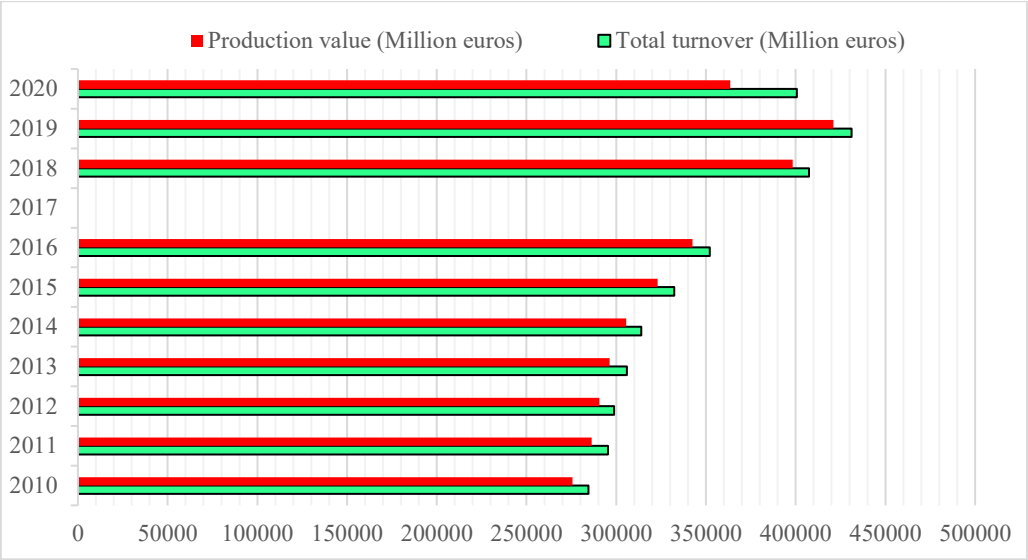

Figure 2. Total turnover and production value of the services sector in the Netherlands
Source: Prepared based on (Eurostat, 2024).
Note: Data for 2017 are treated as missing because they are not available

As shown in Figure 2, the turnover and production value of the Dutch services sector have been steadily growing for years. Total sales value (turnover) increased from €284.5 billion in 2010 to €431.1 billion in 2019, representing an estimated overall growth of about 51.5%, while the value of production reached €421 billion in 2019, up from €275.6 billion in 2010, representing a growth rate of 52.7%. These values demonstrate the strength of the services sector, as continued growth in sales value and production value reflects an expansion in the real value of economic activity in this sector. It is also noteworthy that turnover remained higher than production value by 2-3% annually throughout the same period, which is expected from an accounting perspective, since the value of production is calculated by adjusting turnover for changes in inventories and deducting intermediate consumption of goods and services.

These findings are consistent with Briggs and Sheehan (2019) and Sasmal & Sasmal (2024), who highlighted the positive contribution of the service sector to advanced economies in terms of growth and value creation. Therefore, these results support those previous studies on the contribution of the services sector to Dutch economic growth and value creation, while also suggesting that the increase in the number of service establishments in the Netherlands is not merely quantitative, but was accompanied by a parallel improvement in its productive capacity.

In contrast, 2020 recorded a sharp decline in turnover and production value for the services sector, compared to 2019, by 7.1% and 13.6%, respectively, to €400.6 billion and €363.6 billion. This situation was primarily due to the COVID-19 pandemic and the accompanying lockdown and social distancing policies, which have significantly impacted various service sectors, including transportation, hotels, restaurants, and others.

Nevertheless, the Netherlands exhibits a strong expansion in both sales volume and output value for the services sector, reflecting a higher level of efficiency and value generation within this sector than the general patterns described in previous literature.

Assessing any sector within an economy involves more than merely evaluating its economic activity; it also requires an understanding of its capacity to generate economic value. That can be measured by value added, which reflects the sector's contribution to the Gross Domestic Product (GDP), and gross

operating surplus, which indicates the net profits and returns generated. The following figure 3 illustrates these indicators for the services sector in the Netherlands.

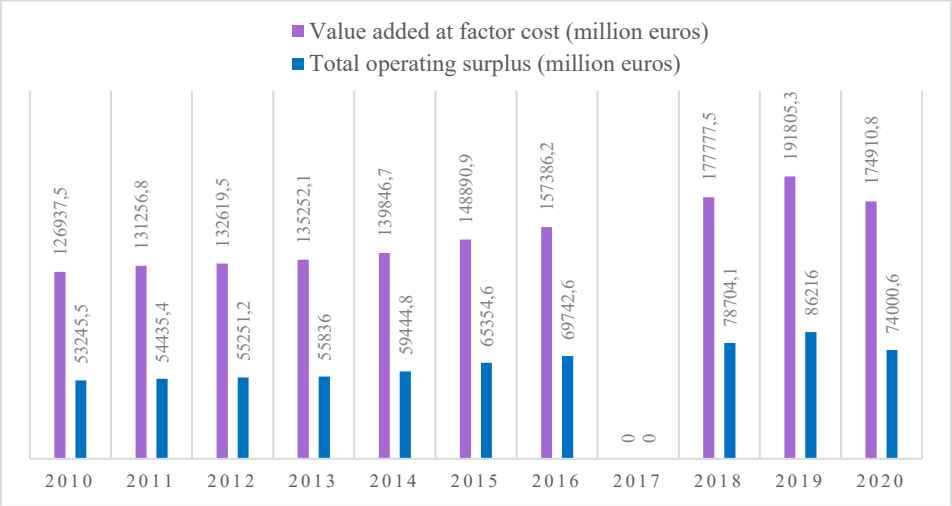

Figure 3. Total Value Added and Gross Operating Surplus for the Services Sector in the Netherlands
Source: Prepared based on (Eurostat, 2024).
Note: Data for 2017 are treated as missing because they are not available

The results indicate strong and profitable performance of the Dutch services sector up to 2019, as evidenced by the growth in the sector's added value and the continuous rise in its operating surplus.
The value added of the services sector saw a significant increase between 2010 and 2019, rising from €127 billion to €192 billion, representing a growth rate of nearly 51%. These results highlight the sector's substantial contribution to the Dutch economy, as its expansion extends beyond turnover to include the creation of added value. At the same time, the services sector's profitability grew faster than its added value, with its operating surplus increasing from €53.2 billion in 2010 to €86.2 billion in 2019, representing an estimated growth of 62%. This significant growth in operating surplus, growing faster than added value, reflects the relatively strength and profitability of the sector, showing that service establishments in the Netherlands convert an increasing part of their added value into operating profit.
However, this situation changed in 2020 due to the COVID-19 pandemic, which saw a sharp decline in the profitability of the services sector. This decline is reflected in a 14.2% drop in operating surplus compared to 2019, reaching €74 billion in 2020, and a smaller decrease in value added, estimated at 8.8%. This smaller decrease is relatively low considering the severity of the crisis and may be attributed to the relative resilience of value added in the sector. The significant decrease in profitability, compared to the decrease in value added, had a considerable impact on the profit margins of the services sector. Despite continued production, its ability to generate profit was affected due to ongoing costs such as rent and salaries, coupled with a decline in revenue.
This increase in added value demonstrates the growing economic role of services in the Dutch economy. These results reinforce what Karam and Zaki (2015), Khoury and Savvides (2006), and Maune (2019) have shown regarding a positive correlation between the expansion of services and trade within them and economic performance and GDP growth, particularly in advanced economies, which highlights services as a notable element of value creation within them.

From the previous results, the continuous evolution of service establishments, the sustained growth in turnover and production value of this sector, and the increasing contribution of value added, and operating surplus are associated with *hypothesis H1, indicating that the services sector in the Netherlands plays an important role in economic performance*.

4.1.2. Structural Evolution and Subsector Composition in the Netherlands

The services sector encompasses a range of sub-fields and activities, the most important of which, apart from commerce, can be illustrated in the following figure:

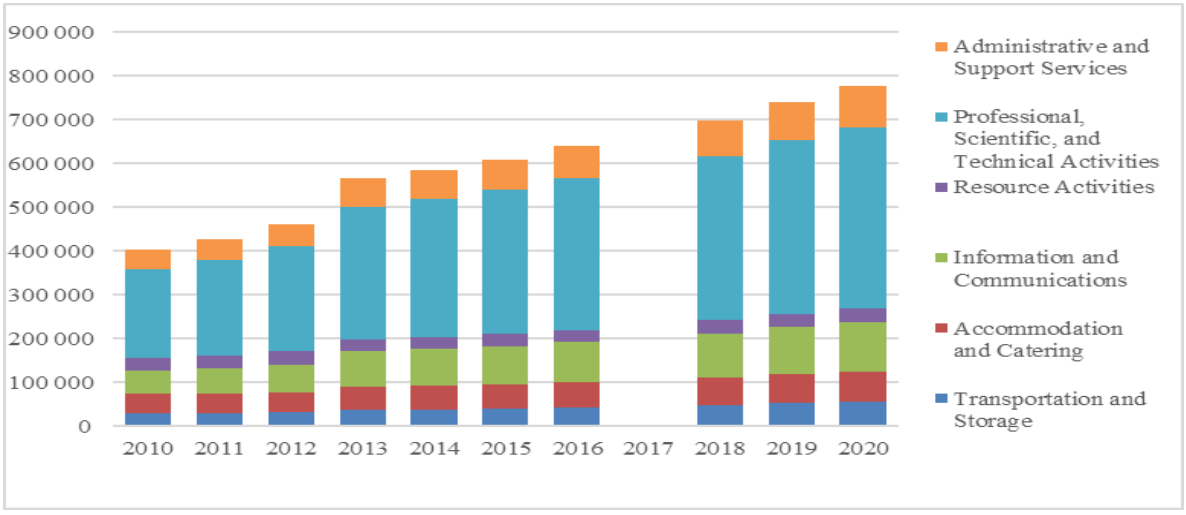

Figure 4. Classification of Service Establishments in the Netherlands
Source: Prepared based on (Eurostat, 2024)
Note: data for 2017 are treated as missing because they are not available

Service activities in the Dutch economy span several fields, with varying numbers of establishments and annual growth rates, where the professional, scientific, and technical activities sector is the main component. It is the largest and fastest-growing sector during the study period, accounting for approximately 53% of the total number of service establishments in 2020, with 413.127 establishments compared to 201,715 in 2010, an increase of 104.9%. These results reflect an important shift in the Netherlands towards a knowledge economy, with the spread and prevalence of consulting, marketing, and technical services, and the ease of establishing small-specialized projects.

With a 14.4% share of all service establishments, information and communication activities ranked second, reaching 111,594 establishments in 2020, up from 52,968 in 2010, thus achieving a strong and stable growth of 110.7% during this period. These results are likely explained by the digital revolution in the country, driven by the growth of software, applications, and e-commerce businesses, indicating the Netherlands' centrality on knowledge-intensive and digitalized services, which in turn has increased demand for internet services and digital infrastructure. This provided opportunities for the services sector establishments to expand and grow.

Establishments operating in administrative activities and support services also experienced remarkable growth, with approximately 109.1% between 2010 and 2020. This service sector can reflect the preference of large organizations to outsource certain tasks and services, such as security, administrative services, cleaning, and others, where this trend is part of efforts to streamline and specialize operations,

leading to an increase in the number of temporary staffing agencies and office support services, for example.

On the other hand, growth in accommodation and food services was moderate (58%) due to intense competition in these activities and the constant entry and exit of companies, despite the dynamism of the tourism and leisure sector in the Netherlands. Meanwhile, the transport and storage sector grew at a rate of 86.1% during the study period, largely driven by e-commerce growth, leading to increased demand for express home delivery services, small shipping services, and related services. Real estate activities, however, are known to be the slowest growing and have the smallest market share among service establishments in the Netherlands, due to the general dominance of large companies in this sector.

This structure demonstrates that the Dutch economy is moving rapidly and steadily towards innovation, knowledge, and digitalization, with e-commerce playing an increasingly vital role in the growth of the transport and warehousing sector and the need for flexible supply chains. Consequently, the Dutch economy is not only experiencing an increase in the number of service providers but also a radical transformation in their quality, as technical and knowledge-based services become a key driver of the economy. These results are consistent with Wache et al. (2024) and Bilderbeek and Hertog (1998), who indicated the increasing role of professional, knowledge-intensive, and technology-based business services in the Dutch case.

The Netherlands has been gradually shifting from manufacturing to services; for example, since 2000, the share of manufacturing activities in total income within global goods value chains has declined significantly, while the share of professional services, such as marketing, legal, and others, has risen considerably. The study by Wache et al. (2024) found that, since 2018, professional services have been one of the largest contributors to total income, accounting for 27%, while administrative, organizational, and engineering activities have remained relatively stable. The role of non-manufacturing sectors in value chains has also increased, driven by service activities such as trade, information, and communications. Technology-based knowledge-intensive business services (T-KIBS), including information technology, engineering, and architectural services, have played a significant role in this evolution, serving as a key driver of innovation and knowledge transfer while connecting service providers to various industries. This, in turn, boosts the nation’s economic competitiveness (Bilderbeek and Hertog, 1998).

In this context, the Dutch case reflects a more advanced structural shift, where digital and knowledge-intensive services play a dominant role compared to traditional service activities, highlighting the importance of a higher level of integration in global value chains.

After clarifying the overall economic performance of the services sector in the Dutch economy, it is necessary to examine the economic performance of the activities and sub-sectors within this sector, after presenting their respective shares, thus highlighting their contribution to economic performance. The following analysis presents the economic indicators for each major services sector.

Figure 5. Evolution of production value and turnover by sub-sectors of Dutch services
Source: Prepared based on (Eurostat, 2024)
Note: Data for 2017 are treated as missing because they are not available

The preceding figures illustrate that both professional, scientific, and technical activities, as well as transport and storage activities, are fundamental to the service economy in the Netherlands and are active components of the overall economic structure. This is reflected in their ranking first and second, respectively, in terms of turnover and production value among all service activities in the country. The turnover and production value of professional, scientific, and technical activities exceeded €90-100 billion by the end of the study period, reflecting their pivotal role as high-value, knowledge- and technology-related services. Meanwhile, in 2020, the turnover and production value of transport and storage activities reached €87 billion and €65 billion, respectively, reflecting their strategic role in the Dutch economy, stemming from the country's geographical location as a global trade gateway.

These findings confirm the findings of Wache et al. (2024) noted the Netherland's remarkable specialization in professional services, surpassing countries with similar specializations, such as the Scandinavian countries and the European Union average. They also extend the evidence by highlighting that the Dutch specialization is observed in its services sector's turnover and production value, not just its position within value chains. Therefore, the Netherlands' distinctive position is relatively based on two pillars that reflect its role as a business hub in Europe: knowledge-intensive professional services and logistics.

The information and communications technology (ICT) sector is a rapidly growing activity, with both its turnover and production value increasing steadily, reflecting, as previously explained, the economic shift towards digitalization and technology, and has also strengthened the Netherlands' position as a leader in digital infrastructure in Europe. Although these activities are relatively new, they have become a fundamental pillar of the Dutch services sector, highlighting the Dutch focus on digital innovation and knowledge-intensive services.

In contrast, administrative and support activities are considered more supportive than a primary driver, contributing less than the aforementioned activities to the economy, despite their turnover and production value sometimes exceeding €90 billion. On the other hand, the contribution of real estate activities to the economy remains relatively stable, ranging from €23 billion to €31 billion in both turnover and production value. This is attributed to the sector's ability to maintain stable production levels and its lower vulnerability to fluctuations compared to other sectors.

The accommodation and food services sectors are experiencing rapid and sustained growth, despite being the smallest among service activities in terms of financial value. This is due to their close link with tourism and domestic consumption; as they continue to expand, those two activities have become of great economic and social importance in the Netherlands. However, their high vulnerability to market fluctuations remains a key restriction.

The COVID-19 crisis had varying impacts on service sectors in the Netherlands, depending on their nature. Accommodation, food services, transportation, and storage were the hardest hit, due to the disruption of the retail sector and the closure of the tourism and travel industry, including hotels, restaurants, and related services. Meanwhile, information and communication activities maintained relatively high levels of activity and revenue, due to their reliance on digital services, which saw increased demand during the pandemic. This trend reveals a relative resilience in professional, scientific, and technical activities despite the overall economic downturn. The real estate sector was also affected by the pandemic, experiencing a significant decline in turnover and production value, although this impact was less severe than that on the consumer-oriented sectors.

In terms of weight and contribution to the economy, the preceding results highlight that professional, scientific, and technical activities, administrative and support services, and transport and storage services collectively represent some of the largest shares of the service sector in the Netherlands, exceeding 67% (22-23% each), making them a central pillar of the country's service economy. Following these activities is the information and communication sector, with a share of 19%, a significant percentage that underscores this sector's size and importance compared to other sectors.

All these observations demonstrate that the service sector in the Netherlands is primarily geared towards business-to-business services (B2B), with the logistics sector being the largest contributor and most influential in the country's service economy, compared to consumer sectors such as restaurants and hotels. This structure demonstrates that business services in the Dutch economy are key intermediate inputs that supports its competitiveness and integration into global supply chains. This aligns with the findings of Beverelli et al. (2017), Shen and Liu (2024), and Yu et al. (2021) who identified that business services, information and communication technology, and transport and logistics services all represent strategic intermediate inputs that effectively contribute to supporting productivity and enhancing coordination among supply chains.

The preceding indicators measure the activity of the sub-sectors of services and their market transactions, while understanding their true economic contribution and their role in generating profitability requires other indicators, such as value added and operating surplus, which highlight their contribution to GDP and their ability to generate income and profits, as shown below.

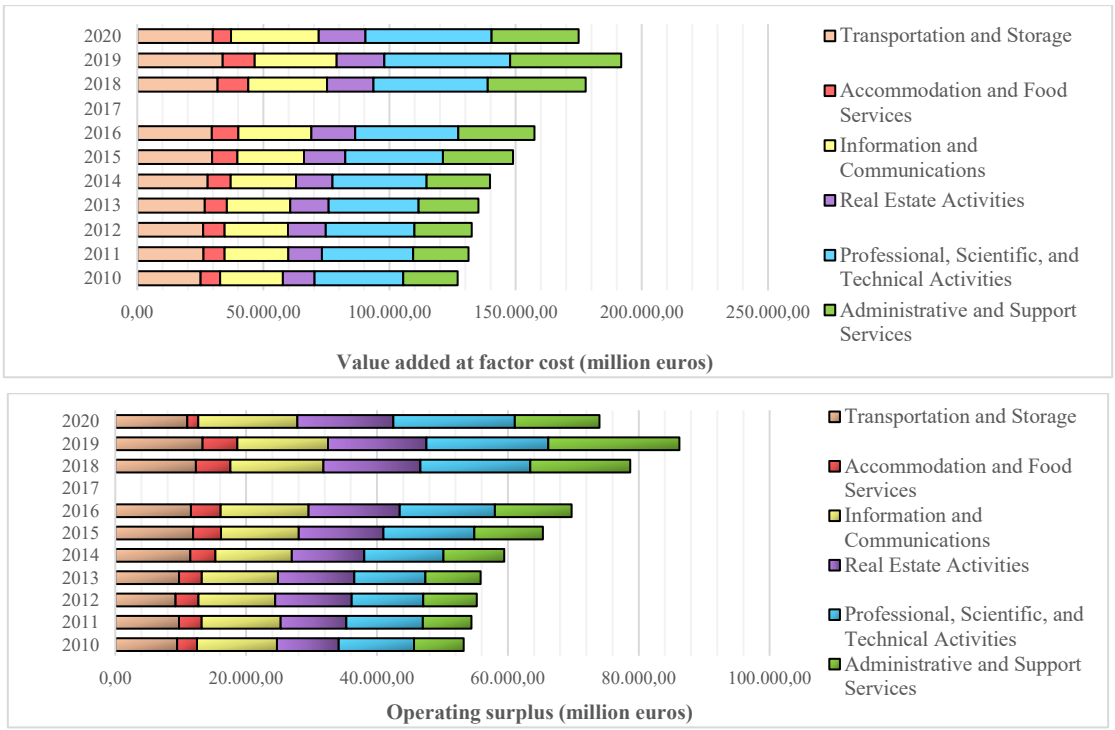

Figure 6. Evolution of value added and operating surplus by sub-sectors of Dutch services
Source: Prepared based on (Eurostat, 2024)
Note: Data for 2017 are treated as missing because they are not available

Figure 6s shows that professional, scientific, and technical activities accounted for approximately a quarter (26%) of the total value added in the services sector at the end of the study period, amounting to nearly €50 billion. These activities consistently outperformed other sub-service sectors throughout this period, indicating their fundamental role in generating added value. Administrative and support services followed, with a value of approximately 23% (€34.5 billion), reflecting the trend towards outsourcing non-core services. The value added of information, communication, transport, and storage services ranged from €25 to €35 billion, further highlighting their crucial importance to the economy. Accommodation and food services had the lowest value added in the Dutch services sector, despite their dynamism due to their connection to the country's thriving tourism and leisure industry.

This situation continued in subsequent years; in 2023, the combined contribution of trade, transport, hospitality, communications, finance, real estate, and business services to the Dutch economy amounted to approximately 54% of the added value. In contrast, non-commercial services in the public sector, education and healthcare, along with relatively small service sectors such as culture and entertainment, accounted for 23% of the total value added in 2023 (CBS, 2024).

In terms of profitability, the ICT sector was the most profitable in the Netherlands from 2010 to 2016, consistently leading in operating surplus. After 2017, this ranking underwent a clear change, as the administrative and support services sector began to surpass the profitability of the ICT sector, by a small margin in 2018, and then by a larger margin since 2019, becoming one of the leading sectors during these years with the professional, scientific, and technical activities, which is commensurate with this sector's considerable size. However, the specific circumstances of the global COVID-19 health crisis, which negatively affected many service sectors, proved beneficial for the ICT sector, which regained its leading position in 2020 in terms of operating surplus.

Based on the aforementioned indicators - turnover, production value, added value, and operating surplus - a clear difference emerges among sub-sectors of the services in the Netherlands in terms of their contribution and weight in the economy. Professional, scientific, and technical activities constitute the highest sub-sector in terms of added value and production value, along with a significant capacity to convert their economic activity into income, reflecting its relatively high efficiency. In contrast, accommodation and food services contribute the least to the economy in terms of added value and operating surplus, thus diminishing their economic efficiency despite their social and economic importance to the country. The variations in those values illustrate the disparity in productivity and profitability among the service sub-sectors in the Netherlands. This analysis addresses *H2 by highlighting differences in efficiency across service sub-sectors in the Netherlands.*

4.2. The Contribution of the Services Sector to the Dutch Foreign Trade

The services sector in the Netherlands plays a central role in its foreign trade with a remarkable contribution in the international services trade. Openness to international markets and excellence in key sectors have helped it achieve this superiority.

Service imports represent a significant share of the Netherlands' trade, as the country imports a variety of services to meet domestic market needs, including those that support economic activities. Service exports are also a vital part of the Dutch economy and a key component of its trade, reflecting growth and the country's position in international trade. The evolution is shown in the figure 7 below.

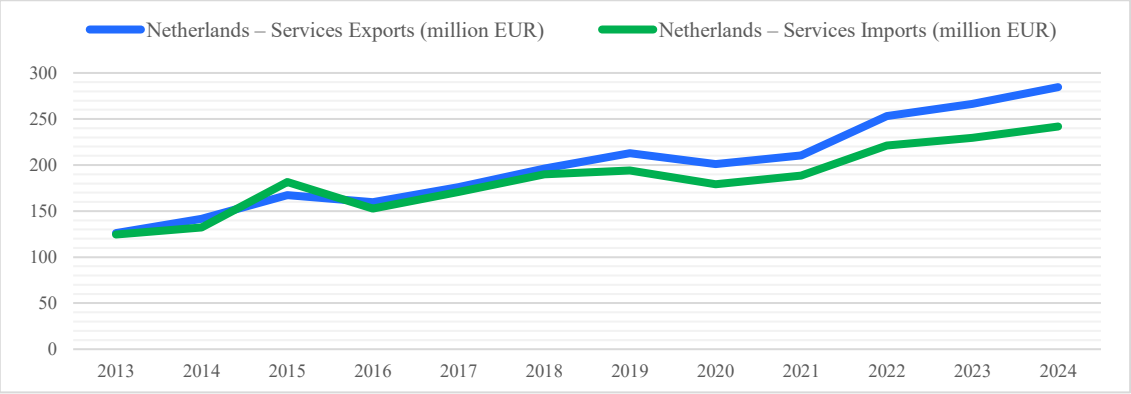

Figure 7. Evolution of Service Imports and Exports in the Netherlands, 2013-2024
Source: Prepared based on (Eurostat, 2026)

Figure 7 highlights the long-term upward trend of Dutch service imports, characterized by significant and sustained growth, despite some occasional fluctuations in certain years. Its total value increased from €124.6 billion in 2013 to €241.8 billion in 2024. It should be noted that a decline was recorded in 2016 and 2020, which may be attributed to the impact of the economic cycle, and the COVID-19 crisis in 2020, with the recovery of the import trend observed after each recorded decline.

Service exports in the Netherlands generally followed an upward trend during the study period, with some minor fluctuations, except for a decline in 2019-2020 due to the COVID-19 pandemic. Overall, however, these exports experienced a significant surge, more than doubling (over 125%), reaching a value of €284.6 billion in 2024, compared to approximately €126.1 billion in 2013. This highlights the dynamism of service sector exports and their high sensitivity to external fluctuations. This sensitivity is evident in the decline experienced in 2016, 2020 in line with imports, indicating the remarkable impact of the global economy and trade on these transactions.

These trends, however, retain the specificities of the sectors and activities associated with it. For example, a continuous upward trend was recorded since 2015 in net Dutch service exports, driven mainly by manufacturing, communications, and transport services, while net imports of travel services experienced a decline during this period (European Union, 2024).

From that, it appears that both service exports and imports in the Netherlands follow a similar growth trajectory, indicating long-term, gradual growth. At the same time, service exports have demonstrated greater dynamism and resilience to crises compared to service imports. This growth in both service exports and imports reflects the country's high level of trade openness, one of the highest globally, which has been facilitated since the beginning of the millennium by the growth of global trade and advancements in transport and communication technologies (OECD, 2025).

Those findings are also consistent with an OECD (2025) report, which addressed the growing importance of services trade in the Netherlands, where the contribution of services exports to GDP more than doubled from 7% in 1995 to 14% in 2022. This indicates a sustained and significant increase in service exports over time, confirming the growing role of services in the Dutch economy.

These results may be explained by the nature of the Dutch economy, which relies heavily on imported intermediate services such as business services, information technology services, logistics, and others to support domestic production. This pattern explains some of the fluctuations recorded in the Dutch service imports in certain years of the study, as they are linked to the productive sector and, consequently, to fluctuations in economic activity, both domestically and globally. Therefore, this pattern suggests that the increase in service imports in the Netherlands is more closely linked to the structural needs of the economy than to potentially temporary consumer demand. These observations are consistent with Shieh (2020), the OECD (2024), and the WTO and World Bank (2023), highlighting that trade in intermediate and business services in advanced economies is an important source of their specialization and international competitiveness. The Dutch case also indicates a reliance on intermediate services as a structural component of its economy, reflecting its deeper integration into global production and trade networks.

Based on the difference between these service exports and imports, the services trade balance emerges, which is one of the indicators that demonstrates the Netherlands' position in international trade, as discussed below.

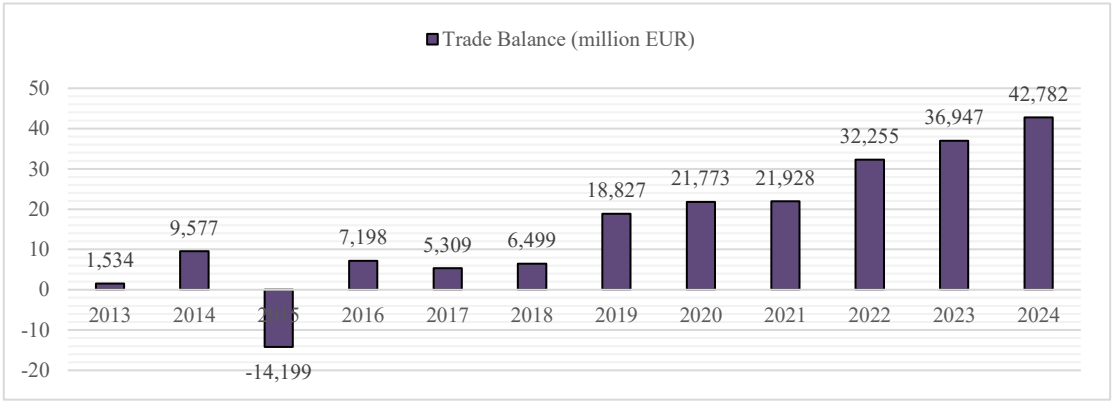

Figure 8. Evolution of the Netherlands' Services Trade Balance
Source: Prepared based on (Eurostat, 2026)

As shown in Figure 8, the Dutch services trade balance has maintained a persistent structural trade surplus throughout most of the study period, with service exports consistently exceeding service imports. This observation indicates a long-term upward growth trend, not just a temporary surplus.

The results also reflect a shift from fragility to structural strength. The services trade balance fluctuated between 2014 and 2018, with a deficit of €-14.199 billion in 2015, likely due to high domestic demand for foreign services that continued to threaten the Netherlands' ability to export services during this period, increasing its competitive vulnerability. Since 2019, this balance has recorded a gradual increase in surplus, marking a turning point in the balance with an €18.827 billion surplus. A surplus is also noted during the COVID-19 crisis, with €21.773 billion in 2020, despite its disruptions to the global economy and trade and the accompanying negative expectations, indicating the relative resilience of service exports in the Netherlands and the country's integration into international services networks. These findings are in accordance with the study by Tajoli et al. (2021) that discussed the crucial role a country's location and degree of integration within international services trade networks play in shaping its performance in global trade.

The Dutch services trade balance maintained this surplus in the years following the crisis, with an increase from €1.534 billion in 2013 to €42.782 billion in 2024, representing an important growth of 2779%. This significant and sustained trade surplus in the Netherlands reflects dynamic export activity and high competitiveness, even during periods of economic slowdown. This can be attributed to its strong global position as a hub for multinational corporations and their subsidiaries, as well as a centre for transport and logistics (OECD, 2025).

The above demonstrates that the Netherlands is heavily reliant on international trade, making its economy vulnerable to global volatility, geopolitical fragmentation, and supply chain disruptions. The fragility of this economy became particularly evident during the COVID-19 pandemic and the Russia-Ukraine conflict. It is also vulnerable to weak external demand as a result of heightened trade policy uncertainties since 2015 stemming from geopolitical fragmentation, shifting trade alliances, and rising protectionism. These supply chain disruptions pose a concern for digital infrastructure components whose production is concentrated in specific geographic regions, while global demand for them continues to grow (OECD, 2025).

The preceding findings regarding imports, exports, and the trade balance of the services sector in the Netherlands are consistent with hypothesis H3: *The services sector in the Netherlands is associated with its foreign trade.*

To better contextualize the previous results, it is advisable to compare the Netherlands with other countries, specifically by placing it within the European context, where data relating to the service sector highlights its weight in the economy and trade of both the Netherlands and the European Union, as follows:

Table 1. Netherlands' Share in the EU Services value added at factor cost

	2010	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
(%)	-	6.67	6.69	6.66	6.65	6.79	6.87	-	7.07	7.32	6.95

Source: Prepared based on (Eurostat, 2024)

Table 1 indicates a relatively stable share of Dutch services value added at factor cost in the EU total, with a proportion between 6.6% and 7.3% during the study period. This relative stability of its share reflects the ability of the Dutch services sector to maintain its position and standing within the European economy, without experiencing major fluctuations.

Furthermore, the Netherlands achieved service sector growth between 2015 and 2019 that was relatively higher than the EU average. However, the Netherlands was more significantly impacted by the COVID-

19 pandemic than the EU as a whole, with the services sector's share of total EU services value added declining to 6.95% in 2020.

Table 2. Netherlands' Share in the EU Services Trade

	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Exports Share (%)	9.52	9.91	10.60	9.72	9.83	10.29	10.29	11.06	9.87	9.53	9.54	9.48
Imports Share (%)	10.57	10.39	12.44	10.05	10.48	11.09	10.05	10.42	9.98	9.42	9.18	9.12

Source: Prepared based on (Eurostat, 2026)

The results in Table 2 show that the Netherlands maintained a relatively stable contribution to EU services trade throughout the study period, despite some minor fluctuations, indicating its significant role in this trade. Its share of EU services exports ranged between 9.50% and 11.10%, while its share of EU services imports ranged between 9.10% and 12.40%.

Comparing service exports and imports, the share of service imports slightly exceeded that of exports, peaking in 2015 at 12.44%, reflecting the Netherlands' strong integration into the EU services market, with a significant reliance on both exporting and importing services. During the COVID-19 pandemic, specifically in 2020, the Netherlands recorded a significant increase in its share of service exports (11.06%), contrary to expectations of an economic recession at that time. This may suggest structural advantages or resilience within the Dutch service sub-sectors during that period. However, these exports and imports declined after 2020, reaching levels around 9-9.50% by 2024.

The relative stability of the Netherlands' share of EU services sector value added, exports, and imports reflects both its important contribution as a country in the European services economy and the competitiveness of its services sector in international markets.

4.3. Statistical assessment of the hypotheses

As explained in the Methodology section, the descriptive analysis is enhanced by simple tests, including correlation, simple linear and multiple regression models, based on selected indicators such as services value added (measured at factor cost as shown before), GDP, service exports and service imports (measured in current prices). This is done to explore the relationship between the expansion of the services sector in the Netherlands and its overall economic performance.

The correlation analysis is conducted using the commonly available years for the four indicators (2013-2016 and 2018-2020) on the Eurostat database; results are shown in the following table 3.

Table 3. Correlation matrix of service-related indicators and GDP in the Netherlands

Variable	GDP	Services Value Added	Services Exports	Services Imports
GDP	1.000	0.977	0.969	0.825
Services Value Added	0.977	1.000	0.970	0.859
Services Exports	0.969	0.970	1.000	0.933
Services Imports	0.825	0.859	0.933	1.000

Source: Prepared based on (Eurostat, 2024), (Eurostat, 2026)

Table 3 shows a strong positive correlation between the expansion of the services sector in the Netherlands and key macroeconomic indicators. The value added of services is very strongly correlated with GDP (0.977), indicating that the growth of this sector is closely associated with the country's economic performance. Furthermore, Dutch service exports are highly correlated with both service value added and GDP (0.970 and 0.969, respectively); the service imports are also highly correlated with GDP (0.825) and value added (0.859). In addition, the correlation value (0.933) indicates a very strong and close relationship between exports and imports in the Dutch services sector, underscoring the important role of services within the structure of the Netherlands' foreign trade.

This pattern indicates that the services sector is closely linked to production and trade indicators, and that there is significant integration between exports and imports in this sector. This highlights that the Netherlands possesses a sophisticated and interconnected trade structure within the services sector, and that the latter contributes meaningfully to its economic activity. In addition, the relationship between the services sector and economic performance is examined using a simple linear regression model, with GDP as the dependent variable and services value added as the independent variable.

According to Table 4, the relationship between service value added and GDP in the Netherlands is statistically significant with p-value < 0.001. This relationship is relatively strong, where the value of the regression coefficient reached 3.120, which means that a one-unit increase in services value added is associated with an increase in GDP by 3.12 units. At the same time, the model explains a large proportion of the variation in GDP ($R^2 = 0.955$), which indicates a relatively strong association between the services sector and overall economic performance.

Table 4. Simple Linear Regression Results between GDP and services value added

Variable	Coefficient	t-statistic	p-value
Constant (GDP)	240580.5	4.899	0.0045
Services Value Added	3.120	10.295	0.00015
R-squared	0.955	-	-

Source: Prepared based on (Eurostat, 2024), (Eurostat, 2026)

Previous empirical results, including correlation and simple regression, are consistent with H1, which suggests the important role of the services sector in Dutch economic performance.

They also support the descriptive findings and are consistent with previous studies linking the growth of the services sector to economic performance in advanced economies. Even so, this link in the Dutch case should be interpreted as a sign of structural interdependence rather than causation, as services added-value, services exports, services imports, and GDP evolved together. Additionally, the relationship between the services sector and foreign trade is examined using simple regression models between services value added and external trade indicators: services exports and imports.

Table 5. Simple Linear Regression Results between services value added and services exports

Variable	Coefficient	t-statistic	p-value
Constant (services exports)	- 66528.1	- 2.464	0.057
Services Value Added	1.484	8.904	0.0003
R-squared	0.941	-	-

Source: Prepared based on (Eurostat, 2024), (Eurostat, 2026)

Table 5 shows that the relationship between services value added and Dutch services exports is statistically significant with a p-value < 0.001. This relationship is positive, with the regression coefficient value reaching 1.484, which means that a one-unit increase in services value added is associated with an increase in services exports by 1.484 units. The model also explains a large proportion of the variation in services exports (R^2 = 0.941), which reflects the strong relationship between the services sector and external trade.

Table 6. Simple Linear Regression Results between services value added and services imports.

Variable	Coefficient	t-statistic	p-value
Constant (services imports)	- 19870.2	- 0.401	0.705
Services Value Added	1.148	3.760	0.013
R-squared	0.739	-	--

Source: Prepared based on (Eurostat, 2024), (Eurostat, 2026)

Table 6 shows a statistically significant and positive relationship between services value added and services imports, with a p-value < 0.05 (p = 0.013) and a regression coefficient value of 1.148. This means that an increase of one-unit in services value added is associated with an increase of 1.148 units in services imports. The R-squared value, reaching 0.739, indicates that 73.9% of the variation in services imports is explained by this model, indicating a relatively strong relationship between the services sector and services imports.

Based on these results, the simple regression analysis between services value added and both services exports and services imports provide indicative support for H3, suggesting that the services sector in the Netherlands is associated with its foreign trade.

Meanwhile, H2 is examined through the comparative descriptive analysis presented in the previous sections, showing differences between service sub-sectors and their contributions to the Dutch economy. For a more comprehensive empirical analysis, the study explores the effect of services-related indicators on economic performance using a multiple regression model.

Table 7. Multiple Regression Results between GDP and service-related indicators

Variable	Coefficient	t-statistic	p-value
Constant (GDP)	386509.8	6.519	0.0073
Services Value Added	0.748	0.804	0.480
Services Exports	2.568	2.981	0.059
Services Imports	- 1.253	- 2.665	0.076
R-squared	0.989	-	-

Source: Prepared based on (Eurostat, 2024), (Eurostat, 2026)

Table 7 shows that this model explains a large proportion of the variation in GDP (R^2 = 0.989), indicating that the model has relatively high explanatory power. However, statistical significance varies among individual coefficients, and the results should be interpreted with caution due to the limited sample size, as follows:

Despite its positive coefficient (0.748), the value added of services is not statistically significant (p > 0.1), reflecting the lack of clarity regarding its individual effect when other variables are present in the model. Services exports are statistically significant (p < 0.1), albeit marginally (p = 0.059), with a positive coefficient (2.568), suggesting a possible positive association with GDP.

Services imports are also marginally statistically significant ($p = 0.076$; $p < 0.1$), however, they have a negative coefficient (- 1.253), indicating a possible inverse relationship with economic performance.
These results may suggest potential multicollinearity between the explanatory variables, which could influence the statistical significance of individual coefficients.
The previous results showed high bidirectional correlations between the explanatory variables. Therefore, table 8. shows the results of calculating the Variance Inflation Factor (VIF) according to the following relationship: $VIF = 1 / (1 – R^2)$

Table 8. VIF results

Variable	VIF
Services Value Added	22.85
Services Exports	45.85
Services Imports	10.41

Source: Author's calculation (2025)

All VIF values shown in Table 8 are greater than 10, reflecting a strong multicollinearity between the explanatory variables. Accordingly, a strong correlation is observed between the value added of services, service exports, and service imports, which is reflected in the inflation of standard errors and the decrease in the statistical significance of individual coefficients in the multiple regression model.
Therefore, it is important to note that multiple regression results should not be interpreted as strong evidence of independent effects of each variable, but rather as exploratory and diagnostic findings.
Regarding H1, multiple regression analysis offers a more comprehensive interpretation. By including both service exports and imports in the model, the coefficient of services value-added becomes statistically insignificant. This analysis reveals the difficulty of isolating the individual contributions of highly correlated service sector indicators within a small sample size and does not necessarily indicate a lack of relationship between the service sector and economic performance.
The results also suggest that foreign trade in services, especially service exports, is linked to the economic performance of the Netherlands.

5. Limitations

This study has several limitations, the first being the absence of 2017 data related to the services sector in the Netherlands from the selected database (Eurostat), which may affect the consistency of the trend. At the same time, the statistical analysis relies on a small sample comprising a limited number of annual observations, which may influence the interpretation of the results, as they should be interpreted as indicative rather than conclusive. This is because the limited sample size affects the robustness of the statistical inference, with the possibility of inflated correlation and regression coefficients.

6. Conclusion

According to the analysis provided in this study, it is evident that the services sector in the Netherlands has undergone significant structural growth, with the count of service establishments more than doubling within a span of just ten years. This sector demonstrates a consistent rise in value creation and operating surplus, implying a relatively high level of profitability and efficiency in the economy, along with a degree of resilience during crises. Professional, scientific, and technical activities, as well as information

and communication technologies, are vital elements of the Dutch economy, closely linked to the shift towards a knowledge-based and digital economy.
Concurrently, the Netherlands possesses relative strength and competitive advantage in the services trade, particularly in intermediate exports of financial, technological, and logistical services, supporting its position in the international services trade. The services trade balance has shown a growing structural surplus, especially since 2019, highlighting the country's relative strength in service exports compared to its service imports, even during periods of crisis.
These results show that the services sector forms an important part of the Dutch economy and they provide a reference framework for identifying the most dynamic and influential service sectors in the economy. Those findings highlight the importance of investing in digital and knowledge-based services, diversifying the service base, reduce over-reliance on sensitive and crisis-prone sectors such as tourism and transportation, and supporting the development of digital and logistical infrastructure to sustain the Netherlands' competitive advantage in intermediate services trade.

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Sektor usluga u nizozemskom gospodarstvu: ekonomski doprinos i rezultati vanjske trgovine

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Sažetak: Ovaj rad ima za cilj prikazati strukturnu dinamiku i doprinos uslužnog sektora nizozemskom gospodarstvu, kao jednom od gospodarstava država članica Europske unije koje predstavlja vodeći model gospodarstva temeljenog na uslugama. Za analizu službenih statističkih podataka Eurostata o uslužnom sektoru za razdoblje 2010.–2020. korišten je deskriptivno-analitički pristup, dok podaci o trgovini uslugama obuhvaćaju razdoblje do 2024. godine. Rezultati pokazuju da uslužni sektor ima ključnu ulogu u nizozemskom gospodarstvu te značajno doprinosi stvaranju dodane vrijednosti, profitabilnosti i vanjskoj trgovini, uključujući izvoz i uvoz. Unatoč svojoj fleksibilnosti i raznolikosti, uslužni sektor i dalje je osjetljiv na globalne poremećaje i gospodarska kretanja, što naglašava potrebu za strateškim ulaganjima i odgovarajućom potporom javnih politika radi očuvanja konkurentnosti i dugoročnog rasta. Ograničenja istraživanja odnose se na nedostatak podataka za uslužni sektor za 2017. godinu te na mali uzorak korišten u regresijskim modelima. Doprinos studije ogleda se u pružanju kvantitativne analize koja nadopunjuje prethodna kvalitativna istraživanja te dodatno rasvjetljava ulogu uslužnog sektora u nizozemskom gospodarstvu i međunarodnoj trgovini. Za buduća istraživanja preporučuje se provedba sveobuhvatnijih analiza koje bi obuhvatile širi skup podataka i dulje vremensko razdoblje, uključujući proučavanje utjecaja globalnih čimbenika na uslužni sektor u Nizozemskoj ili usporedbu s odabranim zemljama.

Ključne riječi: Uslužni sektor; uslužno gospodarstvo; trgovina uslugama; gospodarska konkurentnost; Nizozemska
JEL klasifikacija: F14; L80; O52

Service Quality in the P2P Economy: SERVQUAL Applied to Airbnb Listings in World Heritage Site

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Abstract: As a result of the rapid growth of peer-to-peer (P2P) as an innovative business model in the hospitality industry and the need for world heritage sites (WHS) protection from over-tourism development, investigating the service quality of P2P accommodation in WHS is of paramount importance. The main purpose of this paper was to identify which service dimensions in P2P accommodation in WHS have been evaluated by guests as of the highest quality. To achieve the main purpose of this paper, empirical research was conducted using a convenience sample of 352 tourists who had used P2P accommodation in the Dubrovnik WHS between April and October 2022 and between May and October 2023. Based on empirical research using the SERVQUAL model, tourists had the lowest expectations for hosts' empathy and responsiveness, compared with tangible elements in accommodation units, which they expected the most. The results indicated that, in WHS, the most prominent dimension of P2P accommodation units, based on perceptions, is responsiveness. Additionally, tourists who stayed in P2P accommodations in the Dubrovnik WHS rated empathy and responsiveness as the two highest-rated quality dimensions. In addition to its theoretical contribution, the findings of this paper could serve as guidelines for categorizing P2P accommodation in WHSs and as indicators for hosts in WHSs of what needs to be upgraded and improved. The results could also help urban planners and P2P promoters in WHS assess the degree of reality or exaggeration in P2P. Given the limitations of this paper and considering the research area and sample, future research should examine more WHSs and conduct comparative analyses of P2P accommodation quality outside WHSs.

Keywords: peer-to-peer (P2P), service quality, world heritage site (WHS)
JEL Classification: L83, Z32

1. Introduction

Internet development, especially Web 2.0, has led to the emergence of a new form of the sharing economy (peer-to-peer economy), defined as a model based on sharing underutilized assets, largely focused on peer-to-peer transactions (Botsman & Rogers, 2011, in Hall et al., 2022). It has also created

opportunities for consumers to engage in sharing consumption and to focus on network relationality (Marques & Gondim Matos, 2020).

The growth of peer-to-peer economy platforms, such as Booking.com, Uber, and Airbnb, is changing how services are consumed, how communication occurs, and how relationships among tourism stakeholders are formed. Accommodation, as a dominant part of hospitality, is the largest and most important segment of the tourism industry. Its volume and importance in tourism necessitate research into the quality of accommodation capacity. In 2024, 854 million nights were booked via collaborative economy platforms – a surge of nearly 19% compared to 2023 (EUROSTAT, accessed 27.02.2026). Many sharing economy studies have used the Airbnb accommodation platform as a research example and have often emphasized that value for money and an authentic experience are components that guests cannot experience in traditional and conventional accommodations such as hotels (Zhu et al., 2019; Makkar, Farrelly & Athwal, 2024). The Airbnb platform has the largest impact on the accommodation sector in destinations. Although hotels are the leading type in the accommodation industry, Airbnb has become a major market challenger. Today, Airbnb has over 8 million active listings, with growth across all regions and markets during the third quarter of 2024 (Airbnb, 2024), and its role is increasingly important in the hospitality industry. Airbnb reported strong financial performance in 2025, driven by record revenue and booking growth. Q4 2025 revenue reached a billion, a year-over-year increase, with full-year gross bookings demonstrating robust demand (Airbnb Newsroom, 2026).

Since the adoption of the Convention concerning the Protection of World Natural and Cultural Heritage in 1972, the UNESCO list of protected natural and cultural sites has grown from 12 sites in 1978 to 1223 sites in 2025 (UNESCO). Historic centers, as destinations for heritage and cultural tourism, have experienced steady growth in tourist flows (Gómez, 2020). WHSs are increasingly used as a tool for national tourism marketing campaigns and to increase tourism arrivals (Li, Wu & Cai, 2008; Adie & Hall, 2017).

Reasons why Dubrovnik WHS is chosen for this research are multiple: 1) it was among the first to be inscribed on the World Heritage List in 1979; 2) it suffers serious problems from mass tourism; 3) there is a strong presence of P2P accommodation facilities within the WHS; 4) tourism is the main economic activity, with a share of over 80% in GDP; 5) the tradition of tourist accommodation rentals in the WHS dates back to the 18th century.

Because WHSs are used to increase tourism arrivals, it is essential to provide high-quality accommodation within a world heritage site. In the Dubrovnik WHS, the number of beds in P2P accommodation exceeds that in hotels.

To identify areas for improvement, this paper analyzes service quality in P2P accommodation within the Dubrovnik WHS using the SERVQUAL model. The SERVQUAL model was used in this study because service quality is the difference between expectations before using the service and the experience after using it.

2. Theoretical background

The term collaborative consumption was first used by Felson and Spaeth in 1978 to describe the shared consumption of economic goods that occurs as part of activities between two or more people, such as sharing drinks and food with relatives or friends (Mondal & Samaddar, 2020). The term sharing economy was first mentioned in 2008 (around the same time that the rapid development of the sharing economy in its "new" form began) and was defined as shared consumption created through joint activities, exchange, or rental of resources without their ownership (Lessing, 2008). The sharing economy was first developed in the B2B (Business-to-Business) option, where different firms share

resources such as machinery in agriculture and forestry, as well as in the B2C (Business-to-Customer) option in the form of self-service laundries, rent-a-car services, public libraries, and use of swimming pools, where companies provide services to consumers (Puschmann & Alt, 2016). Afterwards, the C2C (Customer-to-Customer) model, also called P2P (Peer-to-Peer), appeared as a new business model where transactions took place between private consumers. It has aroused scientists' interest and provoked polemics and discussion. Previous and related research has shown that motives for using P2P accommodation platforms include an authentic experience and communication with the host (Young, Corsun, & Xie, 2017; Pung, Del Chiappa, & Sini, 2019), curiosity and a desire for new experiences (Lalicic & Weismayer, 2018), and enjoyment of a "home-like" experience (Olya et al., 2018). Current tourists are mainly looking for authenticity, socialization, and experience co-creation (Sigala, 2017), which can all be found in P2P accommodation.

Accommodation and transportation are the dominant subsectors within tourism and the sharing economy (Hossain, M., 2020). By offering practical, economically viable services, the sharing economy has strongly influenced the transformation of tourism and hospitality (Dogru & al., 2020). However, the sharing economy in tourist destinations extends beyond accommodation and transportation to include car sharing (e.g., Car2Go), meal sharing (e.g., EatWith), and local knowledge sharing (Sigala, 2015). In general, the sharing economy in tourism can be grouped into four categories: transportation, accommodation, tour guide services, and food services (Kuhzadya, Seyfi, & Béalc, 2022). In tourist destinations, the sharing economy offers local residents the opportunity to "serve" tourists alongside traditional service providers, thereby generating additional profit. Collaborative consumption is characterized by greater elasticity and dynamism, which continuously shape new markets and change tourism structures and experiences (Tussyadiah & Sigala, 2018). Within the P2P market, local residents, traditional service providers, suppliers, and platforms jointly create tourism experiences and redefine values, motives, reasons, and ways in which people travel and experience tourism (Sigala, 2015). Given the importance of P2P accommodation and the points previously mentioned, it is crucial that service quality in P2P accommodation be at the highest level.

In tourism, the service economy dominates because tourists use and pay for transportation, accommodation, food and drink services, and various activities, enjoying them for a limited time and paying for the experiences and accompanying services that enable their consumption. If private accommodation is taken as an example, tourists use the accommodation, the space in which they stay and which is of a material nature, but they do not become its owners but consumers for a certain period. Unlike a product, whose quality can be determined relatively easily based on measurable characteristics, possible performance, or materials from which it is manufactured, determining the quality of a service is much more complex. The quality of services became a focus for scientists in the 1970s, as services began to assume increasing importance in economic development (Prakash & Mohanty, 2013). Namely, the share of services in countries' total GDP, which was previously very low, became equal to that of products (Schneider & White, 2004). On the other hand, with the globalization of the market and increasing competitiveness, companies began to face problems regarding the existence of the tourism market and the differentiation of competition. In the following years, experts from different scientific fields and countries researched and tried to define the concept of service quality, its impact on consumers, and the role of service providers in this process (Schneider & White, 2004). Parasuraman, Zeithaml & Berry (1985) developed the GAP or SERVQUAL model for measuring service quality, which is based on the gap between the service expectation before using the service and the actual experience during the service use. The service expectation before use is created based on previous experiences, media advertising, and word of mouth, and after using the service, the consumer's service perceptions can manifest themselves positively (when the received service was of higher quality than

expected) or negatively (when the delivered service was below the expected quality) (Churchill & Surprenant, 1982). The SERVQUAL model aimed to detect the following differences (Parasuraman, Zeithaml, & Berry, 1985):

• Knowledge gap – the difference between consumer expectations and the provider's perception of what consumers expect from the service

• Standards gap – the difference between the provider's perception of consumer expectations and the service quality specification, i.e., inappropriate service quality standards

• Delivery gap – the difference between the service quality specification and the service that was delivered, i.e., the service delivery gap

• Communication gap – the difference between the delivered service and the service that was promised to consumers during communication; i.e., do consumers receive the promised service

• Service gap – the ultimate difference between the expected and perceived service

A service gap arises when ultimate dissatisfaction with a service stems from at least one of the previously mentioned gaps. To identify the area where the gap has arisen and negatively affected the quality the consumer receives, Parasuraman, Zeithaml & Berry (1985) developed a ten-dimensional measurement scale of service quality. They subsequently revised it in 1988 and consolidated it into five dimensions, namely: reliability (ability to perform the promised service dependably and accurately), assurance (knowledge and courtesy of hosts and their ability to inspire trust and confidence), tangibles (physical facilities, equipment, and appearance of personnel), responsiveness (willingness to help customers and provide prompt service), and empathy (caring, individualized attention the firm provides its customers). The measurement scale consists of 22 individual questions across the five dimensions. Consumers rate their expectations before using the service and their perceptions after using it on a 1-5 scale for each statement. The authors believe that their model allows a deeper understanding of consumer perceptions and evaluation dynamics over time. They also conclude that surveys with negative results do not necessarily indicate poor quality but may result from overly articulated marketing that creates an unrealistic image of the service, thereby distorting consumer expectations (Parasuraman, Zeithaml, & Berry, 1985).

The reason there have been various criticisms of the use of the SERVQUAL model in service industries besides hotels is that, after its introduction, it was mainly used to measure the quality of hotel services. P2P accommodation has all characteristics of service (intangibility, inseparability, variability, perishability, and lack of ownership) and, as such, its quality can be measured by the SERVQUAL model.

Although there is a substantial body of high-quality research in tourism and the hotel industry, there remains a notable lack of literature on service quality in private accommodation. This gap is acknowledged by Brito, Petaković, & Vrtodušić Hrgović (2021), who, in 2020, conducted quality research on private accommodation using a measuring instrument that includes functional and technical dimensions. The aim of their research was to determine differences in perceptions of private accommodation quality with regard to consumers' age, origin, and education, and they found significant differences. They conducted a comparative analysis to determine differences in perceived service quality in private accommodation between domestic and foreign tourists. The research found differing perceptions of service quality in P2P among domestic and foreign consumers and highlighted the elements hosts should focus on, depending on whether they are hosting foreign or domestic tourists. This was confirmed by Mahadevan (2017) and Zhang & Fu (2020). Agyeiwaah, Akyeampong & Amenumey (2014) addressed the influence of socio-demographic status on the choice of private accommodation. On the other hand, there is more literature focused on determining the elements that influence consumers' perception of P2P quality and the reasons that result in choosing this type of

accommodation (Tussyadiah, 2016; Ju, Back, Choi, & Lee, 2018; Pawlicz, Petaković, & Vrtodušić Hrgović, 2022).

A review of recent literature and scientific articles reveals only a few papers that empirically assess P2P quality (Shin, Hwang, & Kim, 2025). More precisely, most papers rely on reviews and analyses of user comments on the Airbnb platform (Ding et al., 2020; Zuo et al., 2022; Ramos, Tanes & Esplanada, 2022; Foroudi et al., 2026). Some authors have used measurement models. Portolan & Olivari (2020) used the SERVQUAL model to study P2P quality in Dubrovnik; Wong & Chan (2023) used P2PSERVQUAL to research P2P quality in Malaysia; Choi, Ann, Lee, & Park (2018) combined the SERVQUAL and IPA models to study P2P quality in rural parts of South Korea; and Frochot & Hughes used HISTOQUAL to measure service quality in historic houses. All previously mentioned studies are "recent," indicating increased interest in researching this type of accommodation. Given the growing popularity of P2P travel and the fact that service quality drives tourist loyalty and attracts new tourists, the number of papers on this topic is expected to increase.

3. Research methodology, results, and discussion

A highly structured questionnaire, which included 22 statements adapted from the SERVQUAL literature and tailored to the current research, was used. Perceptions and expectations were measured on a 5-point Likert scale, ranging from “strongly disagree” (1) to “strongly agree” (5). Perceptions were assessed as perceptions of the performance of hosts providing the services, while expectations were viewed as tourists’ desires or wants, i.e., what tourists feel a host should offer. Service quality was analyzed as the gap between expectations and perceptions (service gap). All statements were phrased positively, as suggested by the authors of the SERVQUAL model. “Dubrovnik WHS gained World Heritage Status at the 3rd session of the World Heritage Committee meeting in October 1979 in Egypt as the first cultural urban and architectural complex in the Republic of Croatia (Report on the UNESCO-ICOMOS Reactive Mission to Old City of Dubrovnik, accessed February 25, 2026). The area that gained World Heritage Status was extended in 1994 at the 18th session of the Committee and included areas outside the city walls, namely the Pile medieval industrial suburb, the Lovrijenac Fortress located on a cliff, the Lazarets (built in the early 17th century to house potential plague-carriers from abroad), Kaše moles (built to protect the port against south-easterly gales), the Revelin Fortress, and the island of Lokrum” (Report on the UNESCO-ICOMOS Reactive Mission to Old City of Dubrovnik, accessed February 25, 2026). As part of Dubrovnik, it is a multiple-use protected area covering 96 ha, with an additional buffer zone of 1188 ha. The empirical research was conducted on a convenience sample of tourists who used Airbnb accommodations in the Dubrovnik WHS during the periods from April to October 2022 and from May to October 2023. Although the research was conducted three to four years ago, the time elapsed has not affected the relevance of the findings, given that the study was conducted at a WHS site where interventions to equip accommodation facilities are demanding, complex, and long-lasting. A total of 411 questionnaires were completed, of which 352 were valid. The data were analyzed using SPSS 29.0. The number of female respondents was higher (59,4%) than that of male respondents (40,6%). The largest share of respondents (43,2%) was in the 30-39-year age group, followed by the 40–49-year age group (20,5%). The majority of respondents had a personal monthly income of 2000 euros or more (63,1%). Respondents were mostly from countries outside the European Union. The dominant motive for visiting was rest and relaxation (83,5%), followed by historical heritage (7.4%). The short stay of tourists is confirmed by the finding that most guests at the Dubrovnik WHS stayed two (24.4%) and three (23.9%) nights. The majority of respondents stayed in apartments or studio apartments

with four (44.9%) and three (38.6%) stars. The largest proportion of respondents listed family and relatives as their travel companions (36.4%). Table 1 presents the sample characteristics.

Table 1. Profile of respondents

Variables	Variables	Frequency	Percentage of total (%)
Gender	Male	143	40,6
	Female	209	59,4
Age	18-29	74	21
	30-39	152	43,2
	40-49	72	20,5
	50-59	36	10,2
	60 and more	18	5,1
Personal monthly income in €	999 and less	6	1,7
	1000-1999	124	35,2
	2000-2999	170	48,3
	3000 and more	52	14,8
Country of origin	within the European Union	126	35,8
	outside the European Union	226	64,2
Length of stay in the unit	one night	40	11,4
	two nights	86	24,4
	three nights	84	23,9
	four nights	46	13,1
	five nights	42	11,9
	six nights	22	6,3
	seven nights	22	6,3
	more than 7 nights	10	2,8
Type of accommodation	studio/apartment 5*	40	11,4
	studio/apartment 4*	158	44,9
	studio/apartment 3*	136	38,6
	room	18	5,1
Dominant motive of visit	rest and relaxation	294	83,5
	business	2	0,6
	VFR	6	1,7
	historical heritage	26	7,4
	wine and gastronomy	18	5,1
	events/festivals	6	1,7
Travel companion	family	128	36,4
	partner	114	32,4
	friends	104	29,5
	none	6	1,7

Source: Author (2026)

Table 2, which presents the ultimate difference between the expected and perceived service for each statement, is presented in Appendix A (Table 2, Appendix A). As suggested by the authors of the SERVQUAL model, items were grouped into five dimension.

Table 3. Reliability Coefficients

	Expectations	**Perceptions**
TANGIBLES (Cronbach's Alpha) The accommodation has authentic furniture	**0,896**	**0,847**
The accommodation has up-to-date (modern) equipment		
The accommodation's physical facilities are visually appealing		
The appearance of the accommodation's physical is in keeping with the type of service provided		
The general cleanliness of the accommodation is satisfactory		
The accommodation's host is well-dressed and appears neat		
EMPHATY (Cronbach's Alpha) The accommodation's host gives guests personalized attention	**0,799**	**0,824**
The accommodation's host has an understanding for guests' special needs		
The accommodation host considers the needs of less-abled guests		
The accommodation's host addresses the guest by name		
The accommodation's host has patience with children		
Accommodation's operation hour is convenient to all its guests		
ASSURANCE (Cronbach's Alpha) Guests feel safe and secure in their stay	**0,728**	**0,729**
The accommodation's host advises undecided guests		
The accommodation's host is always available for the guests		
The accommodation's host is very kind and cordial ton		
RESPONSIVENESS (Cronbach's Alpha) The accommodation's host is highly professional	**0,862**	**0,873**
The accommodation provides its services according to the announcement		
The accommodation’s host responds quickly to any queries		
The accommodation's host is always willing to help, even while busy		
The accommodation provides its services in the domain "value for money"		
RELIABILITY (Cronbach's Alpha) The accommodation's hosts provide service at the time they promise to do so	**0,798**	**0,822**
If you have problems, you can rely on the accommodation's host		
The accommodation's hosts always fulfill their promises regarding service		
The accommodation's host informs guests about all activities in the destination		

Source: Author (2026)

Reliability analysis was used to assess the internal consistency of the items within each dimension (Table 3). It indicates the stability and consistency with which the instrument measures the concept and helps assess the quality of a measure. Johns et al. (2007, p. 93) suggest that values of coefficient alpha equal to or above 0,70 are acceptable indicators of reliability.
Statistical data in Table 4 indicate that service quality in P2P accommodation facilities in Dubrovnik WHS exceeds tourists' expectations.

Table 4. SERVQUAL scores of factors

Service quality dimension	Mean Score Expectation	Mean Score Perception	Mean Score Service Quality
Tangibles	4,28	4,66	0,38
Empathy	3,95	4,66	**0,71**
Assurance	4,11	4,50	0,39
Responsiveness	4,07	4,69	**0,62**
Reliability	4,11	4,65	0,54

Source: Author (2026)

The key elements of service quality are host empathy and responsiveness. Before arrival, tourists expected hosts in P2P accommodation within the Dubrovnik WHS to show low empathy, while the facilities would be clean, modern, and authentic. They were also cautious about host availability and the truthfulness of the promised service. After using P2P accommodation, tourists were delighted by the hosts' empathy and responsiveness.
It is confirmed that equipment in the facility is less important to tourists staying in P2P accommodation in WHS, whereas it is the most important factor for hotel accommodation (Ladhari 2012 in Priporas et al., 2017). The mean perception score across all service quality dimensions was 4.5 or higher, and, together with the mean expectation-perception gaps, indicates high service quality in P2P accommodation facilities in Dubrovnik WHS.
Compared with the most recent research on measuring service quality in P2P accommodation (Ding et al., 2020; Zuo et al., 2022; Ramos, Tanes & Esplanada, 2022; Foroudi et al., 2026), this paper was not based on guest reviews but on primary empirical research. Using a questionnaire ensured that expectations, which are very important in measuring service quality, were not disregarded.
Analyzing P2P accommodation in Malaysia, Wong & Chan (2023) developed a new model, P2PSERVQUAL, which was the first model for measuring service quality in private accommodation. That model was not used in this study because it involved hosts, which affects the objectivity of the results. Only consumers of P2P accommodation facilities are objective when evaluating the facility's service quality.

4. Conclusion

The large number of P2P accommodation facilities on the tourism market and their potential make it necessary to research that type of accommodation. This research was conducted on P2P accommodation units in the Dubrovnik WHS that are listed on the Airbnb platform. The collected data were analyzed using the SERVQUAL five-dimension service model. The outcomes of this study indicate that the service quality of P2P accommodation facilities in the Dubrovnik WHS exceeds the expectations of

tourists who have used them. The key findings of this paper are: the most important element of service quality is the host's empathy, followed by responsiveness; and intangible elements of the service are more important than tangible ones. Based on the findings, service quality in P2P accommodation facilities within the Dubrovnik WHS appears to be influenced by hosts' interactions and relationships with guests. It can be concluded that traditional guest-host relations and hospitality above decoration should be the main elements of service in P2P accommodation in WHS.

SERVQUAL, a model for measuring service quality in P2P accommodation, has been applied only recently, and empirical research in this context remains limited. No prior study has analyzed service quality in P2P accommodation within the Dubrovnik WHS using the SERVQUAL model, so the main theoretical and scientific contribution of this paper is to address this gap in the literature. Furthermore, recent papers analyzing service quality in P2P accommodation have used reviews and comments on the Airbnb platform as the basis for analysis and have thus disregarded expectations. In this paper, empirical research was conducted on a sample of 352 tourists who used P2P accommodation in the Dubrovnik WHS. The research included both expectations and perceptions.

Beyond addressing the theoretical knowledge gap and the WHS risks posed by an excessive number of Airbnb facilities, this paper also offers practical contributions. The results of this paper could serve as recommendations for WHS destination management on future norms and guidelines for categorizing facilities within WHS. It is very important for WHS management to protect the entire WHS and to identify elements that can help raise the quality of WHS as a tourist destination. For P2P accommodation hosts, this research highlights the importance of personal connection with their guests. Only a host who recognizes that caring, individual attention, willingness to help, and speed of assistance are the most important tools for differentiation from other hosts can increase their income. The results of this study also emphasize how tourists evaluate service quality in P2P accommodation within WHS.

This research is not without limitations. The main limitations of this study are its geographical scope and sample size. The research was conducted only in the Dubrovnik WHS using a convenience sample. The data for this study were collected from guests who have used P2P accommodation only within the Dubrovnik WHS, indicating that the data are indicative and that the results cannot be generalized.

Despite the aforementioned limitations, this research has a significant impact on the P2P accommodation industry in UNESCO-protected world heritage sites.

To generalize the results, future research should include more geographically diverse WHSs in the analysis and conduct a comparative analysis of P2P accommodation quality outside WHSs. Service quality in P2P accommodation may differ in WHSs that are not located by the sea. Furthermore, future studies should extend the SERVQUAL model by using exploratory factor analysis to develop a new WHSP2PQUAL model.

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APPENDIX A:

Table 2. SERVQUAL means

	Mean	**Mean**	**Mean**
	Expectations	**Perceptions**	**Service quality**
The accommodation has authentic furniture	3,92	4,27	0,35
The accommodation has up-to-date (modern) equipment	4,29	4,72	0,43
The accommodation's physical facilities are visually appealing	4,31	4,71	0,40
The appearance of the accommodation's physical is in keeping with the type of service provided	4,38	4,74	0,36
The general cleanliness of the accommodation is satisfactory	4,54	4,85	0,31
The accommodation's host is well-dressed and appears neat	4,23	4,65	0,42
The accommodation's host gives guests personalized attention	3,98	4,51	0,53
The accommodation's host has an understanding of guests' special needs	3,93	4,56	0,63
The accommodation host considers the needs of less-abled guests	3,78	4,34	0,56
The accommodation's host addresses the guest by name	3,59	4,36	0,77
The accommodation's host has patience with children	4,03	4,49	0,46
Accommodation's operation hour is convenient to all its guests	4,36	4,75	0,39
Guests feel safe and secure in their stay	4,57	4,87	0,30

The accommodation's host advises undecided guests	3,80	4,46	0,66
The accommodation's host is always available for the guests	3,96	4,68	0,72
The accommodation's host is very kind and cordial ton	4,10	4,77	0,67
The accommodation's host is highly professional	3,96	4,60	0,64
The accommodation provides its services according to the announcement	4,20	4,72	0,52
The accommodation's host responds quickly to any queries	3,97	4,66	0,69
The accommodation's host is always willing to help, even while busy	3,92	4,59	0,67
The accommodation provides its services in the domain "value for money."	4,28	4,70	0,42
The accommodation's host provides service at the time they promise to do so	4,28	4,73	0,45
If you have problems, you can rely on the accommodation's host	4,11	4,66	0,55
The accommodation's host always fulfills their promises regarding service	4,22	4,73	0,51
The accommodation's host informs guests about all activities in the destination	3,84	4,51	0,67

Source: Author (2026)

Kvaliteta usluge u *P2P* ekonomiji dijeljenja: Primjena SERVQUAL modela u Airbnb smještaju u zaštićenoj spomeničkoj baštini

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Sažetak: Kao rezultat brzog rasta *peer-to-peer(P2P)* ekonomije dijeljenja, inovativnog poslovnog modela u ugostiteljstvu, te potrebe za zaštitom svjetske spomeničke baštine od prekomjernog razvoja turizma, istraživanje kvalitete usluge u *P2P* smještaju unutar zaštićene spomeničke baštine je od velike važnosti. Glavni cilj ovog rada je utvrditi koje su komponente usluge u *P2P* smještaju u zaštićenoj spomeničkoj baštini turisti ocijenili kao najkvalitetnije. Kako bi se realizirao postavljeni cilj ovog rada, provedeno je empirijsko istraživanje na uzorku od 352 turista koji su koristili *P2P* smještaj u zaštićenoj spomeničkoj baštini Dubrovnika u razdoblju od travnja do listopada 2022. te od svibnja do listopada 2023. Na temelju empirijskog istraživanja i korištenjem *SERVQUAL* modela, utvrđeno je kako su turisti imali najniža očekivanja od empatije i susretljivosti domaćina u usporedbi s opipljivim elementima u smještajnim jedinicama od kojih su najviše očekivali. Rezultati su pokazali kako je najistaknutija komponenta *P2P* smještajnih jedinica u zaštićenoj spomeničkoj baštini, s obzirom na percepciju, susretljivost. Također, turisti koji su boravili u P2P smještaju u zaštićenoj spomeničkoj baštini Dubrovnika ocijenili su empatiju i susretljivost kao dvije komponente najviše kvalitete. Osim teorijskog doprinosa, rezultati ovog rada mogu biti smjernice za kategorizaciju *P2P* smještaja u zaštićenoj spomeničkoj baštini, kao i pokazatelji domaćinima unutar zaštićene spomeničke baštine što trebaju nadograditi i poboljšati u svojim smještajnim jedinicama. Rezultati bi također mogli pomoći urbanistima i onima koji zagovaraju ekonomiju dijeljenja smještaja u zaštićenoj spomeničkoj baštini da utvrde razinu njezine realnosti ili prenaglašavanja. Zbog ograničenja u ovom radu, s obzirom na geografsko područje istraživanja te uzorak istraživanja, buduća istraživanja trebala bi uzeti u obzir više zaštićenih spomeničkih cjelina u kojima se nudi *P2P* smještaj, kao i komparativnu analizu s kvalitetom *P2P* smještaja izvan zaštićene spomeničke baštine.

Ključne riječi: peer-to-peer (P2P), kvaliteta usluge, zaštićena spomenička baština
JEL klasifikacija: L83, Z32

Kognitivne pristranosti u financijskom i medicinskom odlučivanju: interdisciplinarni pristup i strategije za učinkovitije donošenje odluka

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Sažetak: Svrha ovoga rada je istražiti utjecaj kognitivnih pristranosti na donošenje odluka u područjima financija i medicine te ispitati mogućnosti interdisciplinarnog prijenosa strategija za umanjenje njihova utjecaja. Analiza se temelji na teorijskom okviru dualnog modela razmišljanja (Sustav 1 i Sustav 2) i sekundarnoj analizi relevantne literature iz područja ekonomije, kognitivne psihologije i medicine. Fokus je stavljen na četiri najčešće pristranosti (potvrđivanja, sidrenja, heuristiku dostupnosti i pretjerano samopouzdanje) uz prikaz njihovih manifestacija u oba konteksta i strategija za njihovo umanjenje utjecaja, uključujući metakognitivne tehnike, kontrolne liste, grupno odlučivanje i simulacijske metode poput Monte Carlo analize. Rezultati pokazuju da su temeljni mehanizmi pristranosti konzistentni u različitim kontekstima, iako se njihove posljedice razlikuju ovisno o području i ciljevima odlučivanja. Ta konzistentnost otvara prostor za razvoj zajedničkih strategija i prijenos učinkovitih metoda između ta dva analizirana područja. Praktične implikacije uključuju mogućnost primjene medicinskih strukturiranih protokola u financijama te integraciju kvantitativnih modela iz financija u kliničke procjene. Ograničenja rada odnose se na nedostatak primarnih empirijskih podataka, fokus na ograničen broj pristranosti i teorijsku razinu prijedloga interdisciplinarnog prijenosa. Buduća istraživanja trebaju kombinirati teorijske uvide s praktičnim rješenjima i tehnološkim inovacijama kako bi se otvorio prostor za učinkovitije i robusnije okvire odlučivanja. Interdisciplinarni pristup dodatni je iskorak u povećanju kvalitete stručnih odluka u financijskom i medicinskom odlučivanju.

Ključne riječi: kognitivne pristranosti, heuristike, medicinsko odlučivanje, financijsko odlučivanje, interdisciplinarni pristup
JEL klasifikacija: D90, G41, I12, D81

1. Uvod

Donošenje stručnih odluka u financijama i medicini odvija se u okolnostima koje karakteriziraju visoka složenost, nedostatak vremena i neizvjesnost. U oba područja odluke zahtijevaju procjenu rizika često na temelju ograničenih informacija, a njihove posljedice mogu biti dalekosežne. U takvom kontekstu odlučivanja ljudi se često oslanjaju na heuristike, mentalne prečace koji omogućuju brzo donošenje prosudbi i odluka. Premda heuristike često pomažu u brzom donošenju odluka, njihova upotreba može dovesti do sustavnih i ponavljajućih pogrešaka u prosudbama i odlučivanju.

Kognitivne pristranosti javljaju se kada se heuristički obrasci razmišljanja koriste u okolnostima koje zahtijevaju sustavniju i analitičku obradu podataka umjesto intuitivnog prosuđivanja. Riječ je o ponavljajućim obrascima procesa razmišljanja koji mogu dovesti do suboptimalnih odluka. Njihova prisutnost osobito dolazi do izražaja u rizičnim, emotivno intenzivnim, neizvjesnim, dvojbenim situacijama s potencijalno visokim posljedicama. U takvim situacijama ljudski um ima sklonost oslanjati se na brze, intuitivne procjene umjesto na objektivne inpute temeljene na analitičkoj obradi podataka. U medicini, primjerice takav pristup može rezultirati pogrešnom dijagnozom ili izborom terapije, a u financijama brzopletim investicijskim odlukama ili zanemarivanjem relevantnih informacija s tržišta kapitala.

Dosadašnje strategije za umanjenje utjecaja pristranosti u odlučivanju razvijale su se uglavnom unutar pojedinačnih disciplina, što je rezultiralo fragmentiranom bazom znanja. Takva jednodisciplinarna ograničenost dovodi do toga da znanja i učinkovite prakse ostaju „zarobljene“ unutar specifične domene. Kao posljedica toga, prijenos znanja između financijskog i medicinskog sektora ostaje neformalan i nesustavan.

Konkretno, medicinski su stručnjaci rijetko u dodiru sa sofisticiranim kvantitativnim metodama scenarijske analize i stres-testiranja, dok financijskim profesionalcima nedostaju sustavni komunikacijski protokoli i strukturirane procedure koje su u medicini ustaljena praksa. Stoga je potreba za sustavnim interdisciplinarnim pristupom više nego akademska, ona je praktična nužnost koja može značajno poboljšati kvalitetu odlučivanja u oba područja.

Ovaj rad polazi od hipoteze da će analiza zajedničkih kognitivnih procesa i prijenos provjerenih strategija za smanjenje pristranosti između financija i medicine omogućiti stvaranje snažnijeg i fleksibilnijeg okvira za prepoznavanje i ublažavanje njihova učinka u donošenju stručnih odluka.

Ovaj rad temelji se na sljedećim istraživačkim pitanjima:

1. Jesu li kognitivne pristranosti u financijskom i medicinskom odlučivanju utemeljene na istim mehanizmima djelovanja? Ovo pitanje ispituje razlikuju li se mehanizmi pristranosti s obzirom na područje odlučivanja, što je ključno za procjenu mogućnosti prijenosa znanja između dviju domena.
2. Mogu li se dokazane strategije za smanjenje pristranosti u medicinskom odlučivanju (npr. kontrolne liste, strukturirane pauze, timsko odlučivanje) učinkovito primijeniti u financijskom kontekstu i obrnuto? Pitanje se fokusira na praktičnu izvedivost interdisciplinarnog prijenosa metoda radi povećanja kvalitete odlučivanja.

Rad je strukturiran kako slijedi. Poglavlje 1 uvodno obrazlaže pojam, značaj i utjecaj kognitivnih pristranosti u donošenju odluka u financijama i medicini, naglašava potencijalne prednosti interdisciplinarnog pristupa u prepoznavanju i ublažavanju pristranosti, opisuje metodološki pristup te formira istraživačka pitanja na koja se rad odnosi. Poglavlje 2 donosi teorijski pregled dualnog modela donošenja odluka, objašnjavajući dva temeljna načina kognitivne obrade informacija – brzi (Sustav 1) i spori (Sustav 2). Poglavlje 3 detaljno analizira četiri ključne kognitivne pristranosti (potvrđivanja, sidrenja, dostupnosti i pretjeranog samopouzdanja) s primjerima iz financija i medicine te predstavlja

dokazane strategije za umanjenje njihova utjecaja. Također, obrazlaže se potencijal interdisciplinarnog pristupa u unapređenju kvalitete odlučivanja. Poglavlje 4 raspravlja o interdisciplinarnom pristupu i mogućnostima prijenosa znanja i metoda između financija i medicine, kao i o ograničenjima rada te smjeru budućih istraživanja. Zaključak sintetizira ključne nalaze i naglašava značaj interdisciplinarne suradnje za stvaranje robusnijih okvira odlučivanja s ciljem kvalitetnijih stručnih odluka u područjima financija i medicine.

2. Metodologija

Ovaj rad temelji se na sustavnom pregledu i sintezi relevantne akademske literature iz područja ekonomije, bihevioralne ekonomije, kognitivne psihologije i medicine. Cilj je analizirati kognitivne pristranosti u kontekstu financijskog i medicinskog odlučivanja te ispitati mogućnosti za interdisciplinarni prijenos strategija njihova umanjenja. Analizom su obuhvaćena 34 primarna izvora objavljena u razdoblju od 1949. do 2025. godine, s naglaskom na noviju literaturu. Više od polovice izvora objavljeno je od 2020. godine nadalje, što osigurava da rad uključuje recentne nalaze u ovom području istraživanja. Ključni temeljni radovi su Kahneman i Tversky (1974), Metropolis i Ulam (1949) i Godet (1994), koji su dopunjeni suvremenijim istraživanjima iz 2022., 2024. i 2025. godine. Analiza se temelji na sekundarnoj analizi dostupne akademske literature. Korištene su akademske baze podataka Web of Science, Scopus i Google Scholar, s naglaskom na radove objavljene između 1949. i 2025. godine. Pretraživanja su kombinirala ključne termine: "cognitive bias*", "heuristic*", "cognitive distortion*", kombiniran s "decision-making", "financial decision*", "medical decision*" te hrvatskim ekvivalentima "kognitivne pristranosti", "heuristike" i "odlučivanje". Iz dostupne literature i rezultata pretraživanja odabrana su 34 primarna izvora (akademski članci, knjige i monografije autora u polju) koji su korišteni za analizu u ovom radu. Odabir je temeljen na sljedećim kriterijima: (a) relevantnost za temu kognitivnih pristranosti u financijskom i medicinskom odlučivanju; (b) empirijska ili teorijska osnova nalaza; (c) dostupnost punog teksta; te (d) potvrđena akademska reputacija izvora u recenziranim publikacijama. Metodološki pristup uključuje ove korake: (1) analiza i sinteza postojećih teorijskih okvira, osobito dualnog modela donošenja odluka (Sustav 1 i Sustav 2) kako ga opisuje Kahneman (2014) i dalje razrade Evans i Stanovich (2013); (2) usporedna analiza načina na koji se iste pristranosti manifestiraju u financijskom i medicinskom okruženju, što je prikazano konkretnim primjerima iz svakog analiziranog područja; (3) identifikacija i pregled dokumentiranih strategija za smanjenje utjecaja pristranosti, od metakognitivnih intervencija do organizacijskih mjera i simulacijskih metoda; (4) razmatranje mogućnosti interdisciplinarnog prijenosa znanja i metoda između financija i medicine, s procjenom preduvjeta za uspješnu implementaciju u novom kontekstu. Rad se fokusira na četiri najistaknutije i najčešće pojavljujuće pristranosti – potvrđivanja, sidrenja, heuristiku dostupnosti i pretjerano samopouzdanje. Odabir upravo tih pristranosti temelji se na sljedećim kriterijima: (a) njihovoj učestalosti pojave u praksi obaju sektora, što potvrđuju novija istraživanja, osobito Berthet (2022) koji je sustavno analizirao kognitivne pristranosti u četiri profesionalne domene; (b) dokumentiranom utjecaju na ishode odluka s jasnim financijskim ili zdravstvenim posljedicama; (c) dostupnosti empirijskih nalaza i dokazane učinkovitosti strategija za njihovo umanjenje; te (d) mogućnosti praktičnog testiranja interdisciplinarnog prijenosa znanja. Korišteni izvori uključuju studije provedene na velikim uzorcima – poput istraživanja na 108 000 pacijenata autora Ly et al. (2023), metaanalize 20 studija sa 6810 liječnika autora Saposnik et al. (2016) i istraživanja među 300 profesionalnih upravitelja fondova autora Montier (2006) – što osigurava da su zaključci temeljeni na robusnijim empirijskim dokazima. Posebnu vrijednost imaju nedavna istraživanja iz 2024. i 2025. godine (Begum et al., 2025;

Berthet, 2022; De Neys, 2025; Kumari i Parashar, 2025; Lei, 2025; Pherson, Donner i Gnad, 2024; Xing, 2024; Othman, 2024), koja predstavljaju najnovije razvojne putove u razumijevanju kognitivnih pristranosti i njihova umanjenja. Posebna pozornost dana je simulacijskim metodama i kvantitativnim pristupima, uključujući Monte Carlo analizu (Metropolis i Ulam, 1949; Seco i Verhaegen, 2021) i scenarijsko planiranje (Godet, 1994), jer te metode predstavljaju most između financijskog i medicinskog odlučivanja. Analizom literature identificirane su konkretne aplikacije tih metoda u oba sektora – od testiranja investicijskih hipoteza do modeliranja kliničkih scenarija što osigurava praktičnu primjenjivost predloženih strategija.

3. Teorijski pregled: Dualni model donošenja odluka

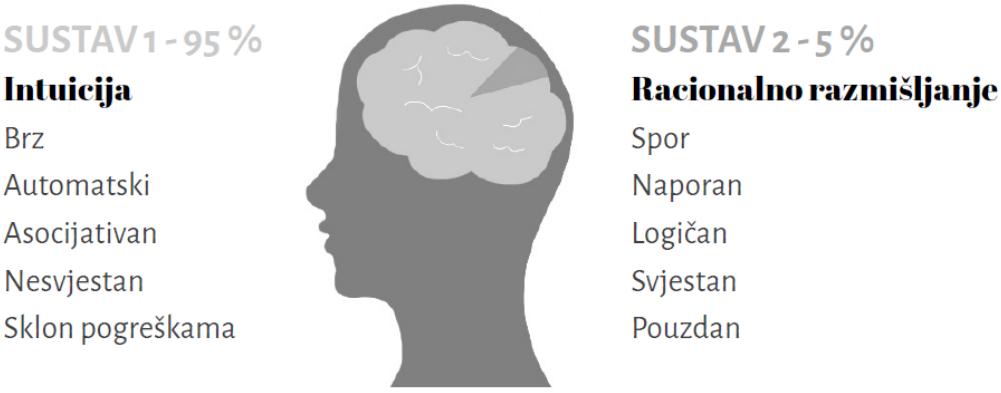
Razumijevanje procesa ljudskog odlučivanja temelj je za istraživanje utjecaja kognitivnih pristranosti u financijskom i medicinskom kontekstu. Prije analize pojedinih pristranosti, potrebno je objasniti kako funkcionira ljudski um pri donošenju odluka i u kojim se okolnostima povećava rizik od suboptimalnih ishoda. Dualni model razmišljanja, koji je popularizirao nobelovac Daniel Kahneman u djelu *Misliti, brzo i sporo*, uvodi konceptualnu podjelu između Sustava 1 i Sustava 2 razmišljanja (Kahneman, 2014). U nastavku se detaljno razmatra taj model koji objašnjava dvije kvalitativno različite vrste kognitivne obrade i njihove uloge u profesionalnom odlučivanju. Upravo on pruža okvir za razumijevanje zašto čak i iskusni stručnjaci podliježu sustavnim i ponavljajućim pristranostima te kako prepoznati trenutke u kojima je nužno aktivirati analitički pristup.

3.1 Dualni model donošenja odluka

Proces ljudskog odlučivanja može se promatrati kroz dvije međusobno povezane, ali funkcijski različite vrste kognitivne obrade. Sustav 1 karakterizira brzina, automatizam, intuitivnost i emocionalnost. Djeluje bez svjesnog napora, oslanjajući se na heuristike koje omogućuju brzu procjenu situacija. Primjeri obuhvaćaju prepoznavanje poznatih obrazaca, automatsko dovršavanje fraza ili instinktivne reakcije u stresnim okolnostima. Sustav 1 razmišljanja je evolucijski stariji i dominantan u svakodnevnim odlukama (Kahneman i Tversky, 1974).

Sustav 2 aktivira se u situacijama koje zahtijevaju svjesnu analizu, logičko promišljanje i kognitivni napor. Uključuje se pri rješavanju složenijih zadataka, evaluaciji rizika ili donošenju strateških odluka. Iako sporiji i energetski zahtjevniji, Sustav 2 ima potencijal za korekciju pogrešaka koje proizlaze iz automatiziranih reakcija Sustava 1 (Evans i Stanovich, 2013). Kahneman (2014) ističe da se većina misaonih procesa temelji na interakciji ovih dvaju sustava. Međutim, u uvjetima stresa, nedostatka vremena, emocionalnog opterećenja ili nedostatka ostalih relevantnih resursa, Sustav 1 često preuzima dominaciju, čime se povećava sklonost kognitivnim pristranostima poput pristranosti dostupnosti, sidrenja ili potvrđivanja (De Neys, 2025; Nadurak, 2025). Iako Sustav 1 omogućuje brze i često korisne procjene, njegova sklonost korištenju heuristika čini ga ranjivim na pogreške u prosudbama i odlučivanju. Sustav 2, iako sporiji, može djelovati korektivno, ali samo ako se svjesnom pažnjom aktivira.

Sposobnost razlikovanja situacija u kojima je nužno aktivirati analitički pristup ključna je stručna kompetencija u okruženjima visokog rizika. Kod financijskih i medicinskih odluka to znači svjesno usporavanje procesa, propitivanje početnih pretpostavki i sustavno razmatranje alternativnih objašnjenja.



Slika 1. Dualni model donošenja odluka (Kahneman and Tversky, 1974; Kahneman, 2014).
Izvor: Prilagođeno prema Dvornik (2024).

Slika 1. prikazuje osnovne karakteristike Sustava 1 i Sustava 2 razmišljanja. Lijeva strana na Slici 1. reprezentira brzinu, automatizam i emocionalnost Sustava 1, dok desna strana prikazuje racionalnu i analitičku stranu Sustava 2. Slika vizualno prikazuje da je najveći dio našeg razmišljanja i donošenja odluka pod utjecajem Sustava 1 (95 %), dok je vrlo mali dio pod utjecajem Sustava 2 (5 %). Iako je granica između tih sustava u stvarnosti fluidnija i kompleksnija nego što model prikazuje, pojednostavljeni prikaz omogućuje razumijevanje kognitivnog funkcioniranja oba sustava te činjenicu da oba mogu biti simultano aktivna. Istovremeno, model ilustrira da Sustav 1 obično dominira, ali donositelj odluke može u kritičnim momentima aktivirati Sustav 2 kako bi preispitao početne prosudbe. Upravo je sposobnost prepoznavanja situacija u kojima je nužno angažirati Sustav 2 ključna kompetencija za donošenje kvalitetnijih stručnih odluka, osobito u kontekstima visokog rizika (Pherson, Donner i Gnad, 2024).

4. Četiri najčešće i najutjecajnije pristranosti u financijskom i medicinskom odlučivanju

Rad se usredotočuje na četiri kognitivne pristranosti koje predstavljaju najveći izazov kvalitetnom odlučivanju u financijama i medicini: pristranost potvrđivanja, sidrenja, heuristiku dostupnosti i pretjerano samopouzdanje. Odabir upravo tih pristranosti temelji se na njihovoj učestalosti u oba konteksta, mogućnosti kvantificiranja učinaka te dostupnosti empirijskih dokaza o njihovim specifičnim manifestacijama. Svaka pristranost obrađena je detaljno, uz naglasak na konkretne primjere iz prakse i razlike u načinu na koji se manifestiraju ovisno o kontekstu. Nakon analize slijedi prikaz dokazanih strategija za umanjenje njihova utjecaja. Poglavlje završava razmatranjem kako interdisciplinarni pristup može dodatno povećati učinkovitost tih strategija. Analiza svake pristranosti strukturirana je tako da prvo objašnjava mehanizam i teorijsku osnovu, zatim predstavlja primjere iz financija i medicine, a na kraju provjerene metode za njihovo ublažavanje.

4.1 Pristranost potvrđivanja

Pristranost potvrđivanja (*confirmation bias*) odnosi se na sklonost da donositelj odluke preferira informacije koje podupiru njegovo početno uvjerenje, dok informacije koje bi to uvjerenje mogle

dovesti u pitanje zanemaruje ili tumači kao manje relevantne. U uvjetima informacijske preopterećenosti, iscrpna analiza svake informacije zahtijeva značajno vrijeme i kognitivni napor, pa se um često oslanja na heuristike radi učinkovitosti (Dvornik, 2024). Ti se procesi uglavnom odvijaju nesvjesno. Pristranost potvrđivanja djeluje na tri razine kognitivnog procesa: selektivno prikupljanje podataka, selektivna interpretacija i selektivno pamćenje informacija. Umjesto nepristrane evaluacije svih dostupnih podataka, mentalni fokus usmjerava se na podatke koji intuitivno podržavaju početnu hipotezu. Istraživanja pokazuju da je dvostruko vjerojatnije da će pojedinci tražiti informacije koje potvrđuju njihova uvjerenja nego one koje ih dovode u pitanje (Montier, 2010).

Primjeri iz medicine:

- Dijagnostička pristranost: Liječnici u hitnoj medicinskoj službi zabilježili su slučajeve u kojima je početna dijagnoza, poput primarne glavobolje, „zamaskirala" kasniju dijagnozu moždanog udara. Upravo je zanemarivanje alternativnih uzroka posljedica pristranosti potvrđivanja. U ovom slučaju liječnici su aktivno tražili isključivo simptome koji potvrđuju početnu dijagnozu, ignorirajući znakove ozbiljnijeg stanja (Kunitomo et al., 2022).
- Anamneza i dijagnoza: Liječnik koji unaprijed pretpostavi dijagnozu može postavljati pitanja i tražiti podatke koji potvrđuju njegove pretpostavke, dok istovremeno zanemaruje informacije koje bi je mogle osporiti (Dvornik, 2024).

Primjeri iz financija:

- Analiza izvješća: Investitori ponekad ignoriraju ključne stavke u financijskim izvješćima, promjene ključnih ljudi u upravi ili neke druge tržišne signale ako ti podaci proturječe njihovu uvjerenju o vrijednosti određene dionice (Fobellah, 2025).
- Selektivna interpretacija: Investitor koji vjeruje u kontinuirani rast određenih tehnoloških dionica može zanemariti upozorenja o precijenjenim valuacijama ili lošim poslovnim rezultatima, dok istodobno preuveličava pozitivne vijesti poput najave novog proizvoda.

Strategije za umanjenje utjecaja pristranosti potvrđivanja:

1. Obrazovne intervencije uključuju primjenu metakognitivnih tehnika, poput metode „razmotri suprotno", potičući aktivno traženje alternativnih objašnjenja i dokaza (Begum et al., 2025). Primjena metakognitivnih tehnika smanjuje utjecaj potvrđujuće pristranosti jer potiče sustavno razmatranje alternativnih hipoteza i dokaza koji ne podržavaju početne pretpostavke.
2. Organizacijske mjere obuhvaćaju primjenu diferencijalnih kontrolnih lista radi sustavnog razmatranja alternativnih dijagnoza, obvezno pribavljanje drugog mišljenja i strukturirane prekide procesa realizacije zadataka kako bi se omogućila ponovna evaluacija prije donošenja odluka visokog rizika (Begum et al., 2025).
3. Alati za odlučivanje obuhvaćaju primjenu strukturiranih dijagnostičkih algoritama radi standardizacije postupka, angažiranje timova za kritičku evaluaciju investicijskih odluka (tzv. crveni timovi) i provođenje pre-mortem analiza kako bi se pravodobno identificirale potencijalno pogrešne pretpostavke (Begum et al., 2025; Soll et al., 2015).
4. Simulacijske tehnike imaju ključnu ulogu u smanjenju utjecaja potvrđujuće pristranosti jer omogućuju sustavno ispitivanje alternativnih scenarija i ishoda. Primjenom scenarijskog planiranja ili Monte Carlo simulacija može se testirati različite pretpostavke i varijable, čime se potiče razmatranje opcija koje odstupaju od početnih uvjerenja. Monte Carlo metoda, koju su razvili Metropolis i Ulam (1949), temelji se na računalnim simulacijama s nasumičnim varijablama radi procjene distribucije mogućih ishoda, dok scenarijska analiza, čiju je metodologiju sustavno razvio Godet (1994), omogućuje strukturirano razmatranje različitih budućih stanja okruženja. U financijskom odlučivanju te metode služe za testiranje investicijskih hipoteza brojnim kombinacijama varijabli, dok se u medicini Monte Carlo simulacije

primjenjuju za modeliranje kliničkih scenarija i optimizaciju terapijskih postupaka (Seco i Verhaegen, 2021), čime se smanjuje rizik fokusiranja na jednu dijagnostičku pretpostavku. Osim toga, tehnika pre-mortem analize koju je razvio Gary Klein (2007) temelji se na konceptu „prospektivne retrospektive", u kojem se polazi od pretpostavke da je projekt već propao te se sustavno analiziraju mogući uzroci tog neuspjeha.
Tako simulacijski pristupi djeluju kao kognitivni korektiv, potičući donošenje odluka utemeljenih na široj analizi informacija i alternativnih scenarija umjesto na potvrđivanju postojećih pretpostavki.

4.2 Pristranost sidrenja

Pristranost sidrenja (*anchoring bias*) označava tendenciju da početna informacija, primjerice brojčana vrijednost, hipoteza, preliminarna dijagnoza ili očekivanje nesvjesno postane referentna točka koja utječe na sve naknadne procjene i zaključke. Taj se učinak najčešće pojavljuje u situacijama ograničenog kognitivnog kapaciteta, primjerice u nedostatku vremena, visoke razine stresa odnosno informacijske preopterećenosti.
U takvim okolnostima prevladava intuitivni način prosuđivanja, što otežava temeljito preispitivanje početne procjene i povećava rizik od djelomičnog ili nedovoljnog prilagođavanja (Soll et al., 2015). Drugim riječima, početna informacija ima nerazmjerno velik utjecaj na cijeli proces odlučivanja, čak i kada je objektivno dvojbena ili netočna.
U medicinskom kontekstu, sidrenje može dovesti do ozbiljnih dijagnostičkih i terapijskih pogrešaka. Liječnici se često oslanjaju na podatke iz trijaže, ranije dijagnoze ili pretpostavljene uzroke simptoma, zanemarujući nove informacije koje upućuju na drukčiji klinički smjer. U hitnim službama, gdje su odluke podložne vremenskom pritisku i ograničenim resursima, rizik od sidrenja dodatno raste (Kunitomo et al., 2022; Ogdie i et al., 2012).
Primjeri iz medicine:
• Pogrešna pretpostavka o dijagnozi
Pacijent s anamnezom moždanog udara dolazi s bolovima u stopalu. Liječnik se usmjerio na raniju dijagnozu periferne neuropatije i zanemario znakove ishemije, što je dovelo do zakašnjele dijagnoze i amputacije (Etchells, 2015).
• Zatajenje srca i zanemarena embolija
Opsežna studija na više od 108 000 pacijenata pokazala je da liječnici rjeđe provode testiranje na plućnu emboliju kada je u dokumentaciji navedeno kongestivno zatajenje srca, iako simptomi upućuju na mogućnost embolije (Ly, 2023).
U financijskom kontekstu, efekt sidrenja ogleda se u donošenju prosudbi i odluka koje su utemeljene na početnim (referentnim) brojčanim vrijednostima, osobnim stavovima, procjenama ili očekivanjima.
Primjeri iz financija:
• Cijena kupnje dionica kao referentna točka
Investitori često uspoređuju trenutačnu vrijednost dionica s cijenom po kojoj su je kupili. Kada stručne analize upućuju na potrebu prodaje dionica, kupci ih nerado prodaju (Xing, 2024).
• Prognoze analitičara
Financijski analitičari nerijetko ostaju vezani za prethodne optimistične procjene, čak i nakon objave lošijih rezultata. Korekcije su minimalne, što dovodi do sustavnih pogrešaka u procjeni (Xing, 2024).
Strategije za umanjenje utjecaja pristranosti sidrenja uključuju sljedeće pristupe:

1. Svjesno preispitivanje početne informacije podrazumijeva da se umjesto automatskog prihvaćanja prvog podatka postavi pitanje: „Što ako je početna pretpostavka pogrešna?“ (Dvornik, 2024). Ovaj pristup potiče aktivaciju analitičkog razmišljanja i otvara prostor za alternativna rješenja.
2. Razvijanje alternativnih scenarija znači da se tijekom procesa odlučivanja razmotri više mogućih ishoda i usporedi ih se, čime se smanjuje ovisnost o početnoj referentnoj točki.
3. Grupno odlučivanje uključuje više stručnjaka u proces kako bi se smanjio rizik oslanjanja na istu početnu informaciju, a različite perspektive potiču divergentno razmišljanje i širu analizu.
4. Korištenje strukturiranih alata obuhvaća kontrolne liste, protokole i algoritme koji usmjeravaju pažnju na sve relevantne informacije, a ne samo na one koje su prve dostupne, čime se smanjuje subjektivno oslanjanje na početni dojam.
5. Kod tehnike „razmotri suprotno“ aktivno se traže razlozi zašto početna procjena može biti pogrešna, potičući kritičko razmišljanje i razmatranje alternativnih mogućnosti (Soll et al., 2015).
6. Simulacijske metode značajno doprinose smanjenju utjecaja efekta sidrenja jer potiču razmatranje šireg spektra mogućnosti i smanjuju oslanjanje na jednu referentnu točku. Metode poput scenarijskog planiranja i Monte Carlo simulacija omogućuju testiranje različitih pretpostavki i varijabli, čime se potiče objektivnija procjena i smanjuje rizik od prevelikog oslanjanja na početne informacije. Cilj ovih strategija je osigurati da se početna informacija promatra kao hipoteza koju je potrebno provjeriti, a ne kao implicitna istina koja se ne dovodi u pitanje.

4.3 Heuristika dostupnosti

Heuristika dostupnosti (*availability heuristic*) označava kognitivnu sklonost procjeni vjerojatnosti ili važnosti događaja na temelju lakoće s kojom se iz pamćenja prizivaju povezani primjeri. Umjesto oslanjanja na objektivne podatke, prosudbe se često oblikuju prema subjektivnoj dostupnosti informacija, što može biti uvjetovano emocionalnim intenzitetom događaja, recentnošću pojave, medijskom izloženošću ili osobnim značajem. Taj mentalni prečac omogućuje brzu orijentaciju u složenim situacijama, ali istodobno povećava rizik od pogrešnih procjena. Upečatljivi ili nedavni slučajevi nerazmjerno utječu na procjene u odnosu na statistički utemeljene podatke, što može dovesti do precjenjivanja ili podcjenjivanja stvarne vjerojatnosti ishoda, ovisno o tome koje su informacije trenutačno najlakše dostupne u pamćenju.
Primjeri iz medicine:
• Nedavna iskustva
Liječnik koji je nedavno liječio pacijenta s plućnom embolijom može kod sljedećeg pacijenta s nespecifičnim simptomima odmah posumnjati na isti uzrok, iako su drugi uzroci statistički vjerojatniji. Odluka se temelji na dostupnosti prethodnog iskustva, a ne na objektivnoj procjeni (Whelehan, 2020).
• Medijska izloženost:
Nakon intenzivnih medijskih objava o širenju bolesti poput meningitisa ili ebole, liječnici bilježe porast sumnji na te dijagnoze, čak i kod pacijenata s niskim rizikom. Emocionalno snažne vijesti čine te dijagnoze kognitivno dostupnijima, što dovodi do pretjeranog testiranja i povećane zabrinutosti (Schwarz i Vaughn, 2002).
Primjeri iz financija:
• Averzija prema riziku
Nakon financijske krize 2008. godine mnogi investitori godinama izbjegavaju ulaganja u dionice unatoč povoljnim tržišnim valuacijama. Snažna sjećanja na gubitke čine tržišne slomove kognitivno dominantnima, što dovodi do precijenjene percepcije rizika i propuštanja prilika (Lei, 2025).
• Impulzivno trgovanje

Investitori često reagiraju na nedavne promjene cijena dionica, vjerujući da će se trend nastaviti. Takva dostupnost svježih informacija potiče impulzivne odluke uz zanemarivanje dugoročnih pokazatelja (Lobão et al., 2022).

Strategije za umanjenje utjecaja heuristike dostupnosti:

1. Oslanjanje na objektivne podatke i standardizirane smjernice podrazumijeva primjenu strukturiranih dijagnostičkih i investicijskih protokola, što smanjuje utjecaj subjektivnih sjećanja i vraća fokus na činjenične informacije (Whelehan et al., 2020; Loncharich et al., 2023).
2. Primjena grupnog odlučivanja uključuje više stručnjaka u proces donošenja odluka kako bi se smanjio rizik da svi budu pod utjecajem istih dostupnih informacija. Različita gledišta i mišljenja pomažu neutralizirati ovu pristranost.
3. Edukacije kojima je cilj povećanje svijesti o postojanju heuristike dostupnosti, što stručnjacima pomaže da prepoznaju kada se oslanjaju na lako dostupne, ali nereprezentativne informacije.
4. Strukturirano reflektivno razmišljanje obuhvaća metode koje zahtijevaju svjesno razmatranje alternativnih scenarija, čime se aktivira sporiji, analitički proces odlučivanja i smanjuje dominacija intuitivnog prosuđivanja.
5. Diversifikacija izvora informacija podrazumijeva oslanjanje na kvantitativne modele i široke podatkovne skupove, umjesto na nedavne vijesti ili osobna iskustva, što doprinosi objektivnijem odlučivanju (Lei, 2025; Kumari i Parashar, 2025).

4.4 Pristranost pretjeranog samopouzdanja

Pristranost pretjeranog samopouzdanja (*overconfidence bias*) je sklonost donositelja odluka da precijene točnost vlastitog znanja, procjena ili sposobnosti donošenja odluka. Umjesto prilagodbe uvjerenja objektivnim podacima, donositelj odluke razvija pretjerani osjećaj sigurnosti u vlastitu prosudbu, što često dovodi do smanjene provjere činjenica, izbjegavanja traženja drugog mišljenja te zanemarivanja rizika i alternativnih mogućnosti.

U financijskom kontekstu, ta pristranost može rezultirati prekomjernim trgovanjem dionicama, lošim upravljanjem rizicima i donošenjem investicijskih odluka bez dovoljno analitičke podloge. U medicini, pretjerano povjerenje u vlastitu dijagnostičku procjenu može uzrokovati izostanak dodatnih testova, ignoriranje alternativnih dijagnoza i povećan rizik od pogrešaka. U oba slučaja posljedice mogu biti ozbiljne jer se odluke temelje na subjektivnoj procjeni, a ne na objektivnim informacijama.

Primjeri iz medicine:

• Dijagnostička procjena bez provjere

Liječnici često pokazuju visoku razinu sigurnosti u vlastitu dijagnozu, čak i kada postoje podaci koji upućuju na druge mogućnosti. Takva uvjerenost može dovesti do izostanka dodatnih pretraga ili konzultacija, čime se povećava rizik od dijagnostičke pogreške (Graber, 2008).

• Sistematski pregledi

Analiza 20 studija koje su obuhvatile 6810 liječnika pokazala je da je pristranost pretjeranog samopouzdanja jedan od ključnih uzroka dijagnostičkih netočnosti. Liječnici su često donosili odluke s visokom razinom sigurnosti, bez provjere ili razmatranja alternativnih mogućnosti (Saposnik et al., 2016).

Primjeri iz financija:

• Percepcija vlastite sposobnosti

U istraživanju provedenom među 300 profesionalnih upravitelja fondova (Montier, 2006), čak 74 % ispitanika smatralo je da su iznadprosječno sposobni, dok nitko nije naveo da je ispodprosječan. Ta

statistički nemoguća raspodjela jasno ukazuje na snažnu pristranost samopouzdanja, koja može dovesti do lošeg upravljanja rizicima.

• Ponašanje investitora

Studija provedena na francuskom tržištu pokazala je da investitori koji su prethodno ostvarili dobitke postaju pretjerano samopouzdani. Posljedično, počinju agresivnije trgovati, što dovodi do povećane volatilnosti i prekomjernog volumena. Takvi investitori češće reagiraju na privatne informacije, zanemarujući javne podatke, što dodatno narušava racionalnost tržišta (Rahma i Scalera, 2019).

Strategije za umanjenje utjecaja pretjeranog samopouzdanja:

1. Povratna informacija i evaluacija učinka

Redovito praćenje stvarnih rezultata donesenih odluka te njihova usporedba s očekivanjima učinkovit je način smanjenja utjecaja pristranosti koja proizlazi iz pretjeranog samopouzdanja. U medicinskoj praksi to se može ostvariti sustavnim revizijama dijagnoza, dok se u financijskom sektoru primjenjuje analiza portfelja i vođenje dnevnika trgovanja (Soll et al., 2015; Croskerry et al., 2013).

2. Grupno odlučivanje i konzultacije

Uključivanje većeg broja stručnjaka u proces donošenja odluka smanjuje rizik od individualne sklonosti precjenjivanju vlastitih sposobnosti. Timovi imaju mogućnost prepoznati pretjerano samopouzdanje te potaknuti razmatranje alternativnih opcija.

3. Strukturirane kontrole i ograničenja

Primjena obveznih konzultacija, ograničenja veličine pozicija, stop-loss pravila i upravljačkih pragova je mehanizam kojim se sprječava preuzimanje prekomjernog rizika (Begum, 2025; Ahmad, 2022).

4. Korištenje analitičkih alata

Algoritmi, smjernice i modeli odlučivanja doprinose objektivizaciji procesa i smanjuju oslanjanje na subjektivnu procjenu. Sustavi potpore odlučivanju koji zahtijevaju obrazloženje odstupanja od preporuka dodatno umanjuju rizik (Soll et al., 2015; Othman, 2024).

5. Razvijanje kulture povratnih informacija

Stvaranje organizacijskog okruženja u kojem je traženje i davanje povratnih informacija uobičajena praksa pomaže smanjiti rizik donošenja odluka temeljenih na pretjeranom povjerenju u vlastitu procjenu. Posebno se učinkovitima pokazuju postupci koji predviđaju kratko „zaustavljanje“ prije konačne odluke, trenutak u kojem se provjeravaju ključne pretpostavke i aktivno razmatraju alternativna mišljenja (Croskerry et al., 2013).

6. Simulacijske tehnike

Primjena metoda poput Monte Carlo simulacija, scenarijskog planiranja i pre-mortem analize pomaže smanjiti pristranost pretjeranog samopouzdanja u procesu donošenja odluka. Te tehnike prikazuju raspon mogućih ishoda, uključujući nepovoljne scenarije, čime se smanjuje iluzija kontrole i potiče kritičko razmatranje pretpostavki te uravnoteženije donošenje odluka.

4.5 Potencijal interdisciplinarnog pristupa u financijama i medicini u unapređenju kvalitete odlučivanja

Interdisciplinarni pristup donošenju odluka omogućuje dublje razumijevanje kognitivnih procesa jer povezuje metodologije, spoznaje i provjerene prakse dvaju naizgled različitih područja – financija i medicine. Iako se razlikuju po kontekstu, oba područja suočavaju se sa zajedničkim izazovima: donošenjem odluka u uvjetima neizvjesnosti, vremenskog pritiska, visokih uloga i potencijalno značajnih posljedica. Prijenos znanja između tih domena može pridonijeti razvoju učinkovitijih mehanizama za prepoznavanje i umanjenje kognitivnih pristranosti.

U medicini su tijekom desetljeća razvijene različite metode i alati za unapređenje kvalitete odlučivanja, među kojima se ističu strukturirane kontrolne liste, obvezni „time-out" protokoli te postanalitičke rasprave o pogreškama. Ti modeli dokazano smanjuju dijagnostičke pogreške i poboljšavaju timsku komunikaciju. Njihova prilagodba financijskim procesima odlučivanja mogla bi pridonijeti smanjenju impulzivnosti, povećanju discipline u donošenju investicijskih odluka i boljem razumijevanju rizika.

S druge strane, financijski sektor razvio je sofisticirane kvantitativne metode – procjene rizika, stres-testiranje i scenarijske analize koje se mogu primijeniti i u medicini. Takvi pristupi omogućuju objektivizaciju kliničkih procjena i optimizaciju raspodjele resursa u situacijama kada su dostupni podaci nesigurni. Na taj način medicinski protokoli unose redoslijed i transparentnost u financijsko odlučivanje, dok financijske metode doprinose većoj objektivnosti u kliničkim provjerama.

Primjer: Od kirurškog k investicijskom time-outu

Jedan od primjera prijenosa dobre prakse je prilagodba koncepta medicinskog „kirurškog time-outa" financijskom okruženju. U kirurškoj praksi time-out označava obveznu stanku neposredno prije zahvata, tijekom koje tim sustavno provjerava identitet pacijenta, planirani zahvat, mjesto operacije, dostupnost potrebne opreme, moguće rizike i alternativne postupke. Svrha te procedure nije samo provjera činjenica, nego i prekid rutine i automatizma. Time-out omogućuje donositeljima odluka da zaustave proces, ponovno razmotre ključne pretpostavke i zajednički potvrde elemente koji se smatraju „očitima". Na taj način kognitivna obrada prelazi s brzog, intuitivnog Sustava 1 na sporiji, reflektivni Sustav 2.

Slična logika može se primijeniti na donošenje velikih financijskih odluka. Koncept „investicijskog time-outa" podrazumijeva kratku, ali strukturiranu stanku u trajanju od 5 do 10 minuta neposredno prije transakcija koje premašuju određeni vrijednosni prag, primjerice kod otvaranja velikih pozicija, značajnih promjena portfelja ili ulaska u složene financijske instrumente. Protokol obuhvaća tri ključne provjere:

1. Provjera pozicije – Što se točno kupuje ili prodaje? Koja je veličina pozicije, tržište i valuta? Poklapa li se transakcija s definiranim investicijskim ciljem?
2. Procjena rizika – Koja su tri glavna rizika povezana s ovom odlukom (npr. tržišni, kreditni, likvidnosni ili regulatorni)? Što ako se svaki od njih ostvari? Gdje se nalazi prag neprihvatljivog gubitka?
3. Razmatranje alternativa – Koje su tri moguće alternativne opcije: (1) pričekati dodatne informacije, (2) smanjiti veličinu pozicije ili (3) odabrati drukčiji instrument ili strategiju? Jesu li temeljne pretpostavke za preferiranu opciju i dalje valjane?

Takav pristup omogućuje usporavanje procesa donošenja odluka, smanjuje rizik impulzivnih reakcija i potiče prijelaz s intuitivnog na reflektivni način razmišljanja.

Za operacionalizaciju interdisciplinarnog prijenosa znanja potrebno je formalizirati suradnju putem zajedničkih radionica, istraživačkih projekata i pilot-inicijativa. Primjerice, u nekoliko financijskih institucija ili investicijskih fondova mogla bi se testirati učinkovitost investicijskog time-outa praćenjem smanjenja broja pogrešnih odluka, smanjenja prosječnog volumena gubitaka i povećanja transparentnosti procesa odlučivanja. Ista logika mogla bi se primijeniti u kliničkim timovima testiranjem medicinske primjene financijskih scenarijskih analiza ili Monte Carlo simulacija u kliničkim odlukama.

Takve pilot-inicijative omogućuju empirijsko testiranje prenosivosti metoda i procjenu njihove učinkovitosti u novom kontekstu prije nego što se uvedu kao standardni protokol. Time se otvara prostor za sustavno poboljšanje procesa odlučivanja utemeljeno na dokazima, a ne samo na teorijskim pretpostavkama. Na taj način interdisciplinarni pristup postaje praktičan skup alata za smanjenje kognitivnih pristranosti u okruženjima gdje su pogreške značajne, a njihove posljedice ozbiljne.

5. Rasprava

Rezultati ovoga rada pokazuju da su temeljni mehanizmi djelovanja kognitivnih pristranosti univerzalni, dok se njihove manifestacije i posljedice razlikuju ovisno o kontekstu. Taj zaključak je potvrđen i komparativnom analizom Bertheta (2022), koji je sustavno analizirao kognitivne pristranosti u četiri profesionalne domene – menadžmentu, financijama, medicini i pravu. Berthet je identificirao desetak kognitivnih pristranosti u analiziranim područjima, pri čemu je pretjerano samopouzdanje najčešće pojavljujuća pristranost. Univerzalnost mehanizama pristranosti u odlučivanju omogućuje interdisciplinarni prijenos znanja, ali primjena mora biti prilagođena specifičnostima svakog okruženja. Dokazane strategije umanjenja pristranosti u odlučivanju iz jednog područja mogu se primijeniti u drugom području uz uvjet da se prilagode specifičnom kontekstu odlučivanja. Temeljni mehanizmi pristranosti, poput heuristika dostupnosti ili sidrenja, djeluju univerzalno, što omogućuje prijenos metoda poput strukturiranih kontrolnih lista, simulacijskih tehnika ili grupnog odlučivanja. Međutim, preduvjeti za uspješnu primjenu obuhvaćaju osiguranje relevantnih podataka, prilagodbu terminologije i protokola te edukaciju stručnjaka o specifičnim rizicima i ciljevima u novom okruženju. Na primjer, kontrolne liste iz medicine mogu se koristiti u financijama, ali uz izmjenu kriterija i metrika, dok se pre-mortem analiza iz poslovnog konteksta može učinkovito primijeniti u kliničkim timovima uz naglasak na sigurnost pacijenata. Ključni preduvjet je razumijevanje da se strategija ne prenosi mehanički, već uz kontekstualnu adaptaciju i integraciju u postojeće procese odlučivanja.

5.1 Ograničenja i smjerovi budućih istraživanja

Unatoč sveobuhvatnoj analizi, ovaj rad ima nekoliko metodoloških i konceptualnih ograničenja koja je potrebno uzeti u obzir. Prvo, istraživanje se temelji na sekundarnoj analizi dostupne literature, što znači da zaključci proizlaze iz interpretacije postojećih teorijskih i empirijskih nalaza.

Nedostatak primarnih podataka ograničava mogućnost kvantitativne verifikacije utjecaja pojedinih pristranosti u specifičnim kontekstima financijskog i medicinskog odlučivanja. Drugo, fokus je bio na četiri najčešće pristranosti – potvrđivanja, sidrenja, heuristici dostupnosti i pretjeranom samopouzdanju – dok druge pristranosti (npr. efekt status quo, pristranost optimizma) nisu detaljno obrađene, iako mogu imati utjecaj na donošenje odluka. Treće, prijedlog interdisciplinarnog prijenosa strategija temelji se na teorijskoj izvedivosti, bez empirijskog testiranja u realnim uvjetima, što ostavlja otvorenim pitanje praktične implementacije u različitim organizacijskim kulturama i regulatornim okvirima.

Smjerovi budućih istraživanja trebali bi uključivati nekoliko dimenzija.

Prvo, nužno je provesti empirijske studije koje kvantificiraju učinke pojedinih pristranosti u financijskim i medicinskim okruženjima, koristeći eksperimentalne i longitudinalne dizajne.

Drugo, preporučuje se razvoj i testiranje interdisciplinarnih edukacijskih programa koji integriraju metode smanjenja pristranosti, uz evaluaciju njihove učinkovitosti u praksi.

Treće, buduća istraživanja trebala bi ispitati ulogu tehnologije, osobito sustava potpore odlučivanju temeljenih na umjetnoj inteligenciji, u detekciji i korekciji pristranosti u realnom vremenu.

Četvrto, korisno je proširiti analizu na dodatne pristranosti i ispitati njihove međusobne interakcije, jer se u složenim okruženjima često javljaju u kombinaciji.

Peto, potrebno je istražiti kulturne i organizacijske čimbenike koji utječu na uspješnost implementacije strategija za umanjenje pristranosti kako bi se osigurala prilagodba različitim profesionalnim kontekstima. Buduća istraživanja trebaju kombinirati teorijske uvide s praktičnim rješenjima i tehnološkim inovacijama, čime se otvara prostor za stvaranje robusnih, empirijski utemeljenih okvira odlučivanja.

6. Zaključak

Kognitivne pristranosti poput potvrđivanja, sidrenja, heuristike dostupnosti i pretjeranog samopouzdanja predstavljaju sustavni izazov u donošenju odluka u financijama i medicini. Analiza pokazuje da, unatoč razlikama u kontekstu i prirodi rizika, temeljni mehanizmi djelovanja tih pristranosti ostaju univerzalni. Upravo ta univerzalnost otvara mogućnost razvoja zajedničkih strategija i prijenosa provjerenih metoda između sektora, čime se stvaraju robusniji okviri odlučivanja.

Praktične implikacije rada vidljive su u potencijalu primjene medicinskih sigurnosnih protokola – poput strukturiranih kontrolnih lista i obveznih konzultacija – u financijskom odlučivanju, dok kvantitativni modeli iz financija, primjerice Monte Carlo simulacije i scenarijsko planiranje, mogu unaprijediti objektivnost kliničkih procjena. Interdisciplinarni pristup stoga nije samo teorijski koncept, nego nužan alat za smanjenje rizika od kognitivnih pogrešaka u okruženjima visokog rizika.

Posebnu ulogu u budućnosti imat će tehnologija, osobito sustavi potpore odlučivanju temeljeni na umjetnoj inteligenciji, koji mogu detektirati obrasce pristranosti u realnom vremenu i djelovati kao korektiv intuitivnim procesima. Time se otvara put prema donošenju odluka koje su brže, transparentnije i utemeljene na višoj razini objektivnosti.

Zaključno, interdisciplinarna razmjena znanja između financija i medicine prilika je za stvaranje inovativnih, empirijski utemeljenih okvira odlučivanja. Ovaj rad pokazuje da je prijenos znanja i alata između financija i medicine u kontekstu donošenja odluka ne samo moguć, nego i poželjan. Jača suradnja tih područja omogućila bi implementaciju provjerenih rješenja iz jednog sektora u drugi, čime se unapređuje kvaliteta stručnih odluka u okruženjima visokog rizika.

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Cognitive Biases in Financial and Medical Decision-Making: An Interdisciplinary Approach and Strategies for More Effective Decisions

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***Abstract*:** The purpose of this paper is to investigate the impact of cognitive biases on decision-making in the fields of finance and medicine, and to examine the possibilities for the cross-disciplinary transfer of strategies to mitigate their influence. Grounded in the theoretical framework of dual-process theory (System 1 and System 2), the analysis relies on a secondary review of relevant literature in economics, cognitive psychology, and medicine. Emphasis is placed on four prevalent biases: confirmation bias, anchoring, the availability heuristic, and overconfidence, outlining their manifestations in both contexts as well as strategies for mitigation, including metacognitive techniques, checklists, group decision-making, and simulation methods such as Monte Carlo analysis. The results indicate that while the underlying mechanisms of bias are consistent across contexts, their consequences differ depending on the field and decision-making objectives. This consistency opens the door for developing shared strategies and transferring effective methods between the two domains under analysis. Practical implications include the potential application of structured medical protocols in finance, as well as the integration of quantitative financial models into clinical assessments. Limitations of the paper relate to the lack of primary empirical data, the focus on a limited number of biases, and the theoretical nature of the proposed interdisciplinary transfer. Future research should combine theoretical insights with practical solutions and technological innovations to establish more effective and robust decision-making frameworks. Ultimately, an interdisciplinary approach represents a significant step forward in enhancing the quality of professional judgment in both financial and medical decision-making.

Keywords: cognitive biases, heuristics, medical decision-making, financial decision-making, interdisciplinary approach
JEL classification: D90, G41, I12, D81

Fluktuacije deviznoga tečaja u sustavu zlatnoga standarda

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Sažetak: Tri su cilja ovoga rada. Prvo, objasniti funkcioniranje sustava zlatnoga standarda. Drugo, objasniti kako su devizni tečajevi fluktuirali u različitim razdobljima zlatnoga standarda. Treće, objasniti razloge prestanka postojanja zlatnoga standarda. Metodološki temelj istraživanja u ovome radu je povijesni pristup. Uz analitičko-sintetički okvir istraživanja, primijenjene su primarno deskriptivna i komparativna metoda, a istraživanje je temeljeno na sekundarnim izvorima podataka. Temeljna osobina sustava zlatnoga standarda bila je neograničena konvertibilnost domaće valute za zlato koju je jamčila središnja banka neke zemlje po unaprijed utvrđenom paritetu. Također, bila su dopuštena međunarodna plaćanja zlatom, to jest zlato se moglo slobodno kretati iz jedne zemlje u drugu. U početku, u ovome sustavu devizni tečajevi su fluktuirali u uskom rasponu između gornje i donje zlatne točke. Pri tome su gornja i donja zlatna točka bile određene zlatnim paritetom uvećanim ili umanjenim za troškove prijevoza i osiguranja zlata. Poslije, u razdoblju brettonwoodskoga sporazuma, devizni tečajevi fluktuirali su u odnosu na postavljeni paritet u rasponu fluktuacije od ±1 %, koji je održavan intervencijama središnjih banaka na deviznom tržištu. Iako je sustav zlatnoga standarda imao svojih prednosti koje su se očitovale ponajprije putem stabilnosti deviznoga tečaja, njegov osnovni nedostatak bio je vezanost količine novca u optjecaju za količinu zlata kojom je neka zemlja raspolagala. To je bio ograničavajući čimbenik u razdobljima rata ili recesije, ali i u okolnostima rasta vrijednosti međunarodnih transakcija. Zbog posljedica njegovih nedostataka, zlatni standard službeno je ukinut 1971. godine.

***Ključne riječi*:** devizni tečaj, zlatni standard, Bretton Woods, zlatna točka, prilagodljivo vezanje
JEL klasifikacija: F31, F32, F33

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1. Uvod

Cilj ovoga rada je trojak. Prvo, objasniti kako je funkcionirao zlatni standard kao vrsta međunarodnoga monetarnog sustava. Drugo, objasniti kako su devizni tečajevi fluktuirali u pojedinim razdobljima funkcioniranja zlatnog standarda, preciznije u sustavu klasičnoga zlatnog standarda, zlatnopolužnoga standarda i zlatnodeviznoga standarda. Treće, objasniti zašto je zlatni standard prestao postojati. Zbog svoje specifičnosti, sustav zlatnoga standarda ograničavao je fluktuacije deviznoga tečaja. Drugim riječima, ovaj sustav smatran je fiksnim sustavom deviznoga tečaja, to jest sustavom u kojem su tečajne fluktuacije bile moguće u vrlo uskom rasponu. No, od njegova početka pa do kraja razdoblje zlatnoga standarda nije bilo homogeno. U početku, zlatni novac bio je propisan kao zakonsko sredstvo plaćanja. Nadalje, moglo ga se konvertirati u papirnati novac po utvrđenom tečaju bez ikakvih ograničenja. Međunarodna plaćanja zlatom, to jest uvoz i izvoz zlata, bila su dopuštena bez ograničenja. Također, međunarodna plaćanja moglo se izvršavati i papirnatim novcem koji je imao pokriće u zlatu. No, rastom vrijednosti međunarodnih transakcija, ratnim zbivanjima tijekom Prvoga svjetskog rata i Velikom depresijom 1929. godine, monetarne vlasti počele su ograničavati ili čak potpuno onemogućavati posjedovanje zlata privatnim imateljima. Na primjer, Ujedinjeno Kraljevstvo je zakonom odredilo da se papirnatim novcem može kupiti samo zlatna poluga, a ne zlatni novac. To je poskupjelo međunarodnu razmjenu u segmentu u kojem je trebalo transakciju platiti papirnatim novcem jer je više sudionika međunarodnih transakcija bilo prinuđeno plaćati transakciju papirnatim novcem, a ne zlatom. Ipak, u tom je razdoblju sustav međunarodnih plaćanja u Ujedinjenom Kraljevstvu ostao isti, jedino su transakcije rjeđe bile plaćane zlatom. S druge strane, Sjedinjene Američke Države zabranile su posjedovanje zlatnoga novca, poluga i certifikata privatnim imateljima 1933. godine. Sve zlato privatni imatelji morali su prodati američkoj središnjoj banci. Nakon Drugoga svjetskog rata, u zlatnodeviznom sustavu, troškovi prijevoza i osiguranja zlata nisu više bili ograničavajući čimbenik fluktuacije deviznoga tečaja. Naime, samo su središnje banke mogle kupiti zlatne poluge i njima platiti međunarodnu transakciju, a ostali sudionici plaćanja su izvršavali papirnatom konvertibilnom valutom čiji prijenos iz zemlje u zemlju nije imao takve troškove kao prijenos zlata. U tom razdoblju, monetarne vlasti zemalja članica Međunarodnoga monetarnog fonda obvezale su se da će intervencijama na deviznom tržištu ograničiti fluktuacije deviznoga tečaja domaće valute prema američkom dolaru ili prema cijeni zlata izraženoj u domaćoj valuti u iznosu od jedan posto.

Struktura ovoga rada je sljedeća. Nakon uvoda, u drugome poglavlju objašnjeno je funkcioniranje klasičnog zlatnog standarda koji je postojao od približno 1870. do početka Prvoga svjetskog rata 1914. U tom poglavlju prikazane su i fluktuacije deviznoga tečaja između gornje i donje zlatne točke. U trećem poglavlju objašnjeno je razdoblje zlatnoga standarda i fluktuacija deviznoga tečaja između Prvoga i Drugoga svjetskoga rata. To je bilo razdoblje velikih turbulencija kako zbog Prvoga svjetskog rata tako i zbog Velike svjetske depresije 1929. godine. U tom su razdoblju mnoge zemlje suspendirale konvertibilnost domaće papirnate valute u zlato i zabranile izvoz zlata u međunarodnim plaćanjima. U četvrtom poglavlju izloženo je funkcioniranje zlatnodeviznoga standarda, to jest Bretton Woodski sustav. U okviru toga sustava, sve zemlje članice Međunarodnog monetarnog fonda morale su intervencijama na deviznom tržištu održavati pojas fluktuacije deviznoga tečaja u odnosu na američki dolar ili na zlato u rasponu od jedan posto, a u slučaju fundamentalne neravnoteže u bilanci plaćanja, mogle su, uz odobrenje Međunarodnoga monetarnog fonda, provesti devalvaciju ili revalvaciju domaće valute. U petom poglavlju ovoga rada izloženi su razlozi prestanka zlatnoga standarda. U šestom poglavlju donosi se zaključak.

2. Međunarodni monetarni sustav

Međunarodni monetarni sustav ili režim čine tržišta, pravni propisi, instrumenti i institucije koje omogućuju plaćanja na međunarodnoj razini. Postoji nekoliko kriterija klasifikacije međunarodnog monetarnog sustava, no za potrebe ovoga rada važna su dva (prilagođeno prema Chacholiades, 1990, 482): 1. promjenjivost deviznoga tečaja i 2. priroda međunarodnih pričuva. S obzirom na promjenjivost deviznoga tečaja, međunarodni monetarni sustav može se klasificirati na sustav trajno fiksnoga deviznog tečaja, sustav slobodno fluktuirajućega deviznog tečaja i niz drugih sustava koji se nalaze između ova dva ekstrema, a od kojih je za povijest zlatnog standarda značajan sustav prilagodljivoga vezanja deviznoga tečaja (adjustable peg system) o kojemu će biti više riječi u poglavlju o Brettonwoodskom sporazumu. U današnje vrijeme Međunarodni monetarni fond klasificira međunarodni monetarni sustav na deset različitih sustava deviznih tečajeva (International Monetary Fund, 2024, 8). Uvažavajući vrstu međunarodnih pričuva kao kriterij, međunarodni monetarni sustav može se klasificirati kao: 1. čisti robni standard, u kojem se međunarodne pričuve sastoje od robnoga novca kakav je primjerice zlatni novac u sustavu zlatnoga standarda, 2. čisti fiducijarni standard u kojem međunarodne pričuve čine papirni novac nekonvertibilan za robni novac i 3. miješani standard, u kojem međunarodne pričuve čine i robni novac poput zlata i papirnati novac, ali konvertibilan za zlato, kakav je primjerice zlatnodevizni standard.

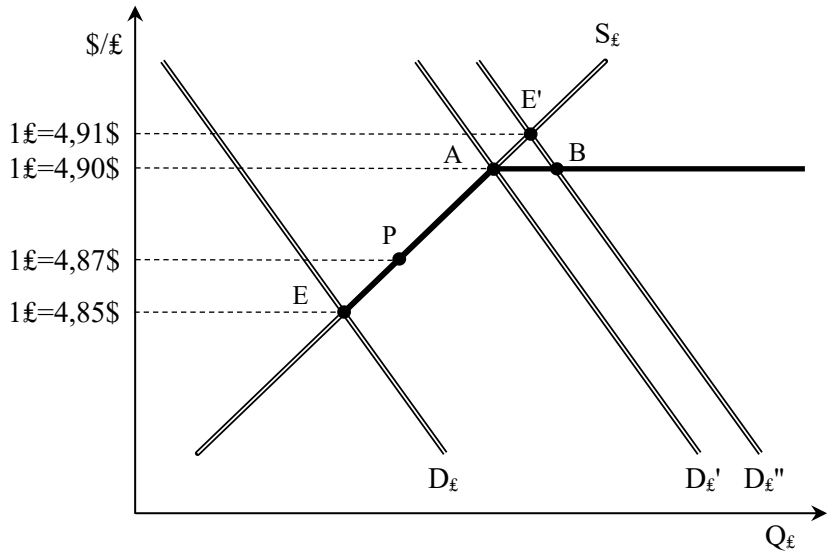
2.1. Zlatni standard u razdoblju od 1870. do 1914. godine

Razdoblje u ekonomskoj povijesti u kojem su zlatne kovanice korištene kao novac zove se klasični zlatni standard (*classical gold standard*). Iako je zlatni novac u davnoj povijesti imao svoje funkcije, funkciju sredstva razmjene, funkciju jedinice obračuna i funkciju skladištenja vrijednosti, zlatni standard prvi put se pojavljuje kao pravna institucija u Ujedinjenom Kraljevstvu u trenutku kada je ova zemlja ukinula dotadašnja ograničenja na izvoz zlatnika i zlatnih poluga u druge zemlje 1819. godine (Krugman et al., 2023, 600). Uskoro su i ostale zemlje poput Sjedinjenih Američkih Država, Njemačke, Francuske i Japana počele slijediti britanski primjer. Ekonomisti se danas slažu da je razdoblje zlatnoga standarda počelo približno 1870. godine te trajalo do početka Prvoga svjetskog rata 1914. godine (Krugman et al., 2023; Melvin i Norrbin, 2013; Salvatore, 2020).

U okviru zlatnoga standarda središnja banka neke zemlje odredila je cijenu određene količine zlata u domaćoj valuti. Po toj cijeni središnja banka obvezala se kupovati ili prodavati zlatnike za papirni novac bezuvjetno, svima koji to od nje zatraže neovisno je li riječ o privatnim korisnicima ili državnim institucijama domaćim ili stranim. Dakako, da bi kupoprodaja bila izvediva, središnja banka morala je raspolagati određenom količinom zlatnih pričuva. S obzirom na to da se zlato koristilo i u međunarodnim plaćanjima, deficiti u bilancama plaćanja promatranih zemalja mogli su se podmirivati zlatom, ali i papirnatim novcem koji je konvertibilan za zlato. U trenutku kada i druga središnja banka druge zemlje odredi cijenu određene količine zlata u svojoj valuti moguće je izračunati devizni tečaj valute jedne zemlje izražen u valuti druge zemlje. Na primjer, u ono vrijeme središnja banka Sjedinjenih Američkih Država odredila je cijenu unce zlata u iznosu 20,67 $, a Ujedinjeno Kraljevstvo 3,89 £ pa je devizni tečaj funte sterlinga iznosio 1 £ = 4,87 $. S obzirom na to da je temeljen na zlatnoj osnovi, taj tečaj zvao se zlatni paritet. U takvom sustavu devizni tečaj mogao je fluktuirati samo između gornje i donje zlatne točke koje su uz paritet bile određene troškovima prijevoza i osiguranja zlata iz jedne zemlje u drugu.

Hallwood i MacDonald (2000, 352) navode da je u takvom slučaju pojas fluktuacije iznosio približno ±0,5 %.

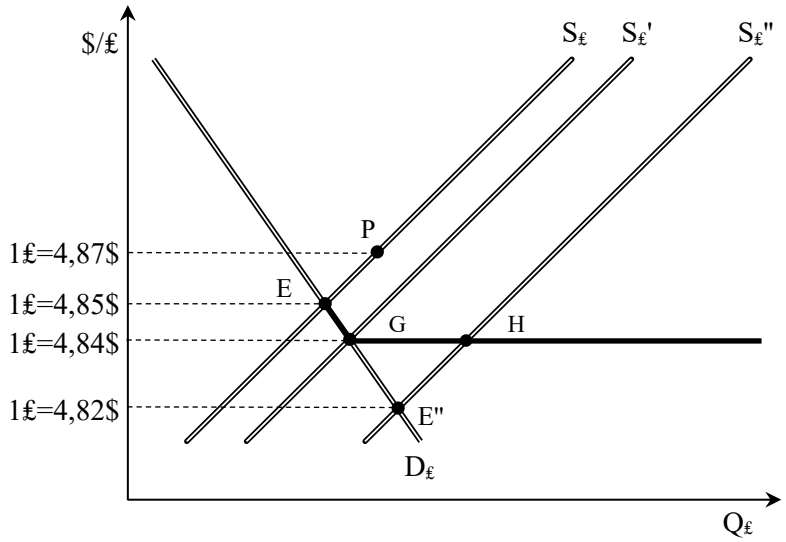
Na Slici 1. prikazano je kako nastaje gornja zlatna točka. Pravci $S_£$ i $D_£$ označuju ponudu i potražnju za funtom sterlinga na američkom deviznom tržištu. Sjecište ponude i potražnje nalazi se u točki E u kojoj je ravnotežni devizni tečaj 1 £ = 4,85 $. Točka P prikazuje iznos tečaja funte sterlinga temeljenoga na zlatnom paritetu. Uz pretpostavku da trošak prijevoza i osiguranja zlata iz Sjedinjenih Američkih Država u Ujedinjeno Kraljevstvo iznosi 30 američkih centi po jednoj funti sterlinga, ukupan trošak plaćanja uvoza zlatom iznosio bi 4,90 $. Drugim riječima, američki uvoznik mogao bi u banci kupiti zlato (pri čemu bi po funti sterlinga platio prema zlatnom paritetu 1 £ = 4,85 $) te platiti troškove prijevoza i osiguranja tog zlata u iznosu od 30 centi. Zbog toga, sve dok je tečaj funte sterlinga ispod 1 £ = 4,90 $, američkom uvozniku bit će isplativije platiti uvoz funtama sterlinga kupljenim na deviznom tržištu. Ako bi tečaj premašio iznos od 1 £ = 4,90 $, uvoznik bi uvoz platio zlatom. Na primjer, ako bi potražnja za funtom sterlinga porasla s $D_£$ na $D_£$", tečaj bi narastao na 1 £ = 4,91 $. No, to bi bilo moguće u sustavu slobodno flukturirajućih deviznih tečajeva, što je prikazano točkom E` na Slici 1. Uvozniku bi se tada dug isplatilo podmiriti u zlatu što bi ga koštalo, kako je već istaknuto, 4,90 $ po funti sterlinga. Zbog toga se točka A na Slici 1. zove gornja zlatna točka ili točka izvoza zlata. No, u sustavu zlatnoga standarda rast tečaja iznad 1 £ = 4,90 $ bio bi spriječen izvozom zlata. Dužinom AB na Slici 1. prikazana je količina zlata koja bi se u tom slučaju izvezla.



Slika 1. Gornja zlatna točka
Izvor: Prilagođeno prema: Salvatore (2020,463)

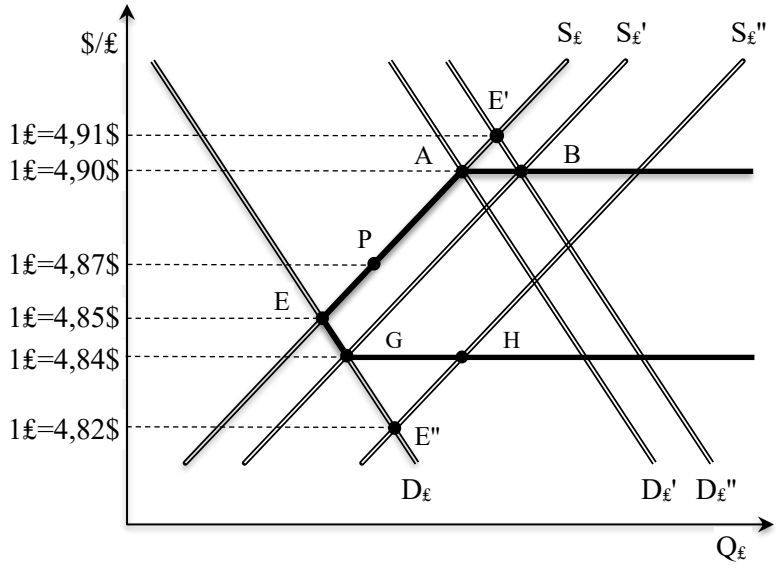
Na Slici 2. prikazan je nastanak donje zlatne točke. U ovome slučaju pretpostavlja se da američki izvoznik snosi troškove prijevoza i osiguranja zlata. Slično kao i američki uvoznik, američki izvoznik može naplatiti izvoz u zlatu ili u funtama sterlinga koje će potom konvertirati u američke dolare na deviznom tržištu. Ako bi naplatu izvoza izvršio u zlatu, nakon podmirenja troškova prijevoza i osiguranja zlata u iznosu od 30 centi ostalo bi mu 4,84 $ po funti sterlinga. To znači da bi se izvozniku isplatilo naplaćivati izvoz u funtama sterlinga samo dok tečaj ne padne ispod 1 £ = 4,84 $. Na primjer, u sustavu slobodno fluktuirajućih deviznih tečajeva u uvjetima rasta ponude sa $S_£$ na $S_£$" tečaj bi pao na 1 £ = 4,82 $ što pokazuje točka E" na Slici 2. Pad tečaja ispod 1 £ = 4,84 $ u sustavu zlatnoga standarda

bio bi spriječen uvozom zlata. Zbog toga se točka G na Slici 2. zove donja zlatna točka ili točka uvoza zlata. Količina uvoza zlata u tom slučaju prikazana je dužinom GH na Slici 2.



Slika 2. Donja zlatna točka
Izvor: Prilagođeno prema: Salvatore (2020, 463)

Na Slici 3. prikazan je pojas moguće fluktuacije deviznoga tečaja u razdoblju klasičnoga zlatnog standarda. Taj pojas čine gornja i donja zlatna točka odnosno vodoravni dijelovi pravaca ponude S£ i potražnje D£ koji se nalaze na vrijednostima tih točaka.



Slika 3. Pojas fluktuacije deviznoga tečaja u sustavu zlatnoga standarda
Izvor: Prilagođeno prema: Salvatore (2020, 463)

Pravci imaju svoj vodoravni dio jer su ponuda i potražnja u gornjoj i donjoj zlatnoj točki beskonačno elastične. Beskonačna elastičnost rezultat je činjenice da uvoznici i izvoznici mogu neograničeno kupovati ili prodavati zlato po fiksnoj cijeni od središnje banke.

Zlatni standard omogućavao je automatsko uravnoteženje bilance plaćanja zemalja koje su ga primjenjivale. Mehanizam automatskoga uravnoteženja bilance plaćanja zvao se mehanizam cijena i tijeka zlatnoga novca (*price-specie-flow mechanism*). Prvi put ga je analizirao francuski ekonomist Richard Cantillon u svojoj knjizi „Ogled o naravi trgovine općenito" napisanoj 1730., a objavljenoj 1755. godine. Važnost mehanizma dodatno je istaknuo škotski filozof David Hume u svojem djelu „O bilanci trgovine" 1752. godine (Bordo, 1999, 31). Ovaj mehanizam funkcionirao je na sljedeći način. S obzirom na to da se deficit u bilanci plaćanja podmirivao zlatom, zemlja koja je imala deficit morala je taj deficit platiti zlatom. Budući da je zlato bilo sastavni dio novca u optjecaju, plaćanje zlatom značilo je manje novca u optjecaju. Nadalje, posljedica manje novca u optjecaju bio je pad cijena roba i usluga, to jest deflacija. Deflacija je značila rast izvoza (jer je domaća roba postala jeftinija nego strana) i pad uvoza (iz istoga razloga). To je na kraju rezultiralo uravnoteženjem bilance plaćanja. S druge strane, zemlja koja je u svojoj bilanci plaćanja imala suficit, na osnovi tog suficita ostvarila je priljev zlata. Taj priljev zlata rezultirao je rastom količine novca u optjecaju posljedica čega je bio rast cijena roba i usluga, to jest inflacija. Inflacija je značila pad izvoza (jer je domaća roba postala skuplja nego inozemna) i rast uvoza (iz istoga razloga) do konačnoga uravnoteženja bilance plaćanja. No, istražujući međunarodnu trgovinu između zemalja s fleksibilnijim sustavom deviznoga tečaja i zemalja sa zlatnim standardom, Catão i Solomou (2005) pokazali su da se uravnoteženje događalo promjenom nominalnoga bilateralnog tečaja u zemljama s fleksibilnijim sustavom i promjenama nominalnoga i realnog efektivnog tečaja u zemljama sa zlatnim standardom.

Osim automatskoga uravnoteženja koje se događalo na opisani način, središnje banke mogle su instrumentima monetarne politike pojačavati ili neutralizirati učinak ovoga uravnoteženja. Na primjer, u slučaju deficita u bilanci plaćanja promatrane zemlje, središnja banka mogla je operacijama na otvorenom tržištu dodatno smanjiti količinu novca u optjecaju. To bi dodatno povećalo kamatnu stopu i rezultiralo bržim priljevom zlata u zemlju te na taj način ubrzalo uravnoteženje bilance plaćanja. S druge strane, u okolnostima suficita, središnja banka mogla je operacijama na otvorenom tržištu dodatno povećati novčanu masu te bi kamatna stopa dodatno pala što bi dovelo do bržeg odljeva zlata iz zemlje i bržim uravnoteženjem bilance plaćanja. Naime, smanjenje kamatne stope u jednoj zemlji i njezino povećanje u drugoj zemlji potaknulo bi kretanje zlata iz zemlje s nižom kamatnom stopom u zemlju s višom kamatnom stopom. To bi se dogodilo na sljedeći način. Imatelji valute s nižom kamatnom stopom željeli bi investirati u zemlju čija valuta nosi višu kamatnu stopu. Da bi to učinili, najprije bi morali konvertirati domaću valutu u stranu. Međutim, na deviznom tržištu ni jedan privatni imatelj valute s višom kamatnom stopom ne bi je želio prodati za valutu s nižom kamatnom stopom. No, s obzirom na to da je devizni tečaj fiksan i da središnja banka jamči konverziju domaće valute u zlato, imatelji domaće valute prodaju tu valutu središnjoj banci za zlato i to zlato prenose u drugu zemlju. U toj drugoj zemlji za zlato kupuju stranu valutu koja nosi višu kamatnu stopu.

Razlog pojačanja automatskoga uravnoteženja bilance plaćanja u zemlji s deficitom u bilanci plaćanja je sprječavanje odljeva zlata. No, taj postupak mogao je dodatno pojačati deflaciju, a onda izazvati i recesiju u zemlji. S druge strane, zemlje sa suficitom u bilanci plaćanja mogle su biti manje voljne prekidati priljev zlata iako bi to značilo i smanjenje, odnosno prekid inflacije u zemlji. Ono što je moglo prevagnuti u korist takvoga postupka je kamata koju bi, za razliku od zlata, nosile vrijednosnice kupljene putem operacija na otvorenom tržištu. Također, središnje banke mogle su neutralizirati utjecaj priljeva ili odljeva zlata na količinu novca u optjecaju. Takav postupak naziva se sterilizacija. Razlog sterilizacije bio je sprječavanje promjena količine novca u optjecaju te s tim u vezi sprječavanje inflacije i deflacije.

Na primjer, ako je zemlja imala deficit u bilanci plaćanja, središnja banka mogla je sterilizirati utjecaj odljeva zlata na količinu novca u optjecaju kupnjom domaćih vrijednosnica ili smanjenjem diskontne stope, dok bi u slučaju suficita, središnja banka mogla prodavati domaće vrijednosnice ili podizati diskontnu stopu.

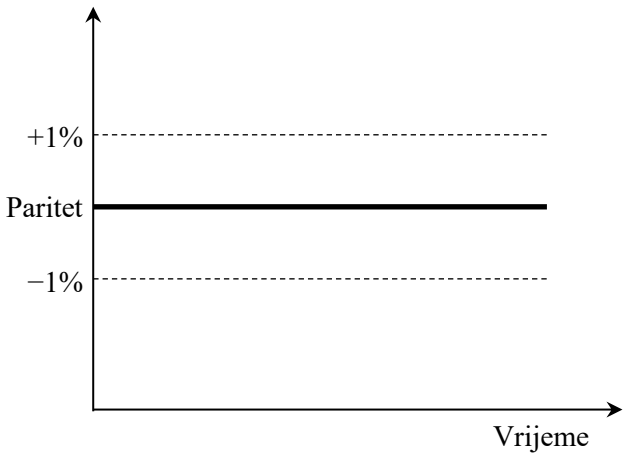
2.2. Razdoblje između dva svjetska rata

Tijekom Prvoga svjetskog rata zemlje su suspendirale zlatni standard. Naime, zbog visoke inflacije prouzročene emisijom novca potrebnog kako za financiranje ratnih djelovanja, tako i za financiranje obnove ratom uništenoga gospodarstva, konverzija papirnatoga novca za zlato nije bila moguća. U lipnju 1919. godine Sjedinjene Američke Države ponovno su uvele zlatni standard ukinućem embarga na izvoz zlata koji su uveli tijekom Prvoga svjetskog rata. U to vrijeme, Sjedinjene Američke Države postale su svjetski dominantni bankar (Melvin & Norrbin, 2013, 28). U svibnju 1925., Zakonom o zlatnom standardu (Gold Standard Act, 1925) i Ujedinjeno Kraljevstvo ponovno se vraća zlatnom standardu, ali u modificiranom obliku. Ujedinjeno Kraljevstvo određuje cijenu unce zlata na predratnoj razini, što je značilo da 1 funta sterlinga vrijedi 4,86 američkih dolara, ali ukida mogućnost kupnje zlatnika papirnatim novcem kod Banke Engleske. Dopušta isključivo kupnju zlatne poluge (približno 400 unci) papirnatim novcem. Tako je nastao zlatnopolužni standard (gold bullion standard) u Ujedinjenom Kraljevstvu. Stanovništvu nije bilo zabranjeno imati u vlasništvu zlatnike koje su imali od prije, ali ono ga je moglo prodavati bankama i koristiti u trgovini jedino po nominalnoj vrijednosti, što nije bilo isplativo jer je tržišna vrijednost zlata zbog inflacije bila znatno veća. Novi zlatnik mogao je biti kupljen jedino kod ovlaštenih trgovaca po tržišnoj cijeni. Krajem 1925. godine prestaje vrijediti embargo na izvoz zlata nametnut krajem Prvoga svjetskog rata, no kako navodi Cannan (1932, 117), Ujedinjeno Kraljevstvo suzdržavalo se embarga od početka stupanja na snagu Zakona o zlatnom standardu.
S obzirom na to da tijekom Prvoga svjetskog rata Ujedinjeno Kraljevstvo pretrpjelo znatnu inflaciju, fiksiranje cijene unce zlata na predratnu razinu značilo je precijenjenu funtu sterlinga u odnosu na cijenu zlata te zbog toga i znatne deficite u njegovoj bilanci plaćanja. Zbog toga je Ujedinjeno Kraljevstvo Zakonom o zlatnom standardu (amandman) (Gold Standard Act (Amendment) 1931), 1931. godine, ukinulo mogućnost kupnje zlatnih poluga papirnatim novcem, što je bilo kraj ovoga razdoblja zlatnog standarda u Ujedinjenom Kraljevstvu. Kao rezultat inflacije, a u uvjetima novonastaloga slobodno fluktuirajućeg deviznog tečaja, funta sterlinga deprecirala je 25 % (Isard, 1995, 42). Prema Melvinu i Norrbinu (2013, 28), nakon što je Ujedinjeno Kraljevstvo ukinulo konvertibilnost funte sterlinga za zlato, pozornost je bila usmjerena na Sjedinjene Američke Države. Da bi ublažile odljev zlata, Federalne rezerve povisile su kamatnu stopu. No, kako navodi Kindleberger (1984, 380), to je produbilo depresiju u Sjedinjenim Američkim Državama. Daljnji jaki pritisci na zlatne pričuve bili su uzrokom napuštanja zlatnoga standarda i u ovoj zemlji 1933. godine. Naime, 5. travnja 1933. američki predsjednik Franklin D. Roosevelt Izvršnom naredbom 6102 zabranio je privatno posjedovanje zlatnih kovanica, poluga i certifikata te naredio prodaju zlata Federalnim rezervama po ondašnjoj cijeni od 20,67 $ po unci zlata (Executive Order 6102, 1933). Razlog tomu bio je pokušaj obnove američkog gospodarstva nakon Velike depresije 1929. godine. S obzirom na to da je američki dolar bio fiksiran za zlato, povećanje količine novca u optjecaju potrebnoga za obnovu gospodarstva bilo je moguće jedino povećanjem zlatnih pričuva. Nadalje, Zakonom o zlatnim pričuvama iz 1934. godine (Gold Reserve Act, 1934) Federalne rezerve morale su predati zlato Ministarstvu financija. Prema Aufrichtu (1969, 48), postoji opće suglasje da su Sjedinjene Američke Države ovim Zakonom napustile klasični zlatni standard iako je očito da je to učinjeno i prije, stupanjem na snagu Izvršne naredbe 6102. Odmah nakon donošenja

Zakona o zlatnim pričuvama Sjedinjene Američke Države devalvirale su dolar s 20,67 $ na 35 $ po unci zlata.

2.3. Brettonwoodski sporazum

Pred kraj Drugoga svjetskog rata, od 1. do 22. srpnja 1944., održana je Međunarodna konferencija u Bretton Woodsu, u državi New Hempshire. Na toj konferenciji sudjelovale su Sjedinjene Američke Države, Ujedinjeno Kraljevstvo i 42 druge nacije svijeta. Cilj konferencije bio je dogovoriti se kakav bi trebao biti međunarodni monetarni sustav nakon Drugoga svjetskog rata. Drugim riječima, cilj konferencije bio je reformirati postojeći međunarodni monetarni sustav tako da valute glavnih zemalja budu potpuno konvertibilne čime bi se olakšala međunarodna trgovina i međunarodno financiranje. Na konferenciji su se dogovorili o osnivanju dviju važnih međunarodnih financijskih institucija: Međunarodni monetarni fond i Međunarodnu banku za obnovu i razvoj (poslije Svjetsku banku). Brettonwoodski sporazum (Articles of Agreement – International Monetary Fund and International Bank for Reconstruction and Development, 1944) zahtijevao je da svaka zemlja potpisnica fiksira cijenu jedne unce zlata ili jednoga američkog dolara prema svojoj vlastitoj valuti. Sjedinjene Američke Države fiksirale su cijenu jedne unce zlata u iznosu od 35 američkih dolara. Na taj način, sve valute postale su vezane međusobno, to jest činile su sustav fiksnoga deviznoga tečaja. Zemlje su vrijednost pariteta vlastite valute prema zlatu ili dolaru bile obvezne održavati u rasponu fluktuacije od ±1 %, što je prikazano na Slici 4.



Slika 4. Dopuštene fluktuacije deviznoga tečaja u Brettonwoodskom sustavu
Izvor: Prilagođeno prema: Babić i Babić (2008:331).

To su činile deviznim intervencijama, to jest kupnjom i prodajom domaće valute u zamjenu za stranu valutu, najčešće američki dolar, na deviznom tržištu. Na primjer, ako je tečaj promatrane valute u odnosu na američki dolar porastao više od jedan posto, tada su monetarne vlasti promatrane zemlje prodavale američke dolare iz vlastitih međunarodnih pričuva za protuvrijednost vlastite valute. U suprotnom, ako je tečaj valute promatrane zemlje pao ispod jedan posto u odnosu na američki dolar, tada je zemlja na deviznom tržištu prodavala američke dolare u zamjenu za svoju valutu. U okviru pojasa fluktuacije, tečaj se mijenjao pod utjecajem ponude i potražnje na deviznom tržištu.

Takav sustav nazivao se sustav prilagodljivo-vezanoga deviznog tečaja. Ideja je bila da tečaj bude privremeno fiksan, a samo uz nastanak fundamentalne neravnoteže može biti promijenjen (vrijednost domaće valute može devalvirati ili revalvirati). Mogućnošću promjene deviznoga tečaja pokušalo se ukloniti najveći nedostatak brettonwoodskog sustava – nefleksibilnost u slučaju pogrešnoga određivanja pariteta prema zlatu. Da bi se izbjegle konkurentske devalvacije, svaku devalvaciju veću od 10 % u odnosu na paritet trebao je odobriti Međunarodni monetarni fond. Ovaj sustav nazivao se zlatnodeviznim standardom (*gold exchange standard*) jer je američki dolar bio konvertibilan u zlato za sve službene imatelje ove valute – središnje banke i vlade zemalja potpisnica Sporazuma. U skladu s mogućnostima sustava prilagodljivoga vezanja i ispravljanja fundamentalne neravnoteže, Ujedinjeno Kraljevstvo devalviralo je funtu sterlinga 1949. i 1967. godine, a Njemačka je revalvirala marku 1961. i 1969. godine. Nadalje, do kraja 1960-ih, dolarske obveze Sjedinjenih Američkih Država postale su znatno veće od zaliha zlata u međunarodnim pričuvama ponajprije zbog inflacije i Vijetnamskoga rata. Središnje banke drugih zemalja počele su zahtijevati da im potraživanja od Sjedinjenih Američkih Država budu isplaćena u zlatu, a ne u papirnatim dolarima. Zbog tog pritiska na američke međunarodne pričuve, američki predsjednik Richard Nixon 15. kolovoza 1971. proglasio nekonvertibilnost američkoga dolara za zlato, što je značilo službeni kraj Sporazuma u Bretton Woodsu.

Predstavnici skupine deset nacija sastali su se 17. i 18. prosinca 1971. na Smithsonijanskom institutu u Washingtonu D. C. i potpisale Smithsonijanski sporazum (*Smithsonian Agreement of the Group of Ten*, 1971). U kontekstu deviznih tečajeva Smithsonijanskim sporazumom odlučili su: 1. da će američki dolar devalvirati s 35 $ na 38 $ za uncu zlata i 2. središnje banke potpisnice Sporazuma održavat će sustav fiksnog deviznog tečaja u rasponu ±2,25% u odnosu na postavljeni paritet.

Kako navodi Salvatore (2020, 598): „Predsjednik Nixon pozdravio je Smithonijanski sporazum kao 'najznačajniji monetarni sporazum u povijesti svijeta' i obećao da dolar 'više nikada neće devalvirati'." No, posljedica špekulativnih tijekova kapitala tijekom 1972. i početkom 1973. godine bila je nova devalvacija dolara s 38 $ na 42,22 $ po unci zlata. Ni ova devalvacija nije pomogla uspostavljanju ponovnoga povjerenja u američki dolar. U ožujku 1973. godine valute ključnih zemalja počele su fluktuirati (Johnson, 2000, 30; Salvatore, 2020, 568).

3. Zaključak

Razdoblje postojanja sustava zlatnoga standarda podijeljeno je na tri dijela: 1. klasični zlatni standard – u vremenu od približno 1870. do 1914. godine, 2. zlatnopolužni standard – u vremenu između dva svjetska rata i 3. zlatnodevizni standard – u vremenu od kraja Drugoga svjetskog rata do 1971. godine. U tom razdoblju, devizni tečajevi fluktuirali su u uskom rasponu između gornje i donje zlatne točke koje su bile određene zlatnim paritetom uvećanim ili umanjenim za troškove prijevoza zlata što je iznosilo približno ±0,5 % od pariteta. Slična situacija bila je i u sustavu zlatnopolužnoga standarda, no zbog većih troškova funkcioniranja ovoga sustava, gornja i donja zlatna točka, činile su širi pojas fluktuacija nego u klasičnom sustavu zlatnoga standarda. Za vrijeme Prvoga i Drugoga svjetskoga rata sustav zlatnoga standarda bio je suspendiran pa su valute ključnih zemalja slobodno fluktuirale na deviznom tržištu. U sustavu zlatnodeviznoga standarda zemlje su prihvatile sustav prilagodljivoga vezanja u kojem su tečajevi mogli maksimalno fluktuirati u iznosu od ±1 % od utvrđenoga pariteta prema zlatu ili američkom dolaru. U okviru sustava prilagodljivoga vezanja, u slučaju fundamentalne neravnoteže, bili su dopušteni ispravci pariteta (devalvacije i revalvacije domaće valute), ali samo uz suglasnost Međunarodnoga monetarnog fonda. Ipak, ova suglasnost bila je obvezna samo za ispravke pariteta veće od 10 %.

Zbog uskoga pojasa fluktuacije, sustav zlatnoga standarda smatran je sustavom fiksnih deviznih tečajeva. Stabilnost deviznih tečajeva bila je prednost jer nije bilo deviznoga rizika što je pridonosilo povjerenju u domaću valutu, ali i olakšavalo međunarodnu razmjenu roba i kapitala. Nedostatak sustava zlatnoga standarda bila je vezanost količine novca u optjecaju za zalihe zlata kojima zemlja raspolaže. Ona se pokazala osobito ograničavajućim čimbenikom u vrijeme ratova, kada su zemlje, da bi financirale ratna djelovanja i obnovu ratom razorenih područja morale suspendirati zlatni standard. Dodatno, u vrijeme ekonomskih kriza, zemlje nisu imale dovoljno novca za pokretanje gospodarstva. To je rezultiralo i političkim pritiscima na vlade pojedinih zemalja zbog rasta recesije i nezaposlenosti. No, nisu samo ratovi i ekonomske krize bili problem. Rast međunarodnih transakcija u uvjetima nedostatka novca koji ima pokriće u zlatu, također je bio ograničen jer zlata nije bilo dovoljno. Vlade pojedinih zemalja pokušavale su ovaj problem riješiti devalvacijama svojih valuta. No, pokazalo se da su devalvacije samo kratkoročno rješenje, a dugoročno se gubilo povjerenje u domaću valutu, pa i u cjelokupni međunarodni monetarni sustav. Zlatni standard je potpuno ukinut 1971. godine, u trenutku kad je američki predsjednik Richard M. Nixon ukinuo konvertibilnost američkoga dolara za zlato. Nedugo nakon toga, ključne zemlje napustile su sustav prilagodljivoga vezanja deviznoga tečaja.

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Exchange Rate Fluctuations in the Gold Standard System

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Abstract: This paper has three objectives. First, to explain the functioning of the gold standard system. Second, to describe how exchange rates fluctuated during different periods of the gold standard. Third, to examine the reasons for the cessation of the gold standard. The methodological basis of the research in this paper is a historical approach. In addition to the analytical-synthetic framework, primarily descriptive and comparative methods were used, and the research relied on secondary data sources. The fundamental feature of the gold standard system was the unlimited convertibility of the domestic currency for gold, guaranteed by the central bank at a predetermined parity. Also, international payments in gold were allowed, that is, gold could move freely between countries. In this system, exchange rates fluctuated within a narrow range between the upper and lower gold points. These points were determined by the gold parity, adjusted for the costs of transporting and insuring gold. Later, during the Bretton Woods period, exchange rates fluctuated within a range of ±1% relative to the set parity, maintained by central bank interventions in the foreign exchange market. Although the gold standard system had advantages, primarily manifested in exchange rate stability, its main disadvantage was that the amount of money in circulation was tied to the amount of gold a country possessed. This was a limiting factor in times of war or recession, as well as during periods of increasing international transactions. Due to these shortcomings, the gold standard was officially abolished in 1971.

***Keywords*:** exchange rate, gold standard, Bretton Woods, gold point, adjustable peg
JEL Classification: F31, F32, F33

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Ključne riječi: Ostavite dvije prazne linije ispod Sažetka i navedite 5 do 7 ključnih riječi međusobno odvojenih zarezom, navodeći od općeg prema pojedinačnom. Ključne riječi je potrebno prevesti na engleski jezik.
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Važno: Molimo vas izbjegavajte korištenje fusnota. Ako je potrebno, unesite ih na kraju teksta kao bilješke, prije referenci.

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Rad bi trebao imati najmanje 5.000, a najviše 8.000 riječi. Rad treba biti u formatu A4, 21x29 cm, obostrano poravnat. Predloženi naslovi se ne trebaju slijediti doslovno, što znači da primjerice možete koristiti klasični okvir s Uvodom, Pregledom literature, Materijalima i Metodama, Rezultatima, Raspravom, Zaključkom i Referencama. Naslovi svake cjeline rada trebaju biti lijevo poravnati i masno otisnuti. Obavezno je numeriranje naslova i podnaslova cjelina rada kao i u ovom predlošku. Navedeno numeriranje ne bi se smjelo vršiti primjenom rimskih brojeva. Odlomci se odvajaju razmakom, a svaki odlomak trebao bi imati bar tri retka.
Potrebno je koristiti ***Harvardski stil citiranja i referenciranja*** u cijelom tekstu.

2. Formulacija problema

Molimo Vas da ostavite dvije prazne linije između susjednih naslova. Podnaslovi se odvajaju jednom praznom linijom. Ispod naslova i podnaslovaslijedi redak razmaka te potom tekst bez uvlake. bez uvlake. Sljedeći odlomak slijedi nakon razmaka, kako je već ranije navedeno.
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Slike i tablice trebaju se referencirati kako slijedi: Slika 1, Slika 2, Slika 3, …., Tablica 1, Tablica 2, Tablica 3, …. Svaka referenca slike sadrži i opis slike (što slika predstavlja) i izvor odakle je preuzeta, u slučaju da je riječ o slikama kojima niste autori/ce. Isto vrijedi i za tablice, što podrazumijeva da se pored oznake tablice nalazi i njezin naziv ili kratko objašnjenje što predstavlja, uz navođenje izvora za slučajeve preuzetih tablica. Ispod slike/tablice obavezno je navesti godinu izrade.
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Literatura:

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