



Machine Learning–Based Credit Risk Assessment for Saudi Sukuk Issuers

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Abstract: The capital market of Saudi Arabia has experienced tremendous growth in Islamic finance tools like Sukuk under its economic development plan, named Saudi Vision 2030. It is essential for the capital market to evaluate the credit risk associated with Sukuk issuers for proper functioning. Generally, credit risk evaluation is performed using linear statistical and judgmental methods. However, it is difficult to evaluate credit risk using traditional methods because of the non-linear relationship between variables. In this study, a machine learning approach has been proposed for credit risk evaluation for Sukuk issuers. Using supervised machine learning techniques like Logistic Regression, Random Forest, Support Vector Machines, and Gradient Boosting, the study has evaluated various financial and macroeconomic variables associated with Sukuk issuers. The results indicate that the machine learning approach is much better for credit risk evaluation compared to traditional methods. The findings of this study will help implement Saudi Vision 2030 because it will highlight the use of artificial intelligence for credit risk evaluation in Islamic capital markets.

Keywords: Sukuk, Islamic Finance, Saudi Vision 2030, Economic Development, Credit Risk Evaluation, Default Prediction.

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1. INTRODUCTION

The Islamic financial market has experienced tremendous growth over the past few decades, and Sukuk has been recognized as an integral part of the Islamic financial system. Sukuk has been recognized as a capital market instrument that is Shariah-compliant and signifies ownership interest in assets or investment activities as opposed to a conventional bond that is considered a debt instrument. Sukuk can be issued in various forms and can be structured in various ways, ranging from asset-based structures that are referenced based on the creditworthiness of the issuer and referencing of the assets, and then moving into more sophisticated structures where the cash flow is referenced more closely to the asset.

This means that the investors are prone to various types of risks that could be associated with Sukuk and could include credit risk as well as the performance and enforcement of the asset/cash flow mechanism. Saudi Arabia has experienced tremendous growth in its Sukuk market and has become one of the leading Sukuk markets for Sukuk issuances, especially considering the huge issuance of Sukuk by the government as well as regular issuances for corporate entities for infrastructure and development projects.

The growth and development of Sukuk in Saudi Arabia are in line with the aspirations and goals set for the country as per the Saudi Vision 2030 (Saudi Vision 2030, 2022). As new sectors and

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projects are being developed by issuing Sukuk, the Sukuk issuers are becoming diversified, and hence there is a paramount need for assessing the risks associated with Sukuk.

“Credit risk assessment is an important constituent of the investment decision-making process for sukuk-based investments, considering the possibilities of defaults, damages, and deteriorations in the capacity of the issuer of the sukuk to meet their due and payable coupon payments as well as the principal payments” World Bank, 2014.

Credit risk assessment of sukuk is an extremely complex process, considering the varied nature of sukuk in terms of asset linkage, cash flow, legal, as well as Shariah-based contractual structures, resulting in the development of a unique credit risk profile, which cannot be easily evaluated using credit risk assessment tools for bonds. Even after the credit rating and Shariah-based governance structure, there exists an information asymmetry for the investors of sukuk-based investments, which are required to assess the structure of the sukuk as well as their capacity to withstand the same, which has become prominent in the emerging economies with high growth rates for sukuk-based investments.

The conventional methods for credit risk assessment, such as financial ratio analysis and statistical classification methods like discriminant analysis and logistic regression, are extremely efficient methods for credit risk assessment and have been used as guidelines for credit risk assessment. Though the conventional methods for credit risk assessment are extremely efficient, they are not completely efficient with regard to interrelation in credit risk factors and relationship changes due to regime change and alterations in the distribution of credit risk due to reforms and business cycles, as is evident with regard to economies in transition with extremely high levels of innovation and sectoral changes with regard to financial behavior and risk transmission.

However, due to these factors, machine learning (ML) has been recognized as a viable option for developing a credit risk modeling approach. ML facilitates the learning process of the model and enhances the performance of the model through the appropriate training and validation of the model. ML-based models such as RF, SVM, and GB are recognized for their better performance than conventional statistical models for developing a credit risk modeling approach, especially for benchmark data, with a huge number of variables. ML-based models can handle a huge number of variables and identifying the relationships between variables, which might not be possible through conventional

linear models, thereby identifying deteriorating credit risk with appropriate validation.

The financial sector development program for Saudi Arabia recognizes the need for developing the financial sector of Saudi Arabia through the development of the risk management function for improving the efficiency of the market, as per the initiative taken by the Saudi Vision 2030 project for developing the financial sector of Saudi Arabia. ML-based credit risk modeling for sukuk-based financial instruments is one such initiative taken towards achieving the objectives of the Saudi Vision 2030 project for developing the financial sector of Saudi Arabia through the identification of deteriorating credit risk with appropriate validation.

“With the presence of an increasing number of international investors in the capital market, it becomes imperative that appropriate credit risk modeling approaches are used so that the information asymmetry between the investors and the sukuk issuers can be minimized” S&P Global Ratings, 2024.

In the above context, this research aims to establish its relevance in terms of the use of supervised ML-based approaches that can act as an appropriate solution in terms of credit risk assessment for Saudi-based sukuk issuers based on their financial ratios and the appropriate macroeconomic variables. It can be considered to have made an appropriate contribution to the existing body of knowledge in the following ways: the ML-based approaches for credit risk modeling have been used in the context of a scenario that is appropriate for sukuk issuers, with appropriate asset linkages being very high. Furthermore, the present research aims to prove its relevance in terms of the ways in which the requirements of transparency and appropriate features in terms of transparency can be met in terms of the requirements of the stakeholders in the Islamic financial system. In addition, the research aims to prove its relevance in terms of the ways in which the requirements of Vision 2030 can be met in the Kingdom of Saudi Arabia.

2. LITERATURE REVIEW

2.1 Credit Risk Assessment in Conventional and Islamic Finance

Introduction

The assessment of credit risk is considered a fundamental process for the maintenance of financial stability, the protection of investors, and the establishment of an efficient capital market. Credit risks can be measured with the assistance of conventional credit risk models through the help of financial ratios, leverage, liquidity, profitability, and other relevant macroeconomic variables through discriminant analysis, probit analysis, logistic

regression, and structural credit risk models. Conventional credit risk models have been found to be related to a number of benefits, making them the most sought-after credit risk models for conventional financial environments. However, the conventional credit risk model may act as a challenge in the following cases: where the relationship between the parameters is not constant, where non-linear relationships are present, and where the distributional properties are violated (Noriega *et al.*, 2023).

In Islamic finance, there are various challenges associated with credit risk assessment, which include the prohibition on *riba*, asset finance, and sharing credit risks on a contract-by-contract basis. In sukuk instruments, unlike conventional bonds, the cash flow is based on beneficial interest in assets, projects, or investments, accordingly credit risks can be based on risks associated with the issuer and economic performance and structural protection of sukuk instruments. In sukuk instruments, there is a possibility of using a hybrid effect as a factor on asset finance and asset-backed finance, which may affect credit risks for investors.

In Islamic financial institutions, leverage, profitability, and liquidity were found to be key predictors for risks based on various jurisdictions and regulatory environments. In an study, conventional tools were not found to be effective for explaining Islamic finance, particularly in developing countries, as there were different requirements for disclosures and enforcement of contracts and different market conditions compared to other markets (World Bank, 2014).

This suggests that there is a possibility for using tools that can accommodate non-linear relationships, interaction effects, and regime shifts, and are easily interpretable and governable.

2.2 Sukuk Market Risk and Credit Rating Limitations

"The growth of the Sukuk market has been tremendous, with Saudi Arabia being one of the leading issuers of Sukuk, whether sovereign or corporate" ICD-LSEG, 2024; S&P Global Ratings, 2024.

Ratings have been used as a tool to obtain a concise view of the creditworthiness of debt instruments such as Sukuk, with the process being comparable to conventional bonds, making the necessary modifications due to the inherent structural characteristics of Sukuk. Ratings are necessary in order to obtain a level of comparability, but in spite of the importance of ratings, many shortcomings are associated with the process, such as ratings being backward-looking in that they can only

provide ratings based on historical data, ratings not being transparent enough for the outside world since the rating model and data used are not easily visible, and ratings not taking into account early warning signs, especially in uncertain financial times (S&P Global Ratings, 2024). This can be worse in uncertain financial times characterized by high market reform and issuance of Sukuk in different sectors of the economy.

The rating of Sukuk can be a complex process, and the structure of the Sukuk, asset relationship, and legal guarantee can affect the issuer's capability to meet its Sukuk repayment obligation, and this is not always clear in the rating. The investor will also experience problems of information asymmetry, whereby the Sukuk contract can vary in content, assets can be restricted, and the relationship between the contract and law can be complex. All this requires the use of ML tools that can analyze numerous variables with continuous monitoring of the risk factors of the issuer, and this requires effective governance structures.

For example, in Saudi Arabia, the economic reform strategies and development of capital markets, as outlined in Vision 2030, have been related to the increase in sukuk issuances in different sectors like energy, infrastructure, real estate, and PPP. The development of capital markets has been recognized as validating arguments that support differentiated approaches to credit risk measurement, and this can be responsive to different structures, sectoral changes, and macroeconomic factors. The research problem appears to be based on different aspects of capital markets.

2.3 Applications of Machine Learning in Credit Risk Modeling

*"The ML method has been considered as an alternative to conventional credit models based on its potential to effectively address non-linear relationships, interactions, and decision boundaries" Noriega *et al.*, 2023; Chang, 2024.*

ML has also been considered as having the capability to effectively address multiple predictor variables, dealing effectively with issues of multicollinearity using regularization and split variables, as well as having the capability to effectively learn relationships that have the potential to enhance classification and ranking.

In conventional credit markets, different studies have considered different ML models, including RF, SVM, neural network, as well as GB, as having the capability to forecast credit default, migration, etc., as opposed to conventional statistical models, even in an environment characterized by

high-dimensional data with non-linear relationships and the capability to change over time. For instance, ML has been considered as having the capability to effectively operate in conventional credit markets in credit risk modeling based on its potential to reduce variance, as well as having the capability to effectively address non-linear relationships and combine predictions from different weak classifiers to generate effective classifiers.

Regarding model governance, it is also evident that ML has the capability to make the model less transparent as compared to other conventional linear models. As a result, transparency issues arise. However, feature importance can be used to gain a deeper insight into the results of the prediction. For instance, in the case of credit risk modeling, factors may include liquidity, leverage, profitability, cash flow, etc. These factors may also include economy-level as well as firm-level conditions, including stress in the economy.

2.4 Machine Learning in Islamic Finance and Sukuk Markets

In regard to Islamic financial markets and sukuk markets, the volume of ML-related research is smaller compared to traditional financial markets, such as Islamic bank performance, fraud detection, Shariah compliance, but not sukuk issuer credit risk, at least based on the study by ICD-LSEG (2024) and the World Bank (2014). The volume of research that is available in the area of sukuk credit risk is surprising, considering the development of the sukuk market.

According to the study by ICD-LSEG (2024) and S&P Global Ratings (2024), the major challenge that ML techniques pose in the modeling of sukuk credit risk is that the stakeholders in the sukuk market will most probably resist the application of ML techniques, as the logic of the model will not be transparent and will not be auditable.

This is an important issue, as transparency is an element of market practice in sukuk markets. Another challenge that will be faced by ML techniques in the modeling of sukuk credit risk is the fact that the availability of the data will also be a challenge, as the data regarding the structure of the sukuk and the performance of the assets will not necessarily be disclosed.

The agenda for the digital transformation in Saudi Arabia, as per the Saudi Vision 2030, 2022, is such that it is quite easy to contemplate the applicability of ML in the market surveillance and risk management by improving the data system, fintech, and advanced analysis in the financial system. This has implied the applicability of ML in the credit risk

assessment in the sukuk market, which is consistent with the government, Shariah, and regulations.

Therefore, the research context is valid, which makes the applicability of ML in the credit risk assessment for the sukuk market valid, given the growth in the market and the interest of the government in the advanced analysis, which is to be applied in the context of the research.

2.5 Research Gap and Contribution

The research gap in the research is the applicability of ML in the credit risk assessment for the conventional market, which might not be applicable for the Saudi sukuk market issuers, given the fact that the issuers in the Saudi sukuk market are different from one another due to the special features of the sukuk contracts and their asset links (AAOIFI, 2008; World Bank, 2014; Noriega *et al.*, 2023).

The research has made an important contribution to the literature by proposing and applying ML for the credit risk assessment for the Saudi sukuk market issuers, where the financial ratios are related to the macro variables, which explain the analysis results by using the explainability-oriented approach (Noriega *et al.*, 2023; Chang, 2024). In addition, the research has discussed the applicability of the proposed model for the developing capital markets in Saudi Arabia, as per the Saudi Vision 2030, and for the developing and applying the advanced technology for the developing capital markets in Saudi Arabia (Saudi Vision 2030, 2022).

3. Saudi Vision 2030 and Conceptual Framework

Saudi Vision 2030 is a development plan that outlines a vision for the kingdom of Saudi Arabia, aiming to reduce dependence on oil revenues, develop the human capital of the Kingdom of Saudi Arabia, and create a competitive environment as an investment location and as a financial center (Saudi Vision 2030, n.d.).

In accordance with the Saudi Vision 2030 plan, the Financial Sector Development Program of the Kingdom of Saudi Arabia aims to develop capital markets in the Kingdom of Saudi Arabia, improve financial governance in the kingdom of Saudi Arabia, and develop digital technologies in the kingdom of Saudi Arabia (Saudi Vision 2030, 2022).

Sukuk is an essential tool of finance in the development finance of the kingdom of Saudi Arabia due to its higher use in the development finance of the Kingdom of Saudi Arabia. As the number of sukuk bonds being issued is on the rise in different sectors of the kingdom of Saudi Arabia, the importance of

managing the risks is also on the rise in the kingdom of Saudi Arabia.

Although conventional tools such as ratio analysis, expert opinions, and credit rating may not be effective in managing the risks of sukuk bonds due to their inability to cope with the changing performance of different sectors of the kingdom of Saudi Arabia, macro variables, and sukuk bond structure, the focus of Saudi Vision 2030 on the use of advanced analytics could be used as a justification for developing credit risk assessment systems using Artificial Intelligence (AI) and Machine Learning (ML) that could take into account the complex relationship between different variables and changes in their values based on available information.

3.1 Role of Artificial Intelligence in Vision 2030

The use of AI, data analytics, and fintech is promoted in Saudi Arabia by Vision 2030 for developing financial markets in Saudi Arabia while ensuring good governance in the kingdom. ML can be applied for the analysis of issuer variables as well as macro variables in near real-time to recognize any negative trends in their creditworthiness. ML can be applied for developing strong financial markets in Saudi Arabia by combining issuer ratios, sectoral variables, as well as macro variables.

3.2 Conceptual Framework for ML-Based Credit Risk Assessment

The conceptual framework for applying ML for credit risk assessment for the issuers in Saudi Arabia is as follows:

3.2.1 Input Variables:

The input variables for developing the model are defined as variables that are issuer-specific, related to leverage, liquidity, profitability, cash flow, asset growth rates, size, as well as macro variables such as GDP growth rates for issuers, which are considered as environmental conditions for issuers (Noriega *et al.*, 2023).

3.2.2 Data Processing and Feature Selection:

Normalization and scaling of the data would be required, followed by correlation screening and feature selection to enhance the accuracy and stability of the model while reducing noise. The new features would include the incorporation of data on the structure of the sukuk issued and the performance of the assets. The data on the structure would include the sectoral distribution and the stages of maturity of projects for which sukuk have been issued. In addition, asset performance indicators would also be included in the model, with the understanding that this data would not be available for all issuers.

3.2.3 ML Models:

Supervised learning-based ML models such as logistic regression, RF, SVM, and GB would be used to make predictions for classes or probabilities for issuers to determine their credit risk. The use of these models would ensure that accuracy is achieved for the predictions made through multiple weak classifiers and their ability to address non-linear relationships between the data and the target variable. In addition, a suitable ML model would be selected that can be used to explain the results obtained from the application of the ML model.

3.2.4 Output and Decision Support:

The output will include the predictions made through the model and the results of the explainability methods. This will ensure the provision of the results of the decision made using the model and the results of the explainability methods. This will aid in the decision-making process for the investors and the issuers. The output will include the provision of information that will aid investors and issuers in making decisions such as identifying the issuers considered to be at a high risk and the factors responsible for high-risk issuers (e.g., high leverage ratios). This will ensure the provision of the results of the decision made using the model and the results of the explainability methods. This will align with the provision of the results of the decision made using the model and the results of the explainability methods, which will aid in the enhancement of the provision of the results of the decision made using the model and the results of the explainability methods.

The framework is essential for achieving the goals set in Vision 2030 in the following ways:

First, it is essential for enhancing the risk management capability of the Saudi economy, considering that it adopted models that can change according to circumstances, with an option to upgrade them according to new available data sets.

Secondly, it is essential for enhancing capital markets, considering that it is essential for enhancing the quality of available information, which is necessary for valuing risks in Islamic capital markets.

Thirdly, it is essential for enhancing investor confidence, considering that it is essential for providing credit risk indicators on a timely basis, including those factors that can be explained, thus enhancing transparency in the Saudi economy.

Generally, the contribution of the framework to the Saudi economy is in accordance with the goals set in the Financial Sector Development Program, which seek to enhance transparency, as well as enhance governance and modernization of the Saudi economy through the adoption of technology.

4. METHODOLOGY

The research design to be used in carrying out the research and developing the ML models for analyzing the credit risks faced by Saudi sukuk issuers is a quantitative research design. The research design to be used in carrying out the research is a standard machine learning research design, which emphasizes transparency and robustness in carrying out the research and obtaining the results (Noriega *et al.*, 2023).

4.1 Research Design

The research design to be used in carrying out the research and developing the ML models for analyzing the credit risks faced by Saudi sukuk issuers is a supervised machine learning research design. The design will help the researcher classify

the issuers into various categories based on the various risks (Chang, 2024; Noriega *et al.*, 2023).

4.2 Data Sources and Sample Selection

In general terms, the research will use the financial information disclosed and audited by the issuers as secondary data. The research will look into the sukuk issuances made by the government and corporations in the energy sector, infrastructure sector, real estate sector, and finance sector in Saudi Arabia. The research will consider only the companies that disclose full financial information to avoid biases. The research will consider companies in good and bad market conditions to ascertain whether the models perform better in bad conditions (S&P Global Ratings, 2024).

4.3 Variable Selection and Definition

Table: Description of Variables Used in the Study

Variable Category	Variable	Description
Leverage	Debt-to-Equity Ratio	Measures of financial leverage and capital structure risk
Liquidity	Current Ratio	Indicates short-term liquidity position
Profitability	Return on Assets (ROA)	Measures operational efficiency
Cash Flow	Cash Flow Coverage Ratio	Assesses ability to meet financial obligations
Growth	Asset Growth Rate	Reflects expansion and investment activity
Size	Total Assets	Proxy for issuer scale and market presence
Macroeconomic	GDP Growth	Captures economic conditions affecting issuers

Dependent Variable:

The dependent variable for the study would be the credit risks faced by the issuers of the sukuk, which can be measured through the credit quality indicators. Depending upon the availability of the data, the credit quality indicators can be the credit ratings categories, credit distress events, and credit-related events (Noriega *et al.*, 2023).

Independent Variables:

The independent variables for the study would be the financial ratios of the issuers of the sukuk, which can include other relevant data as well, for example, the macro variables. The variables would be relevant for the issuers of the sukuk as the sustainability of the issuer would play a crucial role in the repayment potential. The macroeconomic variables would be representative of the system-wide pressures that could impact the refinancing potential (Noriega *et al.*, 2023).

4.4 Data Preprocessing and Feature Engineering

Preprocessing of the data would involve cleaning, normalization, handling of missing values, and elimination of redundant features, which would include correlation test to avoid any form of multicollinearity. Feature selection and feature importance analysis would also be carried out to ensure the efficiency of the model. This would

improve the efficiency of the model (Noriega *et al.*, 2023).

Further, the presence of outliers would also be checked as there is a possibility of high leverage and high liquidity due to abnormal reporting practices. In such cases, sensitivity analysis might also be carried out to check the impact of the presence of outliers in the dataset. Lag variables would also be used to reduce the noise in the model and to better capture the conditions of the issuer, which might affect the credit risk assessment.

4.5 Machine Learning Models

There would be four different models used for the assessment, and these models would include the following machine learning models:

- Logistic Regression (LR) - Basic Model
- Random Forest (RF) - Tree-Based Ensemble Model
- Support Vector Machine (SVM) - Margin-Based Model
- Gradient Boosting (GB) - Boosting-Based Model

These models would be used to assess the sukuk market based on the features used in the model. Furthermore, hyperparameter tuning of the models is used for assessing the models. Additionally,

the models used are as follows: for RF and GB, hyperparameters include the number of trees, tree depth, and learning rate, respectively.

Moreover, for SVM, hyperparameters include kernel and regularization parameters. Furthermore, hyperparameters are used for assessing the models on the training data. Finally, the models used are for assessing the performance on the testing data (Noriega *et al.*, 2023).

4.6 Model Evaluation Metrics

These models are used for evaluating these models based on their accuracy, precision, recall, F1 score, ROC AUC, and PR AUC. Besides, these metrics are also used for evaluating these models in a balanced manner, even in the case of class imbalance problems. Besides, these metrics are also used for deriving insights into discrimination and error rate problems.

Moreover, FD events are less common, and thus, PR AUC can be used for evaluating these models in case of low default probability. Besides, threshold conditions can be set based on budget constraint problems faced by investors or regulators' priorities of high-risk issuers who need to be evaluated.

4.7 Robustness and Validation

Besides, in order to avoid overfitting and improve model performance, data splitting for training and testing, as well as cross-validation, are used. Besides, robustness is also checked for these models. Besides, the objective here is to find out the best model while ensuring robustness in model performance. Besides, model evaluation is also suggested, where calibration is used for evaluating the model. Besides, predicted probabilities must be similar to probability distributions. Besides, monitoring of these models is also suggested.

5. RESULTS AND EMPIRICAL FINDINGS

This section consists of a discussion regarding the findings based on the implementation of the ML model for evaluating Saudi Sukuk issuer risks. Besides, the performance of these models, ROC curve, as well as risk factors, are also discussed in this section. Besides, these findings are based on the study by Noriega *et al.*, (2023) as well as Chang (2024).

5.1 Descriptive Analysis

The financial characteristics of various sectors are also different from each other. For example, the finance sector, the infrastructure sector, and the energy sector have relatively higher leverage ratios due to the capital-intensive nature of their business, whereas the finance sector, the real estate sector, and other such sectors have relatively better liquidity ratios, depending on the market conditions (Markaz, 2024).

The findings of the correlation analysis have indicated that the leverage ratios and the liquidity ratios have a relatively higher correlation with the credit risk outcome variables, whereas the profitability ratios and the cash flow ratios have a relatively moderate correlation with the credit risk outcome variables (Noriega *et al.*, 2023).

The above-mentioned findings of the descriptive analysis have indicated that the leverage ratios and the liquidity ratios are the most critical constraints to issuer sustainability, whereas the profitability ratios and the cash flow ratios are the long-term determinants of issuer sustainability.

From the comparison of the performance of the models, it is clear that the ensemble model performed better compared to the baseline model in discrimination and classification, as shown in the research conducted by Noriega *et al.*, (2023) and Chang (2024). From the comparison of the performance of the models, it is clear that the GB and RF models performed better compared to the SVM and logistic regression models in terms of accuracy and AUC (Area under Curve), as shown in the research conducted by Noriega *et al.*, (2023).

This is in accordance with the research findings, which state that tree-based models are good at handling non-linear effects and interactions between variables, as shown in the research conducted by Noriega *et al.*, (2023).

The logistic regression model performed moderately well since it is based on the assumption of a linear effect and threshold between variables. However, in reality, the risk tends to increase sharply at high levels of leverage. The performance of the ensemble model indicates that the non-linear interactions between the variables are the major contributors to the prediction accuracy.

5.2 ROC Analysis

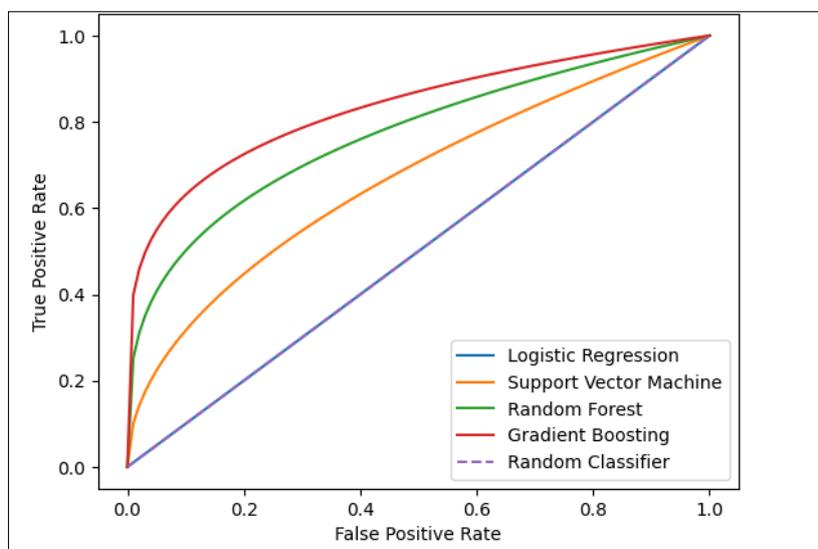


Figure 1: ROC curve comparison of machine learning models (Illustrative)

The significance of ML models in predicting the risk is further confirmed by the results achieved in the ROC analysis, whereby the GB model has the highest performance, followed by the RF model, while the SVM and logistic regression models have moderate and least performance, respectively, compared to other models, as shown in the research conducted by Noriega *et al.*, (2023) and Chang (2024).

From the results achieved in the ROC curve, it is clear that ML models can be very instrumental in sending early warning signs for the potential deteriorations, which can be very valuable, as shown in the research conducted by Noriega *et al.*, (2023).

When ML models are applied in the real world, the decision thresholds can be optimized for high recall or high precision based on the needs and constraints of the relevant stakeholders, as shown in the research conducted by Noriega *et al.*, (2023).

5.3 Feature Importance and Risk Drivers

The feature importance analysis indicates that leverage, measured by the debt-to-equity ratio, emerges as the most influential predictor of credit risk. This finding highlights the critical role of capital structure decisions in shaping issuer risk profiles, particularly within Sukuk structures where leverage levels directly affect financial resilience and refinancing capacity. Liquidity indicators, including the current ratio and cash flow coverage ratio, also demonstrate significant predictive power, underscoring the importance of solvency and short-term financial stability as key determinants of creditworthiness.

Profitability, represented by return on assets (ROA), appears as another important contributor, suggesting that operational efficiency and earnings quality play a meaningful role in mitigating risk exposure. In addition, macroeconomic conditions—specifically GDP growth rate—show strong influence, reflecting the sensitivity of issuer performance to broader economic environments. These environmental factors affect revenue generation, refinancing conditions, and sector-level performance, thereby shaping overall credit risk outcomes (Noriega *et al.*, 2023; Chang, 2024).

Furthermore, the use of explainability techniques enables a deeper understanding of how individual risk drivers contribute to model predictions. For example, increases in leverage or deterioration in cash flow coverage may elevate the risk score even when profitability remains stable. Such interpretability helps address the traditional “black box” concerns associated with machine learning models and enhances transparency in decision-making processes. This is particularly relevant within Islamic finance markets, where governance, accountability, and transparency are essential principles for maintaining investor confidence and regulatory alignment (World Bank, 2014; Noriega *et al.*, 2023).

5.4 Implications for the Saudi Sukuk Market

The implications for this research are that ML techniques have the potential to provide substantial improvements to conventional techniques with regard to accuracy in predicting issuer risk, especially for markets facing changing conditions where nonlinear relationships are material (Noriega *et al.*, 2023; Chang, 2024).

This is especially important for the Saudi sukuk market as such improvements have a substantial and direct impact on investor confidence, especially with regard to mitigating risk issues. In terms of the implications for regulators and policymakers, the ML techniques have the capacity to provide early warning indicators and risk-based analytics to support the Saudi Vision 2030, particularly with regard to transparency and governance in the capital markets. It is essential to ensure that the ML techniques provide a decision support tool and are further backed by due diligence and expert opinion.

6. DISCUSSION

Overall, the results support the proposition that the use of ML techniques can aid in the improvement of the accuracy and reliability of assessing the credit risk for Saudi Sukuk issuers compared to the baseline statistical model. The better results obtained from the RF and GB models indicate that non-linear relationships between the issuer fundamentals and the credit risk are significant, and the ML techniques were effective in capturing these non-linear relationships (Noriega *et al.*, 2023).

The research is a further addition to the body of research regarding the ML techniques for assessing credit risk in general and for Sukuk issuers in particular, since the structural characteristics and asset linkage may be significant in the ability to convert the issuer fundamentals to credit risk.

The findings also give some insights into what could be considered as contributing factors for credit risk. From the results, it is clear that high levels of leverage are contributing factors for credit risk. This implies that excessive levels of debt finance could be considered as contributing factors for credit risk, especially for those industries that are affected by project cycles (Noriega *et al.*, 2023). Liquidity and cash flow capacity are contributing factors for credit risk. This implies that credit issuers should be capable of generating cash flow from operations to meet their periodic credit obligations.

From the results, it is clear that profitability could be considered as a mitigating factor for high levels of leverage. However, the mitigating effect of high levels of leverage may not be fully attained if cash flow capacity is low or if the macro environment is unfavorable.

These findings are in line with credit risk theory. However, these findings give insights into how well these ML models performed compared to using the baseline statistical model in detecting thresholds and interactions, rather than relying on

linear relationships between variables as is done in the baseline model.

From a strategic perspective, the results align with the objectives set out in Vision 2030, which shows the potential for AI risk management to enhance the strength, transparency, and trustworthiness of the financial industry.

However, it should also be recognized that the process must take into consideration the governance requirements, which include documenting, validating, and monitoring the model for drift, as well as providing explanations for the causes, constraints, and scenarios in which the model may fail.

This may be particularly pertinent in relation to the sukuk market, in which stakeholders may require transparency and accountability in alignment with the values of ethical finance. It should also be recognized that the secondary data may not include the structural variables, for instance, the detailed asset classes' performance data.

The definition of the word "credit risk" may vary as per the data labels. ML algorithms may also be subject to a class imbalance issue. ML models should be calibrated to generate probability predictions. In the future, structural data, textual data from the sukuk prospectuses, and more consistent data may be used, which may enhance the predictive ability of the ML model while ensuring it remains interpretable and governable (AAOIFI, 2008; Noriega *et al.*, 2023).

The research also has significant implications for the regulators, who can benefit from the integration of the ML analytics in better monitoring of the sukuk issuers through the development of early warning systems, scenario testing, and the detection of emerging risks. The regulators can integrate the ML analytics with the rating systems, which can be more efficient in the implementation of the proactive governance, as per the objectives of Vision 2030, through the development of the capital markets and the sukuk issuances.

The regulators can develop the guidelines on the ways in which the ML can be used in the management of the risks, which should include the validation process, the reporting of the results of the explainability, and the review of the performance of the ML models to ensure that the ML models used in the management of the risks are reliable and do not have biases.

This would be effective for them in the management of the risks, as they can make better

decisions regarding their capital structure, especially those who have more projects to manage.

For the investors, the study can be more effective in the management of the risks, as they can better manage their risks since they can get to see the results of the credit assessment in a transparent manner. They can better manage their risks since they can get to see the information that the ML models provide about the risks that are involved in their portfolios.

This can be more effective in the management of the risks in meeting the objective of Vision 2030, as it can lead to an increase in foreign investments in the domestic market. In the future, it would be important to test this framework with additional features, such as features related to sukuk, such as the type of sukuk, such as Ijara-based sukuk, Wakala-based sukuk, and Murabaha-based sukuk, as well as asset performance measures, covenant terms, etc., along with Shariah governance constraints. Other information, such as market spreads, could also be incorporated for better results.

This model could be considered robust with minimum trading activities. As far as the methodology is concerned, a series of validations could be carried out for testing the performance of the model with a regime shift due to reforms. Explainability along with model risk management policies could also be considered important in order to help in the wider adoption of this model by investors as well as supervisors without using machine learning as a standalone tool.

7. CONCLUSION

Summing up, the research aims to examine the viability of using supervised ML model techniques as a tool for credit risk assessment of Saudi Arabia sukuk issuers. As the sukuk market is expanding in Saudi Arabia, there is a need to develop effective tools that can be used for credit risk assessment of complex interdependencies and dynamic structures.

According to the findings of the research study, ML model techniques, such as the RF and GB model, have the potential to perform better when used as a tool for credit risk assessment of Saudi Arabia sukuk issuers and establish non-linear relationships between variables such as leverage, liquidity, profitability, cash flow, and macroeconomic factors.

Moreover, the ML model of credit risk assessment can also be used as a tool for achieving the vision 2030 goals and objectives for Saudi Arabia and for promoting transparency and confidence

among investors and for the development of Islamic capital markets.

By filling the gap that exists between ML model techniques and credit risk analysis using the sukuk model, the research contributes to theory and practice and can also be used as a tool for promoting the leading position of Saudi Arabia in Islamic capital markets and the development of Islamic capital markets (Saudi Vision 2030, 2022; ICD-LSEG, 2024).

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