

DARYA LAPITSKAYA

Online media analysis and  
financial markets



DISSERTATIONES RERUM OECONOMICARUM  
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UNIVERSITY OF TARTU  
Press

School of Economics and Business Administration, Faculty of Social Sciences,  
University of Tartu, Estonia.

Dissertation has been accepted for the commencement of the degree of Doctor of  
Philosophy (PhD) in Economics on 11th of February, 2026 by the Council of the  
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The public defense will take place on 10.03, 2026 at 09:00 in MS Teams.

The publication of this dissertation was financed by the School of Economics and  
Business Administration, University of Tartu.

ISSN 1406-1309 (print)

ISSN 2806-254X (pdf)

ISBN 978-9908-57-143-0 (print)

ISBN 978-9908-57-144-7 (pdf)

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University of Tartu Press

<http://www.tyk.ee/>

## ABSTRACT

In the modern world, online media plays a crucial role in the spread of information, and its significance in the global economy and the financial markets cannot be overlooked. Traders regularly check online media platforms for the latest news and market trends, and there are examples where a single viral post or comment from a celebrity seems to affect the stock price of a company within hours after appearing online. This way, the dependencies between online media and financial markets are drawing increasing attention from researchers, professional investors, and amateur traders.

Moreover, online media tends to change our everyday lives in many ways: for example, we constantly check online reviews, trends, and advice from influencers (individuals who have gained their popularity and reputation through their online presence and activity). Hence, it is important to understand how to analyse this correlation and which tools to use for accurate analysis.

This doctoral thesis is dedicated to analysing how information spread through online sources affects companies and the everyday purchasing behaviour of regular buyers. Additionally, it explores various methods, including econometric and machine learning models, to determine the most effective way to analyse the stock and cryptocurrency prices. The doctoral study consists of four publications, each describing different theoretical and methodological aspects of the financial market and online media analysis and investigating price predictions using a combination of machine learning and technical analysis. In this thesis, various qualitative and quantitative methods are used: machine learning regressions, econometric models, sentiment analysis, and surveys.

This research contributes to the literature by providing a comprehensive analysis of online media, its correlation with the changes in the financial markets and the everyday behaviour of regular buyers, and highlighting the most accurate methodologies for market analysis. The results of the study demonstrate the effect online media tends to have on financial markets and recommend the most suitable techniques for various types of analysis.

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# LIST OF ORIGINAL PUBLICATIONS

## Papers included in the thesis

**Study I.** Lapitskaya, D., Eratalay, H., Sharma, R. (2022). Predicting Stock Returns: ARMAX versus Machine Learning. (Published in: Terzioğlu, M.K. (eds) *Advances in Econometrics, Operational Research, Data Science and Actuarial Studies. Contributions to Economics*. Springer, Cham. [https://doi.org/10.1007/978-3-030-85254-2\\_27](https://doi.org/10.1007/978-3-030-85254-2_27))

**Study II.** Lapitskaya, D., Eratalay, H., Sharma, R. (2025). Prediction of Cryptocurrency Prices with the Momentum Indicators and Machine Learning. (Published in: *Computational Economics*. <https://doi.org/10.1007/s10614-024-10784-1>)

**Study III.** Lapitskaya, D., Eratalay, H., Sharma, R. (2023). The impact of online media on buyers' purchasing behaviour and the stock market (Peer-reviewed).

**Study IV.** Nõu, A., Lapitskaya, D., Eratalay, M. H., Sharma, R. (2023). Predicting Stock Return and Volatility with Machine Learning and Econometric Models: A Comparative Case Study of the Baltic Stock Market. (Published in: *International Journal of Computational Economics and Econometrics*. <https://doi.org/10.1504/IJCEE.2023.133923>)

## Papers not included in the thesis

**Study V.** Alfieri, L., Eratalay, M. H., Lapitskaya, D., Sharma, R. (2022). The Effects of the ECB Communications on Financial Markets before and during COVID-19 Pandemic. *SSRN Electronic Journal*. 10.2139/ssrn.4109041.

## Other published work of the author

**Study VI.** Assefa, A., Lapitskaya, D., Uusküla, L., (2022). Productivity And Firm Dynamics Over The Business Cycle Pandemic. (Published in *Faculty of Economics and Business Administration Working Paper Series 141*, Faculty of Economics and Business Administration, University of Tartu)

# 1. INTRODUCTION

## 1.1. Research goal and motivation

The global spread and popularity of online media platforms<sup>1</sup> have drastically changed the way people communicate and share information. As discussed in the study by Jazbec et al., 2021, this transformation also concerns the financial sector. As a result, understanding how online media may influence market behaviour is becoming an important area to study and analyse.

In recent years, the relationship between online media and the financial market has become a topic of increasing interest because of the discussions that online platforms have the potential to influence financial market behaviour and provide valuable insights into market trends. Daily, we can observe how certain actions online, such as posts by celebrities and influencers (individuals who have gained their popularity and reputation through their online presence and activity) or discussions on forums, seem to lead to changes in the financial market. However, at the same time, it is not clear whether these changes tend to have any long-term effects or are indeed caused by online media. Even though, according to the Efficient Market Hypothesis (Fama, 1970), stock prices are impacted by all the information available for the market, the exact role of online media remains understudied.

With the rapid development of technology, more advanced analytical methods are becoming available for econometric analysis. Nowadays, machine learning methods are widely used in various fields, including economics, where they change the way the data is analysed and interpreted. As shown in the study performed by Surur et al., 2025, machine learning models can conduct an effective analysis of complex datasets and provide accurate predictions. These models can be used for forecasting economic indicators, analysing financial markets, and understanding consumer behaviour. Another critical, for this research, method that gained popularity in recent years is text mining (Gupta et al., 2020), which extracts the information from large volumes of unstructured textual data, such as news articles, and converts it into quantifiable variables that could help integrate so-called sentiments (emotional attitudes or opinions) expressed in the text into predictive models.

Considering the availability of the methods mentioned above, the main aim of this research is to conduct a comprehensive analysis of factors that tend to affect the performance in the financial market by incorporating dual-methodology methods, which include a combination of machine learning and econometric techniques, and to find more accurate ways to predict different assets, including such volatile ones as cryptocurrencies. The research gap lies in the fact that analytical methods currently applied to studying links between online media and the

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<sup>1</sup>In this research, online media is referred to as the social media platforms, such as X (formerly, Twitter), and to online sources, such as online news platforms.

financial market often lack standardisation and clarity. Additionally, despite the growing interest in how online sentiments correlate with the changes in the financial markets, the existing research often does not include the integration of dual-methodology approaches. This way, a hybrid analytical framework remains understudied, providing a research opportunity to incorporate various data options and different techniques in the analysis of the relations between the online media and the financial market.

It is also important to note that while previous studies (e.g. Ranco et al., 2015) have established correlations between online activity and financial market behaviour, this thesis aims to explore the predictive value of online sentiment in financial forecasting by applying and evaluating various machine learning and econometric models. The thesis focuses on how this correlation can be quantified, modelled, and used; and it analyses the practical applicability of online signals in financial predictions by integrating sentiment analysis and machine learning models with econometric approaches and comparing their predictive performance.

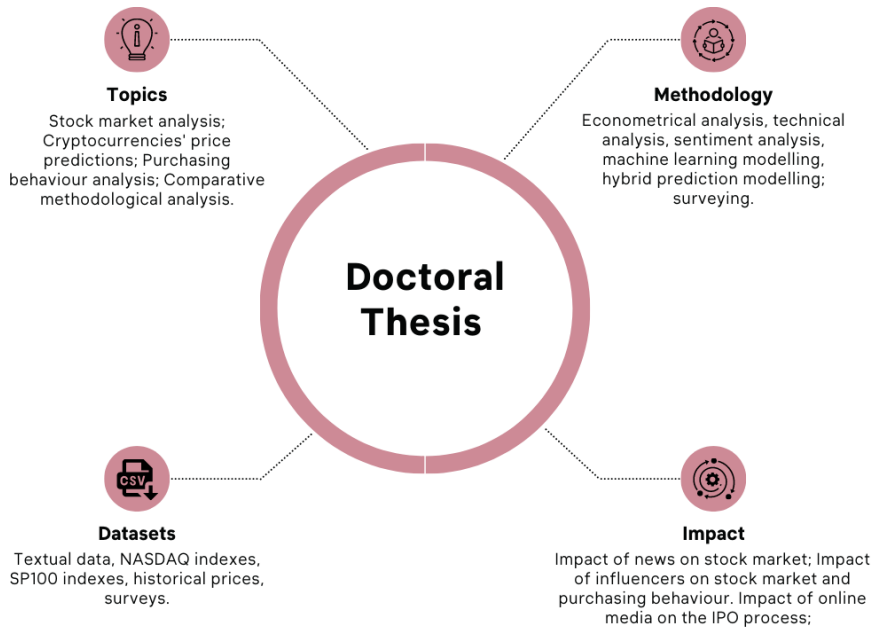
An overview of the thesis structure is described in Figure 1, which clarifies the topics, methodology, dataset and impact estimated in this work. In general, this study aims to understand whether there is a correlation between the online media activity and the financial market and evaluate which methods demonstrate accurate performance for a market analysis. In this work, multiple datasets are used to understand the applicability of the methodology to various types of financial assets, from a more stable S&P100 index to highly volatile cryptocurrencies. These datasets are used for multiple analytical techniques, including text mining of news articles, econometric analysis, technical analysis, and machine learning modelling.

It is also crucial to highlight that this research creates a strong foundation for understanding the interdependencies between online media and financial market movements and provides several potential directions for future research, such as the analysis of data integration from different social media platforms to enhance the generalisability and depth of sentiment insights, in line with growing interest in cross-platform analysis.

## **1.2. Papers overview and contribution**

This doctoral thesis consists of four studies, which, combined, aim to address the main research goal and fill the research gap.

The first study (Study I) is dedicated to analysing how COVID-19-related news affected the stock markets using econometrics and machine learning-based models. Since it was the biggest pandemic in recent decades, it was crucial to understand how the media coverage of COVID-19 affects stock returns. This work was the first considerable research conducted in the course of the doctoral studies, and it provides a crucial overview of machine learning algorithms that can be used in econometric analysis. This paper is written in collaboration with Hakan Eratalay



**Figure 1.** Thesis structure overview

and Rajesh Sharma. Darya Lapitskaya is the first author of this paper and was responsible for data collection, data analysis, literature analysis and documenting the results.

The second paper (Study II) proceeds with the exploration of how machine learning techniques could be applied in econometric analysis, together with other methods. This study represents a combination of machine learning analysis and technical analysis and investigates whether momentum indicators can be included in a machine learning regression model for cryptocurrency price predictions. This paper is written in collaboration with Hakan Eratalay and Rajesh Sharma. Darya Lapitskaya is the first author of this paper and was responsible for methodology and data selection, data collection, results analysis, documentation, and literature review.

The third study (Study III) is the most comprehensive one in this thesis. It represents a comprehensive overview of how the companies behave at different stages of their journey on the stock market. The methodology of this study consists of two parts: quantitative and qualitative. Firstly, machine learning regression analysis is performed to understand which variables have the most impact on a company's (Meta Platforms, Inc., formerly Facebook) IPO; then, we analyse basic financial indicators to understand whether two selected companies (Coca-Cola and Snapchat) were affected by celebrities and social media influencers and their publicly expressed opinions. These companies were chosen as examples, as they were related to some of the biggest examples of influencers' impact on the stock mar-

ket prices discussed in the media. Additionally, each example demonstrates how companies from different industries (such as technology and consumer goods) are affected by online media in the context of financial market behaviour. In this study, we also include a sentiment analysis to understand the general tone of the news articles that claimed an effect on the stock markets. Finally, we conducted a survey to understand how regular buyers' purchasing behaviour is affected by social media. The online questionnaire that was distributed among potential social media users aged 16 to 54 years old consisted of 13 questions and had a total of 147 respondents<sup>2</sup>. This paper is written in collaboration with Hakan Eratalay and Rajesh Sharma. Darya Lapitskaya is the first author of this study and was responsible for data collection, data analysis, survey preparation, and analysis.

The papers included in this thesis are concluded with the fourth study (Study IV), which is dedicated to machine learning applications for stock market analysis. This paper is written in collaboration with Anders Nõu, Hakan Eratalay, and Rajesh Sharma. This paper is based on the Bachelor's thesis of Andres Nõu that Darya Lapitskaya co-supervised, and she is the second author in this study. Darya was the main supervisor and was responsible for methodology structuring, overall research co-supervising, paper re-writing and restructuring.

An additional paper that has a methodological relation to the thesis topic but is not included in the main publication list is the paper on the effects of ECB speeches: The Effects of the ECB Communications on Financial Markets before and during the COVID-19 Pandemic (Alferi et al., 2022). In this study, the methodology of sentiment analysis is applied to the ECB speeches to understand their impact. This paper is written in collaboration with Luca Alferi, Hakan Eratalay, and Rajesh Sharma. Darya Lapitskaya is the third author in this study and was responsible for conducting sentiment analysis and preparing a part of the literature review.

Additionally, Darya Lapitskaya participated in the sixth study during her doctoral studies written in collaboration with Abraham Assefa and Lenno Uusküla. This paper is dedicated to understanding the business dynamics and Darya was responsible for updating the dataset and performing the calculations in Matlab.

The detailed overview of the papers included in this thesis is presented in Table 1 highlighting the aims, methods, and main conclusions of each paper.

It is important to note that in accordance with the data availability statements of the published papers, the data and code are available per requests from the authors.

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<sup>2</sup>It is important to emphasise that the responses were completely anonymous, the survey was distributed via public channels, and participation was voluntary.

**Table 1.** Research overview

Study No	Aim	Methods	Conclusions
Study I	To analyse the impact of COVID-19 related news on the Standard and Poor's 100 companies (SP100) stock returns by collecting news article for the period of 10 months.	Sentiment analysis, ARMAX, k-Nearest Neighbours (KNN), Extreme Gradient Boosting (XGBoost), (Long Short-Term Memory) LSTM	The XGBoost model had better predictive performance than the ARMAX one, while KNN and LSTM models performed worse.
Study II	To combine technical analysis with machine learning-based regression and to investigate the importance of momentum indicators in price prediction modelling.	Technical analysis, XGBoost	The constructed model demonstrates high accuracy and prediction power in both training and test datasets. The results prove that the utilisation of momentum indicators in machine learning-based predictions can be beneficial.
Study III	To provide a comprehensive analysis of the dependencies of the online media and stock markets.	Sentiment analysis, XGBoost, Google Search Volume Index (SVI), Qualitative survey	The study demonstrates that using sentiment scores and Google SVI as predictors of stock returns in the machine learning model has high accuracy and predictive powers and describes how social media and influencers determine the purchasing behaviour and affect spontaneous purchases made because of the influencer's recommendation.
Study IV	To conduct a thorough analysis of the predictive accuracy of several machine learning and econometric approaches for predicting the returns and volatilities on the OMX Baltic Benchmark price index.	ARMA, GARCH, Random Forest, SVR, KNN, GARCH-ANN	The machine learning methods, namely the support vector regression and k-nearest neighbours, predict the returns better than autoregressive moving average models for most of the metrics.

## **2. BACKGROUND WORK AND THEORETICAL FRAMEWORK**

### **2.1. Theoretical framework**

The forecast and analysis of stock and cryptocurrency prices have become central topics in the field of financial econometrics, gaining interest from academic researchers, professional investors, and even amateur traders. Traditionally, such forecasts have relied on historical price data, but the rapid growth of online media has introduced new sources of information that could affect the price changes as it could be seen in the works of Bajo and Raimond, 2017, Puh and Bagić Babac, 2023, Jiao et al., 2020, and Gupta et al., 2025 that demonstrate that online sentiments influence market behaviour. This way the evolving digital landscape of modern economics presents a research problem at the intersections of traditional econometric methods and newer data-driven approaches that incorporate online sentiments into forecasting models.

The theoretical framework of this doctoral thesis outlines the foundational concepts that provide a background for the conducted research and analysis and demonstrate the relationship between online media and financial markets. The main aim is to explore how social media, news sources, and user-generated content influence financial market behaviour, investor sentiment, and purchasing decisions. The framework is constructed based on the literature overview and empirical studies related to online media, financial markets, investors' and buyers' behaviours.

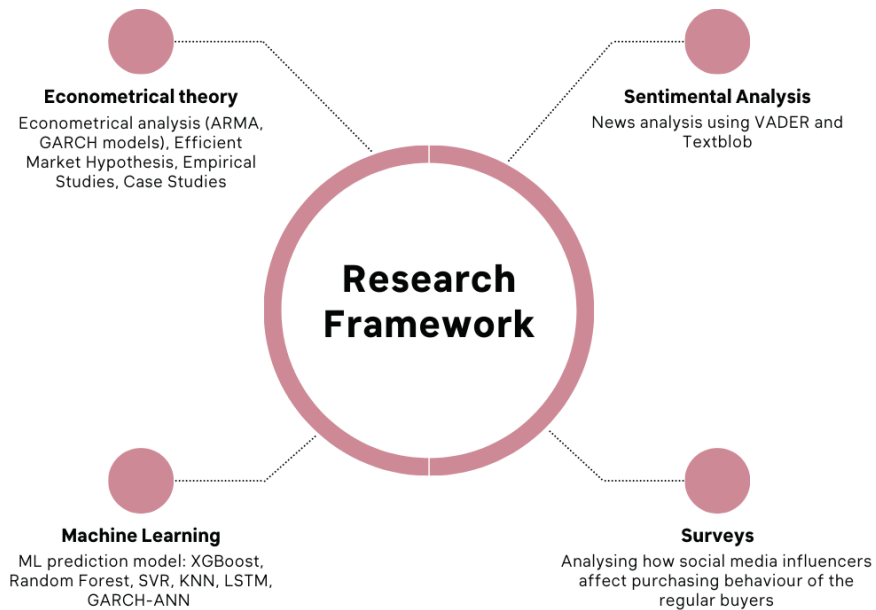
As shown in Figure 2, the research framework consists of the four main methodological pillars: econometric theory, machine learning, sentiment analysis, and a survey (conducted in Study III). The literature background of these theoretical concepts is described in the following section.

The framework used in this thesis covers various methodologies and aims to comprehend the potential effects of online media, the robustness of the forecasting algorithm, and the predictive performance of methods using technical indicators.

By investigating these points, the thesis aims to contribute to both the theoretical and practical understanding of how digital signals received from online media and emerging machine learning practices can be systematically integrated into price prediction models and bridge the gap between classical theories, such as the Efficient Market Hypothesis, and modern data analytics.

### **2.2. Literature review**

Price forecasting is one of the critical fields in financial econometrics which attracts a lot of attention. Hence, it is essential to understand which factors affect prices and markets and which methods are more effective in solving the prediction problem. Usually, the forecast is done with the historical price data; however,



**Figure 2.** Framework structure overview

recent studies (elaborated below) have shown that media sentiments also affect stock and assets price fluctuations and could be included in the prediction models.

With the development of technology and availability of the information on the internet, many scholars have noticed that online media is linked with the financial markets and stock prices. For example, the research of Puh and Bagić Babac, 2023 shows a correlation between the textual information in the news headlines and stock price prediction, which was demonstrated by the gated recurrent unit cell-based model that used pairs of the historical prices and the sentiment score. Moreover, online media can be used by policymakers when considering financial programs. As suggested by Nathanael and Nainggolan, 2022, policymakers should consider social media to stock market participation when developing financial education programs.

News and social media have a similar impact on the financial market, for instance, as shown in the research of Chamberlain et al., 2023, both types of media are positively related to the stock returns of S&P500 companies. Additionally, Wang et al., 2022 find that there is a significant causal effect of social media sentiment on the same-day stock returns.

While investigating the correlation between online media and the financial market, it is important to refer back to the fundamental concepts and understand what affects price formation in general. One of the most fundamental concepts in finance theory is the Efficient Market Hypothesis. The Efficient Market Hypothesis suggests that prices on the financial markets incorporate all the known infor-

mation available by that moment in time, as discussed by Fama, 1970 and Malkiel, 2003. While the Efficient Market Hypothesis has faced challenges and criticisms from different scholars due to such aspects as information asymmetry (Grossman and Stiglitz, 1980) and market bubbles (Haslam et al., 2018), it remains a crucial pillar of financial economics, influencing various investment strategies and risk management practices. In the modern world, information quickly spreads around via social media and online news sources, so we can assume that, in line with the Efficient Market Hypothesis, stock and asset prices are also influenced by the information spread in online media. Adding online sentiments into the prediction models is also an interesting way of testing the Efficient Market Hypothesis in the digital setting, as shown in the study of Komariah et al., 2016, the hypothesis is semi-strong when using prediction Twitter (now X) sentiments and exchange rates, and there is a correlation between online sentiments and exchange rate trends. Moreover, the study of Sun and Zeng, 2022 even suggested a complementary version of the hypothesis - Sentiment Efficient Markets Hypothesis, which incorporates investors' sentiments based on their analysis of the online sentiments extracted from the stock forum, suggesting that the investors' sentiments have a strong impact on the prices of assets. Research of Liu et al., 2023 has also revealed that there is synergy between investors' sentiments and stock prices at the macro level. Moreover, this study demonstrates that during COVID-19, the external anxiety caused by the lockdown significantly affects the synergy between stock prices and investor sentiment.

Hence, we can assume that it is crucial to investigate this further to understand whether online information correlates with the changes in the financial markets and determine the best way to define the potential impact. For example, sentiment analysis can be used in combination with machine and deep learning, as shown in the study of Gangwani and Panthi, 2025. For example, in the research of Maqsood et al., 2022 it is revealed that sentiment analysis of Brexit events using a deep learning model demonstrates more accurate results than machine learning models when analysing the impact of Brexit on stock markets. More recent studies also suggest the continued relevance and effectiveness of lexicon-based sentiment analysis methods used in financial forecasting. For example, the paper of Avila, 2024 shows the importance of considering diverse factors when modelling and predicting stock prices, including the influence of social media on the stock market performance.

While analysing online media's impacts on companies, it is also important to take into account the effect of so-called influencers. Nowadays, we can observe a growth in the number of new celebrities who gained their fame through social media and are also known as social media influencers. Some studies find that information from celebrities, social media influencers, and people whom they know in real life affects consumers' purchasing decisions. Moreover, certain social media platforms can show better results of sponsored content based on the endorsed product. For instance, in their research, Cooley and Parks-Yancy, 2019 found that

Instagram was mostly utilised for apparel information, while YouTube was most relevant for cosmetic and hair products.

Additionally, we can observe that online media tends to start impacting companies as soon as they enter the stock market through their initial public offering (IPO). As noted by Bajo and Raimond, 2017, one of the crucial factors influencing an IPO is the volume and transparency of information available to investors. Before listing on the stock market, the financial state of an issuing company is usually mostly unknown; however, during the IPO process, the company undergoes a dramatic increase in visibility as extensive information is revealed to the investors.

In this doctoral thesis, a primary objective is to assess the performance of the implemented forecasting methodology, designed to manage diverse and volatile data, on different financial assets, including cryptocurrencies. Cryptocurrencies are one of the most debated and complex topics in modern assets price analysis, as highlighted in the work of Pabuçcu et al., 2020. We can see that their rapid and substantial price fluctuations drive investors to make swift trading decisions despite inherent risks, as explored by Huang, 2022. To generalise, accurate price predictions are crucial in financial analysis. As highlighted in the research of Huang, 2022, in the case of cryptocurrencies, such forecasts not only guide investors but also reveal underlying financial dependencies, enhance risk management strategies, and contribute to market stability.

Price predictions may be made through various approaches, varying from traditional econometric models to advanced machine learning techniques. Additionally, technical indicators, such as momentum and divergence measures, can further refine these predictions. Momentum indicators, for instance, offer insights into whether prices are trending upward or downward and are widely employed as tools in trading strategies, as demonstrated in the study performed by Milton, 2021.

## 3. METHODOLOGY

### 3.1. Econometrical analysis

While the primary focus of this study is on machine learning techniques and their combination with traditional econometric research methods, the econometric models are also used independently to compare their performance with the other methods presented in the research.

In this thesis, the following three econometric models are used: ARMA, ARMAX, and GARCH. The Autoregressive Moving Average (ARMA) model is one of the main time-series forecasting methods, which combines two key components to capture the time-series: autoregressive (AR) and moving average (MA) processes. The AR component models the current value as a linear combination of its past values, while the MA component models the current value as a linear combination of past forecast errors. One of the advantages of this model is that it can be tailored to fit a wide range of time-series data and can be applied to solve various econometric problems (Box et al., 1994).

The second model analysed in this thesis is the Autoregressive Moving Average with Exogenous Inputs (ARMAX). It is an extension of the ARMA model, and it represents a refined time-series forecasting model that incorporates exogenous input parts while considering the impact of external variables on the time series (Box et al., 1994).

The final econometric model that is used independently in the thesis is the Generalised Autoregressive Conditional Heteroskedasticity (GARCH) model, designed to capture the volatility and time-varying variance in the dataset and to extend the traditional autoregressive models by modelling the conditional variance of a time-series as a function of its past squared observations. This way, the GARCH model captures the heteroskedastic characteristics of the analysed data (Bollerslev, 1986).

In general, based on the conducted research, more modern and complex analytical methods outperform these models and allow them to work efficiently with large datasets; however, it is essential to consider them to conduct more detailed and in-depth research and compare the performance, as the accuracy may vary depending on the type of problem and the dataset available.

Additionally, another method used in this paper (in combination with machine learning-based regression) is technical analysis, which studies historical price and volume data in order to predict future price movements. Traders and investors widely use technical analysis, which assumes that historical price patterns and trends repeat themselves, making it possible to identify potential buying and selling points (Murphy, 1999).

## 3.2. Machine learning

The principal methodology used in the studies included in this thesis is machine learning modelling. Machine learning is a part of artificial intelligence that builds different systems and learns (in other words, improves performance) based on the data they utilise<sup>1</sup>.

Nowadays, machine learning techniques are widely used in different fields, from computer science to medicine, and they gained popularity among researchers in economics as well. From previous studies (Maqsood et al., 2022, Agrawal et al., 2019, Politis et al., 2021), we can observe that machine learning methods outperform traditional econometric models, especially while working with large datasets. Machine learning algorithms have a high level of flexibility, which allows them to be combined with conventional analysis methods and models. For example, some dual-methodology models (e.g. GARCH-ANN) use combinations of econometric models, such as GARCH or ARIMA, with artificial neural (ANNs). It is important to note that while machine learning models provide accurate results, they also have a potential for overfitting. This issue can be mitigated by using such techniques as cross-validation and regularisation.

The main machine learning algorithms selected for this research include XG-Boost, K-Nearest Neighbours (KNN), Support Vector Regression (SVR), and Random Forest (RF), which were chosen based on their accurate performance in comparable financial forecasting studies reported in previous literature, as mentioned above. Moreover, each model corresponds to a different machine learning family, including boosting, instance-based learning, kernel methods, and ensemble trees. This way, the thesis is able to cover a broad spectrum of methodologies and provide more robust comparative analysis.

It is also important to mention that while deep learning models, such as Long Short-Term Memory (LSTM), are also widely used in time-series forecasting and have some advantages for capturing sequential dependencies in financial data, they were not extensively used in the current work since they have higher data requirements and require increased computational complexity and do not perform well with smaller datasets as demonstrated in Study I. Nonetheless, their usage represents a valuable topic for future research, especially as more extensive financial datasets become available.

The overview of machine learning methods used in this thesis and their descriptions are presented in Table 2.

Machine learning algorithms demonstrate a high degree of flexibility and can be applied simultaneously with other methods. For instance, we can observe that machine learning regression models can be enhanced by incorporating sentiment analysis (described in the Section below) into them. Studies I and III show that the model that includes sentiment score as a predictor demonstrates high accuracy and high predictive power. In the same way, machine learning algorithms can

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<sup>1</sup><https://www.oracle.com/hk/artificial-intelligence/machine-learning/what-is-machine-learning>

**Table 2.** Machine learning techniques' overview

Method	Description	Study Used
Extreme Gradient Boosting (XGBoost)	A tree boosting method that is considered a highly effective and widely used ML approach that can solve practical problems using a minimal amount of resources	I, II, III
k-nearest Neighbour Algorithm (KNN)	In the KNN regression algorithm, the dependent variable of a time series forecast is described as a sequence of interval scaled values. Then, based on the pattern, the KNN algorithm identifies similar past patterns and combines their future values to form predictions	I, IV
Support Vector Regression (SVR)	A supervised learning model based on the Vapnik-Chervonenkis theory	IV
Random Forest (RF)	A supervised learning algorithm proposed by Breiman (2001). The algorithm consists of creating several trees that each cast a vote for the most popular class. Essentially, the random forest consists of several decision trees that use randomly selected inputs.	IV
Long Short-Term Memory (LSTM)	A type of recurrent neural network (one of the general classes of neural networks) deep learning-based algorithm which is commonly used in times series forecasting	I
Generalized Autoregressive Conditional Heteroskedasticity and Artificial Neural Network (GARCH-ANN)	The dual methodology model is created in the following way: firstly, the GARCH model is created and fitted, and the predictions of the previously constructed GARCH model are used to fit the ANN model. Then, the fitted ANN model is used to predict the target value, and the target is then evaluated with the actual value.	IV

be combined with technical analysis, and momentum indicators can be used as predictors in machine learning regression models as described in Study II.

### 3.3. Sentiment analysis

Sentiment analysis is another key method used in this thesis. In recent years, it has become a popular approach across various disciplines, and we can see that it is widely used not only in computer science-related studies but also in economics and econometrics. Sentiment analysis provides insights into the tone of any written text, it is a natural language processing (NLP) technique which is used to identify feelings expressed in textual form. Sentiment analysis is based on a sentiment lexicon<sup>2</sup> where each word of the text has a sentiment score.

When applied to news articles or social media posts, sentiment analysis can demonstrate whether the overall text was positive, negative or neutral. The tone is defined by comparing the text in the article with the dictionary, where each word is assigned a positive or negative score based on the context in which this word is commonly used. For example, the word "love" would have a positive score because it is commonly used in a positive context, while the word "hate" would have a negative score because it is usually associated with a negative context.

There are various dictionaries available for sentiment analysis. One of the most popular dictionaries is the Valence Aware Dictionary for sEntiment Reasoning (VADER) algorithm that was created by the combination of the lexical features with consideration of grammatical and syntactical conventional rules, such as punctuation, capitalisation, degree modifiers, negation, emojis, and slang (Hutto and Gilbert, 2014). VADER is a general dictionary that can be used for both formal and informal social media content. This dictionary is used in Studies I and III. It is important to note that even with the emergence of more advanced sentiment analysis models, VADER maintains its relevance, specifically in the research context. For example, such transformer-based models as BERT (Bidirectional Encoder Representations from Transformers) introduced by Devlin et al., 2019 can provide more advanced sentiment analysis, but they still have certain limitations, such as, for example, requiring substantial computational resources and fine-tuning on domain-specific textual data. Moreover, they are also less interpretable compared to lexicon-based methods. Recent studies also show the continued relevance and effectiveness of lexicon-based sentiment analysis methods like VADER in financial forecasting. For instance, a study by Mamillapalli et al., 2024 integrated VADER with GRU models to enhance stock prediction accuracy. And the work of Avila, 2024 used VADER to evaluate the influence of tweet sentiment on biotech stocks, showing its ability to capture market sentiment without relying on deep learning models like BERT. Another advantage of VADER is its applicability to various data sources. For example, in the study of Isnan et al.,

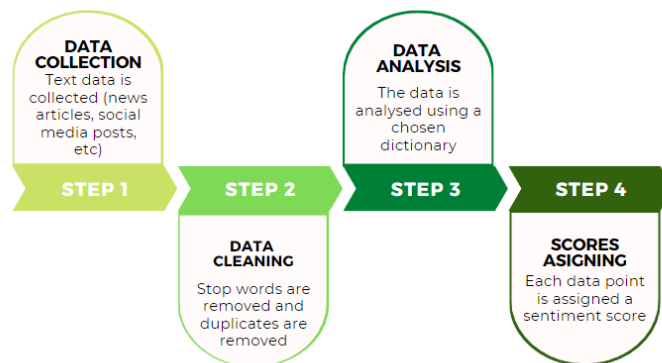
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<sup>2</sup>It is important to note that in this context, sentiment is the tone of a view or opinion.

2023 the authors applied on TikTok reviews, while the work of Amod Agarkar et al., 2025 used it on Reddit posts.

Another method used in Study III is Textblob (Kuzminykh, n.d.), which is a widely used Python library for processing textual data, including sentiment analysis and supports tasks such as part-of-speech tagging, noun phrase extraction, translation, and classification. Compared to more sophisticated models such as VADER, TextBlob offers simplicity and accessibility in analysing formal text such as news articles, which suited the purpose of the study.

Sentiment analysis is widely used because it brings the qualitative text analysis to the quantitative terms by assigning each piece of textual information a score on a scale from -1 to 1. The process of conducting sentiment analysis is described in Figure 3 and consists of 4 steps. It is important to clarify duplicate removal mentioned in Step 2 of this process: while repeated expressions may reinforce the perceived intensity of a sentiment, they sometimes can represent redundant or noisy information rather than genuine emphasis, so it is important to include this step in the data cleaning phase.



**Figure 3.** The process of sentiment analysis

In this doctoral thesis, sentiment analysis is primarily based on publicly available news articles, which usually provide a consistent and structured source of textual data. The choice of news media was influenced by the reliability and accessibility without the imposed Application Programming Interface (API) limitations or issues with data quality. It is also necessary to note that it often can be challenging to isolate the effect of the potential impact of social media on market behaviour from such confounding variables as major news cycles or macroeconomic events. However, this can be mitigated by focusing on short-term data periods or event-specific analyses, where online sentiments can be observed more clearly, together with market responses.

## 4. RESEARCH RESULTS

### 4.1. Results overview

This doctoral thesis is structured around four interrelated studies that explore the roles of online sentiments, momentum indicators, and various forecasting approaches to help understand how machine learning and sentiment analysis can be integrated into forecasting models to enhance predictions and provide insights for investors and policymakers.

Study I demonstrates that the XGBoost model enhanced with news sentiments outperformed ARMAX for the training dataset and gave a similar performance with ARMAX in the testing dataset. At the same time, other machine learning approaches couldn't perform that well, making XGBoost the most suitable algorithm for the chosen data sample, followed by the ARMAX model. It is interesting to note that even though the ARMAX model requires stationarity and invertibility restrictions on the model parameters, it learned well on the training set and was able to predict closely most of the highest and lowest returns; however, its predictions were smoother than the true returns and couldn't catch the variation in them so well. It is important to highlight that the ARMAX model was not able to predict the high and low points accurately in the test dataset, but the spread of the predictions was slightly higher, which resulted in better predictive performance. The prediction mean absolute error (MAE) results were 0.00511 for the training dataset and 0.00487 for the test one. In contrast, the XGBoost algorithm gave the best prediction result on the given dataset with MAE results of 0.00316 and 0.00479 for the training and test datasets. The XGBoost algorithm was able to learn very well from the training set, although the predictive performance in the training set is not so much above that of the ARMAX model. These results showcase that XGBoost has better learning capacity during training, which shows its ability to capture complex, nonlinear patterns more effectively than ARMAX. Despite having similar test results with the ARMAX model, XGBoost showed competitive performance in testing and stronger learning dynamics overall, making it a better model for the given dataset.

Study II reveals that the machine learning-based algorithm shows high accuracy for the model with historical prices and momentum indicators. We can see that momentum indicators contribute to the prediction model and its accuracy, with Moving Average Convergence Divergence (MACD) and Relative Strength Index (RSI) being the indicators with the biggest weights in our models. The XGBoost model used in this study performed well for all the coins for both training and test datasets, with mean absolute percentage error (MAPE) results varied from 0.8% to 8.2%. We can observe that Bitcoin (BTC) had the most accurate result in the training dataset, and Ether (ETH) had the best performance for the test one. The accuracy demonstrated by the model emphasised the high predictive powers of the XGBoost algorithm and advantages of using machine learning in

cryptocurrency analysis.

Study III discusses how the IPO process heavily relies on available information and demonstrates that using a machine learning algorithm for stock returns analysis, combined with news sentiment scores and Google Search Volume Index (SVI) values, yields high-accuracy results. The XGBoost model created to analyse the IPO case study demonstrated MAE results of 0.00148 for the training dataset and 0.0336 for the test dataset, highlighting that the chosen model had high accuracy in the training set with lower accuracy for the test set, which could be related to the dataset size. Additionally, the detailed analysis of social media reveals that it can create short-term market noise, but it does not impact stock prices or company performance in the long term. However, it is important to note that social media contributes to increased brand awareness. We can conclude that social media has become a part of the everyday life of the majority of people and can have an impact on shaping purchasing behaviour.

Study IV provides a comprehensive overview of machine learning and traditional econometric approaches that can be applied to stock market analysis. In this study, multiple models were created, an extensive number of tests were carried out, and a thorough comparison was performed between the different approaches, where the overall effectiveness of the machine learning and econometric models was then compared with the standard residuals. These results indicate that machine learning models, particularly support vector regression (SVR) and k-nearest neighbours (KNN), have had consistently better predictions in most cases we considered. However, when comparing models like Random Forest and GARCH-ANN (a hybrid of artificial neural networks with GARCH) to ARMA and GARCH models, the results were more nuanced. Specifically, the performance varied depending on the amount of training data and the choice of error evaluation metric. This way, when selecting between econometric and machine learning models, it is important to consider not just the model itself but also its data context and the performance metric used.

Combined, these studies provide an understanding of how social media sentiments and dual-methodology prediction methods can improve stock market analysis. Moreover, they support the overarching research goal by evaluating the performance of sentiment-enhanced machine learning models, clarifying the role of technical indicators in boosting prediction accuracy, indicating the nuanced impact of social media on market behaviour, and outlining a course for future studies in the evolving field of financial market analysis.

## **4.2. Limitations and future research**

Even though the conducted research was versatile and extensive, it still has its limitations, and the thesis has the potential for conducting further studies.

First of all, it would be interesting to reproduce the analysis with other datasets or with the changed features. For example, it would be beneficial to analyse the

IPO process of another social media platform and compare it with the Facebook case, as it would be useful to observe the process in real-time to track social media news regarding it and analyse the effects.

Since this research utilises specific datasets and case studies, the findings offer valuable and broadly applicable methodological insights, particularly regarding using machine learning and sentiment analysis in financial forecasting. Even though the external validity of the results may be limited due to the available data, the consistent performance of the proposed models across multiple studies and data types (e.g., stocks, cryptocurrencies, news, and social media sentiment) suggests a degree of generalizability. Future research can further enhance external validity by applying these methods to a broader range of datasets and time periods, enabling more robust cross-context comparisons and replications.

Additionally, predictive models that rely on sentiment analysis from online textual data may be influenced by future algorithm changes or shifts in user behaviour over time, so it would be beneficial to retrain them with the new dataset to maintain accuracy. Future research can also apply more extensive out-of-sample testing to mitigate any potential overfitting of the machine learning models.

Also, we can suggest that sentiment reliability may be affected by synthetic or manipulated information, since currently, there is a spread and popularity of AI-generated content in the digital landscape. Further research could integrate detection mechanisms for such disinformation to enhance model robustness.

Another extension of the research would be to repeat the experiment with a combination of technical analysis and machine learning, but using a different set of momentum indicators and other cryptocurrencies. With the continuous development of machine learning, there is a potential for the emergence of more accurate methods for stock market analysis, rather than the methods specified in this doctoral thesis.

## 5. CONCLUSIONS

We can observe that the global economy has become increasingly dependent on modern trends and online media sentiments. Therefore, it is crucial to understand these aspects to be able to anticipate the potential impacts and incorporate the new digital signals into price prediction models. As prices are affected by numerous factors, finding a suitable model is crucial for accurate predictions.

This doctoral thesis emphasises the importance of analysing online media in order to understand its effects accurately; and it investigates different methods for price analysis, highlighting the correlation between online media sentiments, stock returns, and the financial markets. Additionally, this doctoral thesis explores the influence of online media on various aspects of our lives, including decision-making processes. It implements a dual-methodology for financial assets price forecasting, providing an accurate method to incorporate digital signals into prediction models. It also tackles the inclusion of more traditional financial analysis methods, such as technical analysis, into the machine learning models in order to investigate changes in such volatile assets as cryptocurrency.

This research analyses the usage of online media sentiment for financial predictions using a combination of traditional econometric models and modern machine learning techniques. The work incorporated four empirical studies, each focusing on different asset types, data sources, and model groups (ARMAX, GARCH, XGBoost, SVR, KNN, and GARCH-ANN), while highlighting how online sentiment data and momentum indicators can be integrated into forecasting, together with the machine learning-based methods.

This research confirms that an online activity is associated with changes in the financial asset prices. These findings suggest that online media platforms have become an important channel for spreading the information that is associated with the changes in the financial markets. The findings of this research align with the previous studies and also showcase a semi-strong consistency with the Efficient Market Hypothesis that assumes that prices and, respectively, their changes reflect all publicly available information. Although online media activity correlates with the changes in the financial markets, we can observe that in some cases these changes are short-term, as discussed in Study III.

The key contribution of the thesis is the comparative analysis between econometric and machine learning models and a dual-methodology approach. The results across multiple studies showed that machine learning models, especially XGBoost, SVR, and KNN, generally outperformed the traditional econometric ones in terms of predictive accuracy, especially when online sentiment features were added into the models. Although we can also observe that, in some cases, conventional models like ARMAX remained competitive, highlighting the importance of model selection based on data and evaluation metrics.

We can also see that including additional features in the prediction models provides a high accuracy, and the feature importance analysis also highlights the

value of using dual-methodology in the prediction models, especially for such highly volatile assets as cryptocurrency prices as shown in Study II, where the results of the analysis demonstrate highly accurate results and highlight the importance of the usage of machine learning models, especially in combination with momentum indicators.

The case studies provided in this thesis (e.g. Meta, Coca-Cola, and Snapchat) also demonstrate that the association between online activity and short-term financial market dynamics can be used as a generalisation for other companies, as information spread through online media correlates with financial market behaviour across different industries and across various stages of activity on the financial markets (e.g. IPO versus already trading at the stock exchange).

This research also provides opportunities for future research, such as conducting in-lab experiments to analyse whether social media users prefer products endorsed by influencers and celebrities compared to non-endorsed ones, keeping all other factors equal. To ensure practical and theoretical robustness, future studies could also integrate attention-weighted sentiment indices, cross-platform contagion modelling, and temporal decay mechanisms. These enhancements would support a more dynamic understanding of how online attention shapes financial market behaviour, challenging the assumptions of the Efficient Market Hypothesis and suggesting the presence of persistent pricing inefficiencies driven by online sentiment. Additionally, while the current work includes several more popular cryptocurrencies, extending the analysis to a broader range of data would provide an opportunity to understand dynamics in less-studied use cases.

In conclusion, this doctoral thesis achieved its declared goal, highlighted the links between online media and the financial market and provided an accurate methodological framework that could be used for such analysis.

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# SISUKOKKUVÕTE

## Veebimeedia analüüs ja finantsturud

Veebimeedia on tänapäeva infoühiskonnas võtmetähtsusega ning selle mõju nii globaalsele majandusele kui ka finantsturgudele on märkimisväärne. On näha, et veebimeedia platvormide laialdane kasutamine on oluliselt muutnud inimeste omavahelist suhtlust ja info jagamist. Näiteks jälgivad erinevate kaupade ostjad enne ostu sooritamist pidevalt veebiarvustusi, trende ja mõjutajate (isikud, kes on oma populaarsuse ja maine saavutanud oma veebikohalolu ja tegevuse kaudu) arvamusi. Lisaks jälgivad professionaalsed aktsia- ja finantsvarade kauplejad samuti regulaarselt veebimeedia platvorme, et leida värskeid uudiseid ja turutrende, ning võime näha näiteid, kus üksainus viraalne postitus või mõjutaja kommentaar näib mõjutavat aktsia hinda juba tundide jooksul pärast sotsiaalmeedias ilmumist. Seetõttu võime järeldada, et on oluline mõista, kuidas seda seost analüüsida, ning milliseid tööriistu saab kasutada täpse ja usaldusväärse analüüsi tegemiseks.

See doktoritöö uurib, kuidas veebimeedia kaudu leviv info mõjutab ettevõtete tegevust ja tarbijate ostuotsuseid. Lisaks käsitletakse erinevaid meetodeid, sealhulgas ökonomeetrilisi ja masinõppemeetodeid, et selgitada välja kõige tõhusam viis aktsia- ja krüptovaluutahindade analüüsimiseks.

Tehnoloogia kiire areng on toonud ökonomeetrilisteks analüüsideks kättesaadavaks üha keerukamad tööriistad ja meetodid. Tänapäeval kasutatakse masinõppemeetodeid laialdaselt erinevates valdkondades ning neid saab rakendada ka majandusteaduses. Masinõppemudeleid saab kasutada majandusnäitajate prognoosimiseks, finantsturgude analüüsimiseks ja tarbijakäitumise mõistmiseks. Teine oluline meetod, mis on viimastel aastatel populaarsust kogunud, on tekstikaeve, mis võimaldab suurtest struktureerimata tekstimassiividest, näiteks uudisartiklitest, teavet välja võtta ja muuta see kvantitatiivseteks muutujateks. Need aitavad omakorda integreerida niinimetatud meeoleolusid ehk tekstis väljendatud emotsionaalseid hoiakuid ja arvamusi ennustavatesse mudelitesse.

Arvestades nende meetodite kättesaadavust, on käesoleva uurimistöö eesmärk viia läbi põhjalik analüüs teguritest, mis mõjutavad finantsturgude toimimist, rakendades kahesuunalist meetodilist lähenemist, mis ühendab masinõppe ja ökonomeetrilised tehnikad, ning välja töötada täpsemaid viise volatiilsete varade, nagu krüptovaluutad, hindade prognoosimiseks. Senise uurimistöö kitsaskoht on selles, et analüütilised meetodid, mida praegu kasutatakse veebimeedia ja finantsturu seoste uurimisel, on sageli standardiseerimata ja ebaselged. Lisaks, hoolimata kasvavast huvist selle vastu, kuidas veebipõhised meeoleolud finantsturge mõjutavad, ei sisalda olemasolevad uuringud tavaliselt kahesuunaliste meetodikate integreerimist. Seetõttu on hübriidse kahesuunalise meetodilise raamistiku käsitlemine seni vähe uuritud, pakkudes võimalust kaasata analüüsi erinevaid andmeliike ja mitmesuguseid tehnikaid veebimeedia ja finantsturu seoste uurimisel.

Käesolevas doktoritöös esitatud uuringud analüüsivad veebimeedia meeoleolu

kasutamist finantsprognosides, ühendades traditsioonilised ökonomeetrilised mudelid ja kaasaegsed masinõppe tehnikad. Töö hõlmas nelja empiirilist uurimust, millest igaüks keskendus erinevatele varaklassidele, andmeallikatele ja mudelirühmadele (ARMAX, GARCH, XGBoost, SVR, KNN ja GARCH-ANN), tuues samas esile, kuidas meelevuandmeid ja momentuminäitajaid saab koos uute masinõppe tehnikatega prognoosimisse integreerida.

Doktoritöö peamine panus seisneb ökonomeetriliste ja masinõppemudelite ning kahesuunalise meetodilise lähenemise võrdlevas analüüsis. Mitme uuringu tulemused näitasid, et masinõppemudelid, nagu XGBoost, SVR ja KNN, ületasid üldiselt traditsioonilisi ökonomeetrilisi mudeleid prognoositäpsuse osas, eriti juhul, kui analüüsi olid kaasatud meelevuandmed. Siiski osutusid mõnel juhul ka traditsioonilised mudelid, nagu ARMAX, konkurentsivõimeliseks, mis rõhutab mudelivaliku olulisust sõltuvalt andmetest ja hindamiskriteeriumitest.

Doktoritöö rõhutab veebimeedia analüüsi olulisust selle mõju täpsemaks mõistmiseks ning uurib erinevaid hinnanalüüsi meetodeid, tuues esile seose meedias väljendatud meelevuandmete ja aktsiatoonitluste vahel. Kuna hindu mõjutavad arvukad tegurid, on sobiva mudeli leidmine täpsete prognooside tegemiseks ülioluline. Võime täheldada, et ülemaailmne majandus on üha enam sõltuv kaasaegsetest suundumustest, sealhulgas veebimeedia meelevuandetest. Seetõttu on nende mõjude prognoosimiseks ja hinnaprognosidesse integreerimiseks oluline mõista veebimeedia meelevuandmeid. Käesolev uurimistöö pakub ka põhjalikku ülevaadet sellest, kuidas veebimeedia mõjutab tavakasutajaid ja finantsturge. Tulemused avavad võimalusi edasisteks uuringuteks, näiteks laborikatsete läbiviimiseks, et analüüsida, kas sotsiaalmeediakasutajad eelistavad mõjutajate ja kuulsuste poolt soovitatud tooteid võrreldes soovitamata toodetega, hoides muud tegurid samadena, samuti tähelepanupõhiste meelevuandmete, platvormidevahelise leviku modelleerimise ja ajas nõrgenevate mehhanismide integreerimiseks ning analüüsi laiendamiseks laiemale krüptovaluutaandmete valimile, et paremini mõista vähem uuritud kasutusjuhtude dünaamikat.

Kokkuvõtteks on käesolev doktoritöö saavutanud seatud eesmärgi, toonud esile seosed veebimeedia ja finantsturu vahel ning pakkunud välja täpse meetodilise raamistiku, mida saab selliste analüüside läbiviimiseks kasutada.

## PUBLICATIONS

# CURRICULUM VITAE

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## Scientific work

Published works:

- Lapitskaya, D., Eratalay, H., Sharma, R. (2022). Predicting Stock Returns: ARMAX versus Machine Learning. (Published in: Terzioğlu, M.K. (eds) *Advances in Econometrics, Operational Research, Data Science and Actuarial Studies. Contributions to Economics*. Springer, Cham. [https://doi.org/10.1007/978-3-030-85254-2\\_27](https://doi.org/10.1007/978-3-030-85254-2_27))
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- Nõu, A., Lapitskaya, D., Eratalay, M. H., Sharma, R. (2023). Predicting Stock Return and Volatility with Machine Learning and Econometric Models: A Comparative Case Study of the Baltic Stock Market. (Published in *International Journal of Computational Economics and Econometrics*. <https://doi.org/10.1504/IJCEE.2023.133923>)
- Alfieri, L., Eratalay, M. H., Lapitskaya, D., Sharma, R. (2022). The Effects of the ECB Communications on Financial Markets before and during COVID-19 Pandemic. *SSRN Electronic Journal*. 10.2139/ssrn.4109041.
- Assefa, A., Lapitskaya, D., Uusküla, L., (2022). Productivity And Firm Dynamics Over The Business Cycle Pandemic. (Published in Faculty of Economics and Business Administration Working Paper Series 141, Faculty of Economics and Business Administration, University of Tartu).

Main fields of interest:

- Economics
- Financial Markets
- Price Predictions
- Econometrics Machine Learning

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## Teadustegevus

Avaldatud artiklid:

- Lapitskaya, D., Eratalay, H., Sharma, R. (2022). Predicting Stock Returns: ARMAX versus Machine Learning. (Published in: Terzioğlu, M.K. (eds) Advances in Econometrics, Operational Research, Data Science and Actuarial Studies. Contributions to Economics. Springer, Cham. [https://doi.org/10.1007/978-3-030-85254-2\\_27](https://doi.org/10.1007/978-3-030-85254-2_27))
- Lapitskaya, D., Eratalay, H., Sharma, R. (2025). Prediction of Cryptocurrency Prices with the Momentum Indicators and Machine Learning. (Published in: Computational Economics. <https://doi.org/10.1007/s10614-024-10784-1>)
- Nõu, A., Lapitskaya, D., Eratalay, M. H., Sharma, R. (2023). Predicting Stock Return and Volatility with Machine Learning and Econometric Models: A Comparative Case Study of the Baltic Stock Market. (Published in International Journal of Computational Economics and Econometrics. <https://doi.org/10.1504/IJCEE.2023.133923>)
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Peamised uurimisvaldkonnad:

- Majandusteadus
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