

A Comparative Analysis of Machine Learning Approaches in Sukuk Price Estimation Across Global Regions

**Gazi Taufiq Islam¹, Surajit Malakar², Khondekar Lutful Hassan³, Rajesh Dey⁴,
Rupali A Mahajan⁵ and Salina Kassim⁶**

¹Department of Computer Science & Engineering, Aliah University, Kolkata, India
gazi.taufiq.islam@gmail.com

²Department of Information Technology, Gopal Narayan Singh University, Sasaram, India
msurajit@rediffmail.com

³Department of Computer Science & Engineering, Aliah University, Kolkata, India
klh.cse@gmail.com

⁴IIUM Institute of Islamic Banking and Finance, International Islamic University Malaysia, Kuala Lumpur, Malaysia
rajesh.dey@gnsu.ac.in

⁵Rupali Atul Mahajan, Associate Professor & Head, CSE(Data Science Department) Associate Dean (Research and Development) Vishwakarma Institute of Information Technology, Survey No. 2/3/4 Kondhwa (Budruk), Pune 411 048, INDIA email id : rupali.mahajan@viit.ac.in

⁶IIUM Institute of Islamic Banking and Finance, International Islamic University Malaysia, Kuala Lumpur, Malaysia
ksalina@iium.edu.my

ABSTRACT

Sukuk, also known as Islamic bonds, constitute a significant aspect of Islamic finance, offering Shariah-compliant investment opportunities. Motivated by the increasing prominence of Sukuk in global financial markets and their potential for economic development, this study aims to investigate the effectiveness of machine learning neural networks in Sukuk price estimation. The objective is to evaluate the accuracy and efficiency of various machine learning techniques across diverse global regions with significant interest in Sukuk investment, as determined by the size of the Muslim population. The methodology for literature selection involves a systematic search of academic databases and scholarly repositories, focusing on recent publications within the last five years. Search terms include keywords related to Sukuk and machine learning. Selected papers are screened based on titles and abstracts to ensure relevance to the research topic, prioritizing those that explicitly discuss both Sukuk and machine learning. In addition, articles are evaluated for outcome-based research, particularly those that offer conclusions about the precision and effectiveness of Sukuk pricing or machine learning-based forecasting. The findings suggest that artificial neural networks perform better than traditional statistical methods in Sukuk price estimation. However, restrictions including short dataset sizes, the omission of Sukuk backed by assets, and overly basic rating categories indicate areas that warrant additional investigation. Future studies could explore comparative analyses of different machine learning algorithms, refine models for dynamic market conditions, and incorporate real-time data integration to enhance Sukuk price forecasting accuracy. Considering these drawbacks, the results highlight how machine learning might enhance the effectiveness and precision of Sukuk pricing.

Key Words: Sukuk, Machine Learning, Predictions, Islamic Finance

1. INTRODUCTION

Islamic bonds, or sukuk, are a unique type of fixed-income investment that adheres to Islamic investment principles by granting investors beneficial ownership of certain assets [1]. The sukuk market has experienced significant expansion, attracting scholarly interest in comprehending its essential features, financial theories, and performance in stock markets [2]. Sukuk issuances have expanded beyond conventional Islamic markets, which can be ascribed to the growing integration of Islamic banking into global financial institutions [3].

However, there is a significant discrepancy between the theoretical conceptions and actual applications of sukuk, especially with regard to the supervision of Shariah compliance by Shariah supervisory boards in Islamic financial Institutions. [4]. This makes it necessary to conduct a more thorough analysis and match theoretical foundations with practical implementations in order to guarantee the sukuk market's integrity and future growth.

Sukuk is a prominent player in the Islamic capital market, as it provides a feasible means of financing for both governments and businesses [5]. These tools promote societal trust and confidence by upholding ethical standards and aid in the growth of the market [6]. Their popularity as a substitute source of money and investment has been demonstrated in a number of markets, Tunisia being one prominent example [7]. Malaysia has seen impressive development and potential for Sukuk. This has provided chances for a wider range of investors to engage in Islamic finance [8].

2. MOTIVATION

In the context of the global financial market, Sukuk, an Islamic financial instrument, has attracted significant attention due to its compliance with Islamic law and its potential for offering stable returns [9][10]. The expansion of Sukuk has been largely driven by issuances from government and quasi-government entities, with Malaysia playing a key role in this growth [9]. Scholars have highlighted Sukuk's potential to contribute to financial stability and reduce risks, especially during periods of market volatility [10]. However, the sector faces challenges, including the lack of standardized Sukuk structures and the need for improved risk management practices [11][12].

4. OBJECTIVE

This review paper aims to critically evaluate the application and effectiveness of machine learning (ML) techniques in estimating Sukuk prices, with a specific focus on four global regions showing a growing interest in Islamic finance: Indonesia, Malaysia, Turkey, and China. These countries, representing both established and emerging markets in the Sukuk landscape, provide a diverse backdrop for analysis due to their varied economic dynamics, regulatory environments, and technological advancements. The scope of this investigation extends beyond a simple performance evaluation, seeking to understand the efficiency and accuracy of ML techniques in predicting Sukuk prices across these distinct markets.

A key objective of this study is to conduct a thorough comparison between advanced machine learning techniques and the traditional statistical methods previously used for predicting Sukuk prices. This comparison is essential to demonstrate the potential enhancements in prediction accuracy and efficiency that machine learning algorithms can offer over conventional models, thereby shedding light on technological advancements in Islamic finance.

The paper also aim to identify the key factors for Sukuk indexing through the application of machine learning techniques. Recognizing these factors is crucial for enhancing the price estimation process, as it enables the creation of more precise and effective ML models. By meticulously analyzing various ML algorithms and their capacity to utilize different determinants effectively, the review aims to offer groundbreaking insights that could significantly influence the strategies employed by investors, financial analysts, and policymakers in the Sukuk market. Through this comprehensive approach, the paper aspires to contribute meaningfully to the evolving discourse on

the integration of machine learning in financial markets, particularly within the sphere of Islamic finance.

5. LITERATURE REVIEW

Our research begins with a deep dive into the essence of Sukuk—its definition, characteristics, and historical evolution. As we trace the development of Sukuk from its origins to its current status as a pivotal component of Islamic finance, we contrast traditional pricing methods with the advent of machine learning approaches. Our review extends to examining prior studies that have employed machine learning in finance, setting the stage for our investigation.

5.1. DEFINITION AND CHARACTERISTICS OF SUKUK

The literature review focused on recent papers published within the last four years, carefully selected through a meticulous process using specific keywords related to Islamic finance, Islamic capital market, machine learning, and neural networks. Priority was given to papers that either offered a thorough overview of machine learning applications in Islamic finance or presented empirical studies investigating the use of neural networks in this area. By focusing on recent publications, the review sought to highlight the latest advancements and insights at the intersection of machine learning and Islamic finance, thus offering a current perspective on the topic.

5.2. HISTORICAL BACKGROUND AND EVOLUTION OF SUKUK

The selected studies analyzed various Islamic financial instruments, including Islamic banks, regional Islamic markets, microfinance institutions, Islamic stocks and equities, and Sukuk (Islamic bonds). These studies assessed the effectiveness of neural networks in different areas, such as classification, forecasting, predictions, indexing, and rating. The research aimed to provide a comprehensive understanding of how neural networks can enhance decision-making in Islamic finance. By examining these outcomes, the studies aimed to highlight the potential benefits and applications of neural networks in improving financial practices in Islamic finance.

5.3. DIFFERENCES OF SUKUK VS CONVENTIONAL BONDS

Sukuk and conventional bonds offer two contrasting financial market approaches. This difference arises due to their compliance with Islamic law and avoidance of interest. Unlike conventional bonds, Sukuk provide ownership in physical assets and generate returns from asset profits instead of fixed interest payments. This key structural difference and commitment to Shariah law set Sukuk apart from conventional bonds and highlights their unique role in finance [17] [18] [19]. The literature points out the complexity of Sukuk contracts which include requiring multiple agreements to maintain Shariah compliance and transparency. This reason further distinguishes Sukuk from conventional bonds [20]. With the criticism aside, Sukuk's ethical investment appeal and adherence to Islamic principles continue to attract global interest, emphasizing their importance in the financial sector [21].

5.4. TRADITIONAL METHODS VS. MACHINE LEARNING APPROACHES IN SUKUK PRICING

Sukuk pricing is heavily influenced by both machine learning and classical methods, each of which has unique benefits and drawbacks. Sukuk pricing analysis is based on traditional techniques including ensemble learning, k-Nearest Neighbour (KNN), Support Vector Regression (SVR), and others [22]. These approaches are easily interpretable and simple to apply because they frequently

rely on well-established financial models and statistical tools. They might, however, find it difficult to comprehend the intricate patterns and asymmetrical correlations found in Sukuk pricing data. On the other hand, machine learning techniques such as kernel ridge regression (KRR), support vector regression (SVR), deep neural networks (DNN), Gaussian process regression (GPR), and neural networks (SVR) offer sophisticated computational capabilities for Sukuk pricing research [22] [23]. Large datasets are easily handled by these methods, which also have the ability to pick up on subtle patterns that conventional approaches would miss. With time, machine learning models can adjust to shifting market conditions and increase the precision of their predictions. This will necessitate significant processing power and thorough data preparation.

The goal of hybrid prediction techniques is to capitalise on the advantages of both traditional and machine learning approaches [22]. Hybrid strategies aim to improve Sukuk pricing predictions by combining the interpretability of traditional methods with the predictive capability of machine learning algorithms. This method also reduces the drawbacks of using separate approaches.

Conventional techniques offer a strong basis for Sukuk pricing analysis by being easily comprehensible and simple to apply. On the other hand, machine learning techniques provide more sophisticated computing powers and the ability to identify intricate patterns in Sukuk pricing data.

5.5. PREVIOUS STUDIES ON MACHINE LEARNING TECHNIQUES IN FINANCE

The effectiveness of ensemble models, in particular rule ensembles, in improving fraud detection in financial systems has been shown in earlier research. According to Whiting (2012) [24], ensemble models—such as rule ensembles, random forests, and stochastic gradient boosting—have significantly improved their ability to detect financial fraud patterns, with accuracy levels getting close to achievable values. These ensemble methods have shown success in a number of complex problem domains [24]. They integrate predictions from numerous models via boosting, bagging, or related approaches.

Furthermore, the examination of the development of research themes in finance has been the main focus of trend analysis in machine learning studies. Latent Dirichlet Allocation (LDA) is one probabilistic topic modelling technique that researchers like Khatib (2021) [25] and Aziz (2019) [26] have used to extract coherent research ideas from a varied body of literature encompassing finance, economics, computer sciences, and decision sciences. They provided an organised summary for interdisciplinary academics looking to incorporate machine learning techniques into finance inquiry by using this analysis to identify important study subjects and demonstrate how the focus has changed over time [25] [26].

Literature by Prakhar Vats and Krishna Samdani (2019) [27] stresses the importance of several machine learning methods in trading strategies and quantitative finance, such as Support Vector Machines and neural networks. Their research emphasises how crucial it is to make accurate predictions in crucial financial domains including debt management, risk management, and stock market forecasting. They also classify various trading strategies according to how much they depend on machine learning algorithms and quantitative variables [27].

These studies have emphasised the significance of sufficient prediction in many financial domains, highlighted trends in machine learning research within finance, and showed the promise of ensemble models in fraud detection. These results offer insightful information for the next studies at the nexus of finance and machine learning.

5. METHODOLOGY

5.1. RESEARCH DESIGN AND APPROACH

A comprehensive review of the literature, with an emphasis on recent articles from academic databases, is part of our research design. Our search approach is based on keywords like Islamic

Finance, Sukuk, Machine Learning, and Islamic Capital Market. Papers that cover Sukuk and machine learning approaches are given priority when screening selected papers based on their relevance to the research topic. Analysing machine learning algorithms' efficacy in Sukuk price estimation across international regions, such as Indonesia, Malaysia, Turkey, and China, is a component of data extraction.

5.2. SELECTION CRITERIA FOR LITERATURE

Using keywords to direct our search, we use scholarly databases to find recent publications published within the last five years that meet our requirements. The papers that are chosen for further screening are subjected to a rigorous process that involves evaluating their alignment with the research topic and outcome-based research. The focus is mostly on Sukuk price accuracy through the use of machine learning techniques.

5.3. SYSTEMATIC SEARCH STRATEGY

We use a methodical process to conduct keyword searches across credible academic databases and repositories. To find pertinent studies, we carefully review titles and abstracts and narrow down publications that are older than five years. Reference chaining and citation tracking enhance our search approach.

5.4. DATA EXTRACTION AND ANALYSIS

Relevant information is taken from a few chosen studies, with an emphasis on the machine learning methods used, the metrics for Sukuk pricing accuracy, and the geographies that are covered. Statistical approaches and visualisation methods are employed to synthesise the gathered data for comparative analysis across worldwide areas within the Islamic Capital Market.

5.5. CRITERIA FOR EVALUATING SELECTED PAPERS

The requirements involve geographical coverage, methodological rigour, outcome-based research, and a clear understanding of Sukuk and machine learning methodologies. Selected papers further the field of Islamic finance study by offering insights into the comparative comparison of machine learning techniques in Sukuk price estimation.

6. FINDINGS

The review paper examines several key findings regarding Sukuk pricing using machine learning techniques, drawn from a range of studies in the field.

6.1. OVERVIEW OF SELECTED STUDIES

The selected studies employ various methodologies, including artificial intelligence (AI) and statistical methods, to predict and analyze Sukuk prices. Notable contributions include Metlek (2022) [28] proposing an AI-based network for Sukuk price prediction, Arundina et al. (2016) [29] demonstrating the superiority of AI methods in predicting Sukuk ratings, and Abu Bakar et al. (2021) [30] developing an optimal Islamic investment index. Katterbauer et al. (2022) [31] introduce a deep learning model for automated Sukuk ratings, Solikhun et al. (2021) [32] predict Sukuk sales performance in Indonesia, and Cetin et al. (2021) [33] forecast Turkish sovereign Sukuk prices.

6.2. PERFORMANCE OF MACHINE LEARNING TECHNIQUES IN SUKUK PRICE ESTIMATION

Machine learning techniques, such as artificial neural networks and deep learning frameworks, show promising performance in forecasting Sukuk prices. These techniques exhibit high accuracy rates compared to traditional statistical methods, as demonstrated by various studies. The effectiveness of machine learning models varies based on specific market contexts and dataset characteristics.

6.3. COMPARISON OF DIFFERENT MACHINE LEARNING ALGORITHMS

A comparison of different machine learning algorithms for Sukuk price estimation reveals notable differences in their performance and effectiveness. As summarized in Table 1, studies consistently demonstrate that artificial neural networks exhibit superior predictive capabilities in both Sukuk rating prediction and price forecasting when compared to other methods. Additionally, genetic algorithms and deep learning models are shown to be effective in accurately indexing stocks and reflecting Sukuk values.

Table 1 Findings of ML Models applied in Sukuk Market

Study	Machine Learning Technique	Key Findings
Metlek (2022) [28]	RNN based AI Network	Outperforms traditional methods in Sukuk price prediction
Arundina et al. (2016) [29]	Multinomial Logit Regression, Decision Tree, Artificial Neural Network	Artificial Neural Networks demonstrate superior performance in Sukuk rating prediction
Abu Bakar et al. (2021) [30]	Genetic Algorithm, Deep Learning	Effective in indexing stocks with high returns and manageable risks
Katterbauer et al. (2022) [31]	Deep Learning Framework	Captures nuanced market dynamics and provides accurate Sukuk pricing estimates
Solikhun et al. (2021) [32]	Artificial Neural Network	Achieves high accuracy in predicting regional Sukuk sales performance
Cetin et al. (2021) [33]	Artificial Neural Network	Identifies key determinants for Turkish sovereign Sukuk price prediction

6.4. REGIONAL VARIATIONS IN SUKUK PRICING ACCURACY

The accuracy of Sukuk pricing exhibits regional variations influenced by a multitude of factors and methodologies. As depicted in Table 2, research emphasizes the crucial role of regional considerations in achieving modeling accuracy. While AI-driven frameworks provide precise pricing estimates, their applicability beyond specific regions is limited. The significance of region-specific factors in influencing the accuracy of Sukuk pricing is emphasised, underscoring the need for specialised methods catered to various geographic situations.

Table 2 Results based on Regional Variations in Sukuk Market

Study	Regional Focus	Key Findings
-------	----------------	--------------

Metlek (2022) [28]	Global	Determinants like bond prices and volatility index significantly impact Sukuk price forecasting
Arundina et al. (2016) [29]	Malaysian Sukuk Market	Non-statistical methods like decision trees and artificial neural networks outperform statistical methods in Sukuk rating prediction
Abu Bakar et al. (2021) [30]	Malaysian Stock Exchange	AI-driven frameworks offer accurate pricing estimates but may lack generalizability beyond specific regions
Katterbauer et al. (2022) [31]	Chinese Equities	AI-driven frameworks address unique market dynamics but may face challenges in adapting to diverse regional contexts
Solikhun et al. (2021) [32]	Indonesia	Regional sales forecasts rely on historical data and may overlook dynamic market dynamics
Cetin et al. (2021) [33]	Turkish Sovereign Sukuk	Region-specific determinants influence Sukuk pricing accuracy, with artificial neural networks demonstrating high forecast accuracy

6.5. IDENTIFIED LIMITATIONS AND CHALLENGES

The omission of asset-backed Sukuk, dataset size restrictions, and difficulty in adjusting models to dynamic market situations are only a few of the shortcomings and difficulties in Sukuk pricing research that are noted. Additional issues include the lack of studies on Sukuk markets and the reliance on historical data for regional forecasts. Improving the precision and suitability of machine learning methods in Sukuk pricing requires addressing these constraints.

7. DISCUSSION

7.1. INTERPRETATION OF ALL FINDINGS

Important new insights are revealed by the review paper's findings on Sukuk pricing utilising machine learning techniques. Table 3 provides an overview of the machine learning models that show promise in predicting Sukuk prices across different locations. These models include Artificial Neural Networks (ANN) and deep learning frameworks. Traditional statistical methods have lower accuracy rates than non-statistical methods like artificial neural networks (ANNs) and decision trees. However, depending on particular market situations and dataset characteristics, these models' efficacy vary. Furthermore, issues like small dataset sizes and the absence of Sukuk backed by assets come into play as important factors. To overcome these obstacles and improve the precision of machine learning methods in Sukuk pricing in various parts of the world, more investigation is required.

Table 3 Interpretation from Application of ML Techniques used in the Sukuk Market

ML Technique	Interpretations
RNN based AI Network	Outperforms traditional methods in Sukuk price prediction
Multinomial Logit Regression, Decision Tree, Artificial Neural Network	Artificial Neural Networks demonstrate superior performance in Sukuk rating prediction
Genetic Algorithm, Deep Learning	Effective in indexing stocks with high returns and manageable risks

Deep Learning Framework	Captures nuanced market dynamics and provides accurate Sukuk pricing estimates
Artificial Neural Network	Achieves high accuracy in predicting regional Sukuk sales performance and identifies key determinants for Turkish sovereign Sukuk price prediction

7.2. IMPLICATIONS FOR ISLAMIC FINANCE MARKETS

There are major effects when it comes to Sukuk pricing and Islamic capital markets when machine learning techniques are integrated. Accurate forecasting of Sukuk prices is made possible by advanced models such as ANN and deep learning frameworks. This improves trading methods and risk management. These models enhance credit analysis and pricing techniques, which benefit rating agencies, issuing corporations, fund managers, and banks. Automated Sukuk ratings and Islamic stock indexing using bio-inspired AI present prospects for sophisticated pricing techniques and ideal portfolio management. Precise forecasting of Sukuk sales figures and Turkish sovereign Sukuk prices lowers investors' perception of risk and boosts their profits. This method promotes the expansion and stability of Islamic capital markets.

7.3. ADDRESSING LIMITATIONS AND CHALLENGES

Refinement and improvement of current approaches are necessary due to limitations and constraints in Sukuk price research. Forecasting accuracy can be increased by using a hybrid strategy that combines statistics and artificial intelligence techniques. Data limits can be addressed by using larger and more diversified datasets, and prediction capacities can be improved by investigating additional elements such as guarantee status characteristics and industry-specific trends. Important milestones include extending the applicability of models to global markets, integrating real-time data, and adapting models to changing market situations. Constant model improvement, back testing, and validation guarantee dependability and efficacy in a variety of market scenarios.

7.3. OPPORTUNITIES FOR FURTHER RESEARCH

Future research in Sukuk pricing has the potential to improve methods and fill current gaps. By experimenting with various network architectures and activation functions, we can potentially boost forecasting accuracy. Studying the effectiveness of AI models in different countries and regions would offer a thorough understanding of market dynamics. Evaluating the influence of extra input variables and comparing AI-driven models with traditional methods could reveal unique benefits. Additionally, applying AI to forecast other aspects of Sukuk markets beyond prices could provide deeper insights into market trends and dynamics, leading to stronger and more dependable predictive models in Islamic finance.

8. CONCLUSION

This analysis delves into the global application of machine learning (ML) techniques for estimating Sukuk prices, uncovering significant revelations and ramifications for Islamic finance markets. Artificial Neural Networks (ANN) and deep learning frameworks in particular, which outperform conventional statistical methods, demonstrate promise in properly forecasting Sukuk prices. However, depending on the features of the dataset and the market setting, their efficacy varies.

Obstacles including small dataset sizes and the absence of Sukuk backed by assets highlight the need for more study to improve accuracy in a variety of geographical areas.

For all parties involved, the incorporation of machine learning into Sukuk pricing provides beneficial outcomes, such as enhanced trading tactics and risk control. The Islamic capital markets are expected to flourish as a result of the prospects that bio-inspired AI algorithms offer for portfolio management and sophisticated pricing techniques.

Hybrid approaches that combine machine learning and statistical methodologies should be investigated to overcome the constraints. Important actions include using larger datasets, taking into account extra variables, and modifying models to account for changing market situations. Subsequent investigations ought to concentrate on improving techniques, investigating diverse network configurations, and carrying out analysis that juxtaposes AI-powered models with conventional approaches. By taking advantage of opportunities and resolving obstacles, the field of Sukuk pricing can make great progress towards stronger predictive models in Islamic finance.

REFERENCES

- [1] Vishwanath, S., & Azmi, S. (2009). An Overview of Islamic Sukuk Bonds. *The Journal of Structured Finance*, 14, 58 - 67.
- [2] Paltrinieri, A., Hassan, M.K., Bahoo, S., & Khan, A. (2019). A bibliometric review of sukuk literature. *International Review of Economics & Finance*, 86, 897-918.
- [3] Abdel-Khaleq, A.H., & Richardson, C.F. (2007). New Horizons for Islamic Securities: Emerging Trends in Sukuk Offerings. *Chicago Journal of International Law*, 7, 5.
- [4] Usmani, M.T. (2007). *Sukuk and their Contemporary Applications*.
- [5] Karimzadeh, M. (2012). Role of Sukuk in Islamic Capital Market: Experience of Iran (1994-2011). *Oman Chapter of Arabian Journal of Business and Management Review*, 1, 105-113.
- [6] Hassan, S., Dhali, M., Mehar, S.M., & Zaman, F. (2022). Islamic Securitization as a Yardstick for Investment in Islamic Capital Markets. *Int. J. Serv. Sci. Manag. Eng. Technol.*, 13, 1-15.
- [7] Chermi, H., & Jerbi, Y. (2015). Sukuk as an Attractive Alternative of Funding and Investment in Tunisia.
- [8] Ahmad, N.W., Ripain, N., Bahari, N., & Shahar, W.S. (2015). Growth And Prospect of Sukuk in Malaysian Market: A Review.
- [9] Puszer, B. (2015). Sukuk - the source of raising capital for the Islamic debt market. *Annales Universitatis Mariae Curie-Skłodowska, sectio H – Oeconomia*, 48(3), 307.
doi:10.17951/h.2014.48.3.307
- [10] Shaikh, Salman and Saeed, Shan (2010): Sukuk Bond: The Global Islamic Financial Instrument. Published in: *Business Islamica*, Vol. 1, No. 11 (1 November 2010)
- [11] Ulus, S. (2014). Fixed Income Investment (Sukuk) in Islamic Finance. *Afro Eurasian Studies*, 2(1-2), 298-305.
- [12] Haider, J., & Azhar, M. (2011). *Islamic Capital Market: Sukuk and Its Risk Management in the Current*.
- [13] Lahsasna, Ahcene & Hassan, M. Kabir & Ahmad, Rubi. (2018). *Introduction to Sukuk: Structure and Governing Rules*.
- [14] Hossain, M.S., Uddin, M.H., & Kabir, S.H. (2020). Sukuk and Bond Puzzle: An Analysis with Characteristics Matched Portfolios. *Emerging Markets Finance and Trade*, 57, 3792 - 3817.
- [15] Abubakar, Y.S., Nafees, S.M., Dorloh, S., & Aji, R.H. (2023). The Concept of Sukuk and its Applications in Contemporary Islamic Financial System. *Law and Humanities Quarterly Reviews*, 2.
- [16] Rezaei, Z. (2013). Sukuk: An Islamic Financial Instrument. *Management and Administrative Sciences Review*, 2, 261-267.

- [17] Radzi, R.M., & Lewis, M.K. (2015). Religion and the Clash of “Ideals” and “Realities” in Business: The Case of Islamic Bonds (Sukuk). *Thunderbird International Business Review*, 57, 295-310. Yesuf, A.J. (2016). A Comparative Analysis of Sukuk and Conventional Bonds. 10.1007/978-3-319-18693-1_39.
- [18] Yesuf, A.J. (2016). A Comparative Analysis of Sukuk and Conventional Bonds. 10.1007/978-3-319-18693-1_39.
- [19] Hanefah, M.M., Noguchi, A., & Muda, M. (2013). Sukuk: Global Issues and Challenges. *Journal of Legal, Ethical and Regulatory Issues*, 16, 107.
- [20] Warde, I.A. (2010). *Financial Products and Instruments*.
- [21] Ym, S., & Gaensly, J. (2018). Is There That Much of a Difference: A Comparison Between Conventional and Islamic Investment Vehicles. *The Journal of Internet Banking and Commerce*, 23, 1-11.
- [22] Chen, W., Fu, J.M., Yang, Y., & Yang, Z. (2023). The application of regression models to market rate of return prediction. *Conference on Statistics, Data Science, and Computational Intelligence*.
- [23] Li, L., Gong, Z., Zheng, L., Yu, X., & Deng, M. (2022). The Effect of Regression Methods on the Performance of Options Pricing using Machine Learning. *Proceedings of the 2022 13th International Conference on E-business, Management and Economics*.
- [24] Whiting, D.G., Hansen, J., McDonald, J.B., Albrecht, C.C., & Albrecht, W.S. (2012). MACHINE LEARNING METHODS FOR DETECTING PATTERNS OF MANAGEMENT FRAUD. *Computational Intelligence*, 28.
- [25] Khatib, A.S. (2020). *Machine Learning and Finance*. *International Journal for Innovation Education and Research.
- [26] Aziz, S., Dowling, M.M., Hammami, H., & Piepenbrink, A. (2019). Machine Learning in Finance: A Topic Modeling Approach. *Econometrics: Econometric & Statistical Methods - Special Topics eJournal*.
- [27] Vats, P., & Samdani, K. (2019). Study on Machine Learning Techniques In Financial Markets. *2019 IEEE International Conference on System, Computation, Automation and Networking (ICSCAN)*, 1-5.
- [28] Metlek, S. (2022). inward meaning. *ECONOMIC COMPUTATION AND ECONOMIC CYBERNETICS STUDIES AND RESEARCH*, 56, 107-124. doi:10.24818/18423264/56.1.22.07.
- [29] Arundina, T., Kartiwi, M., Omar, M.A. (2016). Artificial Intelligence for Islamic Sukuk Rating Predictions. In: Dunis, C., Middleton, P., Karathanasopolous, A., Theofilatos, K. (eds) *Artificial Intelligence in Financial Markets. New Developments in Quantitative Trading and Investment*. Palgrave Macmillan, London. doi:10.1057/978-1-137-48880-0_8
- [30] Abu Bakar, N. & Rosbi, S. (2021). Islamic Investment Index with Bio-inspired Artificial Intelligence.
- [31] Katterbauer, K & Hassan, S. & Cleenewerck, L. & Yılmaz Genç, S. (2022). Robo-Sukuk pricing for Chinese equities. doi:10.13140/RG.2.2.34079.64166.
- [32] Solikhun, S. & Pujiastuti, L. & Wahyudi, M. (2021). ANN: Predicting of State Retail Sukuk Based on Region in Indonesia. *Journal of Physics: Conference Series*, 1830, 012021. doi:10.1088/1742-6596/1830/1/012021.
- [33] Çetin, T.D. & Sedat, M. (2021). Forecasting of Turkish Sovereign Sukuk Prices Using Artificial Neural Network Model. *Acta Infologica*.