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RESEARCH ARTICLE

Machine Learning-Based Price Prediction in Islamic Equity Markets: Evidence from the BIST Participation Index

Özgür Özdemir [1] and Erdem Öncü [2]

[1] *Department of International Trade and Finance, KYC School of Applied Sciences, Trakya University, Edirne, Türkiye*
[2] *Department of Banking and Insurance, KYC School of Applied Sciences, Trakya University, Edirne, Türkiye*

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ABSTRACT

Islamic economics is an economic system where individuals conduct their economic activities within the framework of Islamic law, prioritizing moral, ethical, and social dimensions. Islamic finance is built upon fundamental principles such as the prohibition of interest, risk sharing, and the distinction between halal and haram, and has shown rapid growth and diversification on a global scale, especially in the last quarter century. Islamic stock markets consist of the shares of companies operating in accordance with Sharia principles and are referred to as the "Participation Index" in Türkiye. The increasing number of studies on participation indices in the literature reveals that Islamic finance is an increasingly important research area. This study aims to predict the price movements of the BIST Participation All Shares Index (XKTUM) using machine learning methods. In the analysis, the USD/TRY exchange rate, the price of gold per ounce, the Brent oil price, and the overnight TL interest rate were used as independent variables to predict the XKTUM index for the period 16.11.2021–02.12.2025. LightGBM and XGBoost algorithms were used to evaluate the forecasting performance. The dataset contains 1,015 daily observations, and the last 20% of the sample (10.02.2025–02.12.2025) is used as the test set. LightGBM produced a lower forecasting error than XGBoost, with SMAPE values of 17.47% and 20.48%, respectively. The USD/TRY exchange rate is the dominant predictor in both models. Both models tracked the index in the early part of the test period, while they failed to follow the strong upward trend after mid-2025 because tree-based models cannot extrapolate beyond the range of the training data. A six-month forecast based on ARIMA projections of the explanatory variables points to limited variation in XKTUM and is presented as an illustrative scenario.

1 Introduction

The Islamic financial system is designed to eradicate unethical behaviors while also prioritizing the welfare of individuals across social, political, cultural, and economic domains (Çakmak and Efe, 2024). Islamic finance refers to the system in which all financial transactions are conducted in accordance with Islamic principles. The most important feature that differentiates Islamic finance

Corresponding author: Erdem Öncü (erdemoncu@trakya.edu.tr)

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from traditional finance is that it does not involve interest. Paying profit shares to savers instead of interest and directing savings towards real investments are the most important elements that distinguish Islamic finance from traditional finance (Dinçer and Yüksel, 2018). The interest-free finance system can be defined as a financial structure in which economic activities are conducted without interest, and financing is provided through profit–loss sharing, trade, rental, and other Sharia-compliant methods. The interest-free finance system prioritizes not only the prohibition of interest but also ethical and just principles (Koçsoy and Reyhan, 2025). Interest-free finance, or Islamic finance, is predicated on the core principle of "forgoing present trade in return for future monetary gains" (Ulusoy and Altun, 2017). The primary products and procedures in Islamic finance include participation banking, takaful (participation insurance), sukuk (lease certificates), participation index, mudarabah, musharaka, murabaha, ijara, salam, and istisna. The adherence of these financial goods and procedures to Islamic principles is the fundamental cornerstone of Islamic finance (Güçlü and Kılıç, 2020).

The alignment of financial markets with religious sensitivity has emerged as a prominent field of study and practice in recent years. Not all shares listed on the stock market adhere to the parameters of the Participation Index (Bakan, 2025). The compliance of traded shares with Islamic investing principles extends beyond their operational domain; it also necessitates an evaluation of the businesses' assets and liabilities. Investors with religious sensitivity meticulously scrutinize the allocation of assets and liabilities, as well as the activities that create revenue (Güçlü and Kılıç, 2019). This means that Islamic stock indexes have been established, considering the sectors of activity and financial metrics of shares traded in accordance with Islamic principles. The establishment of Islamic stock indexes is crucial in enhancing market transparency and elevating investor awareness. Consistently revising the pertinent parameters enhances the indexes' adherence to international standards.

The growing significance of participatory finance worldwide has expedited the advancement of capital market products adhering to Islamic ideals. Among interest-free financial investment vehicles, a significant component pertaining to capital markets is participation stock market indices (Kotan and Özdemir, 2025). Participation indices include the proportions of enterprises adhering to Islamic law while excluding revenue from forbidden industries, including interest, alcohol, gambling, and pig products. Participation indices allow local and global investors to construct portfolios that adhere to Islamic finance rules. The extensive use of participation indices enhances the development of Islamic finance markets and promotes financial diversity. Globally acknowledged indices such as the Dow Jones Islamic Market Index (DJIM), FTSE Shariah Global Equity Index Series, MSCI Islamic Index Series, and S&P Shariah Index Series provide substantial choices for investors seeking to adhere to interest-free financing rules. Borsa Istanbul participation indices are prominent examples of this domain in Türkiye (Emeç, 2021).

This study focuses on the BIST Participation All Shares Index, which includes all Borsa Istanbul shares that meet the participation finance criteria. The index is referred to as XKTUM throughout the remainder of the paper. Previous machine learning studies on stock price prediction have mainly examined conventional indicators. For example, Büyükkör and Doğan (2024) predicted the direction of the BIST-100 index with tree-based ensemble methods, Çevik and Vuran (2025) forecast the S&P 500 index, and Tayalı (2025) forecast the Turkish industrial production index with XGBoost and ARIMA. Machine learning-based price prediction for participation indices has received little attention so far.

The contribution of this study is threefold. First, it provides machine learning-based price forecasts for XKTUM, a Sharia-compliant index that has not yet been examined with these methods. Second, it uses four macro-financial variables, namely the USD/TRY exchange rate, the gold price, the Brent oil price and the Turkish lira overnight interest rate, as predictors of the index and reports their relative importance. Third, it compares LightGBM, which was not used in the closely related studies above, with XGBoost and supplements the test-set evaluation with a six-month forward forecast. The remainder of the paper is organized as follows. Section 2 introduces XKTUM, Section 3 reviews the related literature, Section 4 describes the data and method, Section 5 presents the findings, and Section 6 concludes with implications for investors.

2 Borsa Istanbul Participation Indices and XKTUM

The BIST Participation 30 Index is the first Islamic index in Türkiye covering stocks compliant with participation banking principles. This index was established on December 31, 2008, and has been calculated as price and return indices from real-time data since January 6, 2011 (Yıldız, 2015). It was created to measure the price and return performance of stocks that customers of participation banks can invest in, in accordance with their operating principles. The compliance of the companies in the index with the index criteria is monitored in three-month periods. The three-month periods are determined as January–March, April–June, July–September, and October–December. Companies that do not meet the index criteria are removed from the index in the next three-month period, and the company with the highest market capitalization among the companies that could not be included in the list is added to the index (Ülev, 2016).

The companies to be included in the index are selected through qualitative and quantitative filters. First, their fields of activity (interest-based finance, gambling, alcohol, pork products, etc.) are evaluated, and then their financial ratios are examined (Şahin, 2022).

Borsa Istanbul later expanded the participation index family with indices such as the BIST Participation 50 and the BIST Participation All Shares Index (XKTUM). XKTUM differs from the Participation 30 and Participation 50 indices because it has no fixed number of constituents and covers all shares that meet the participation criteria. Since it represents the whole Sharia-compliant segment of the market, this study uses XKTUM as the dependent variable.

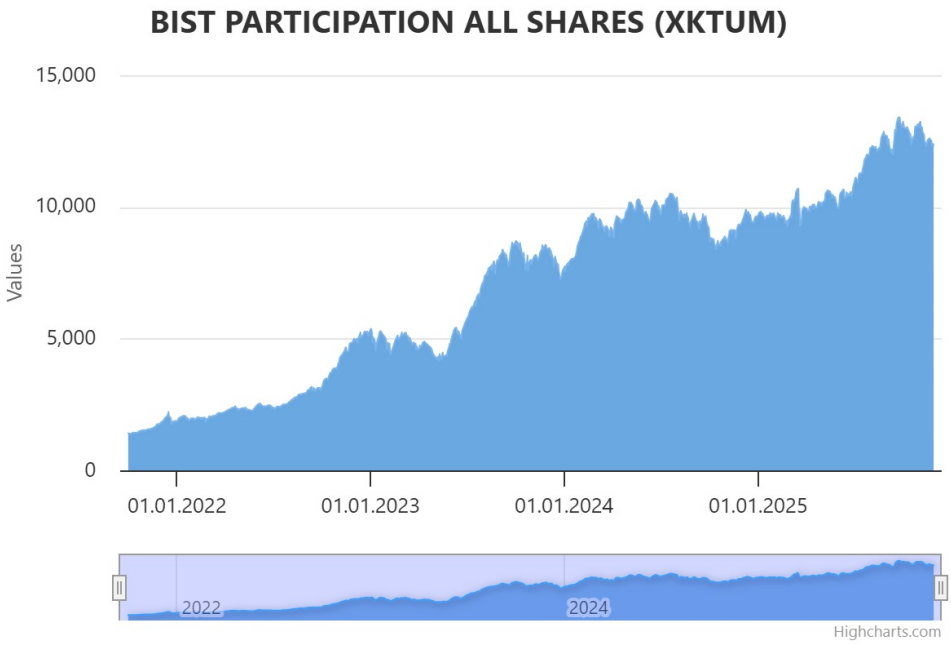


Figure 1. XKTUM price movement.
Source: Borsa Istanbul, https://www.borsaistanbul.com/en/index/xktum.

The price chart in Figure 1 indicates that the XKTUM index had a robust and consistent increasing trajectory from 2022 to 2025. A notable surge in momentum transpired post-2023, with the index reaching its historical peaks by 2025, indicative of robust investor confidence. Despite sporadic declines in 2025, the prevailing trend continued to rise, signifying robust market dynamics.

The sector-specific distribution in Figure 2 reveals that the predominant portion of XKTUM, at 30.2%, is allocated to the "Other" group, indicating a highly diverse composition. Chemicals, petroleum, rubber and plastic products (17.8%), retail trade (16.6%) and defense (14.6%) are prominent sector weights within the index. In contrast, industries like basic metals (9.8%), real estate investment trusts (5.7%) and electricity and gas (5.3%) own more restricted shares, thus facilitating the diversification of the index's risk across several domains.

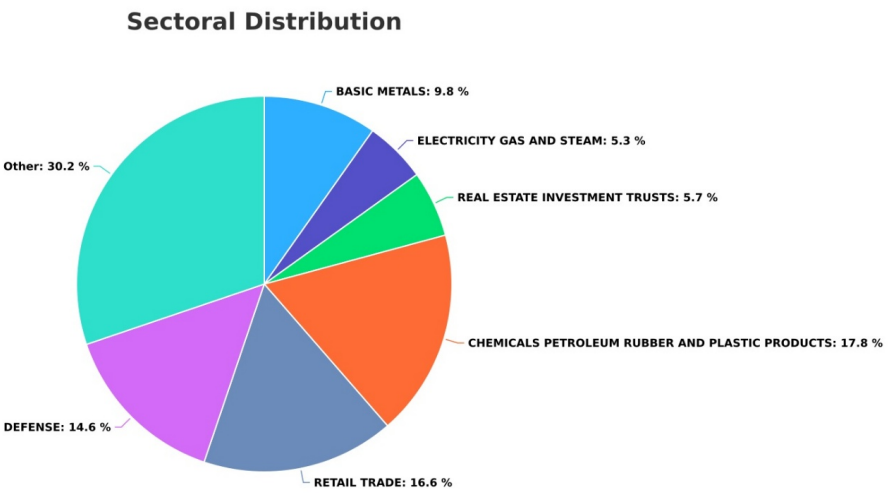


Figure 2. Sectoral distribution of XKTUM.
Source: Borsa Istanbul, https://www.borsaistanbul.com/en/index/xktum.

3 Related Literature

Despite being relatively recent, the Borsa Istanbul participation indices have been the subject of several investigations. This study's literature review examines the Participation Index and price prediction via machine learning.

The research by Emeç (2021) meticulously examined the dynamic interplay of the Borsa Istanbul Participation Index (BIST Participation Index), gold prices, and the wealth amassed by participation banks. The study used the Fourier cointegration test and generalized variance decomposition, therefore statistically confirming the presence of a long-term common movement between the series. The results indicate that gold prices, the fund sizes of participation banks, and the participation index evolve in a complementary fashion over the long run, suggesting an integrated structure within participation financing markets.

Güçlü (2019), in his sectoral study of the BIST Participation 50 (KAT50) and Ziraat Portfolio Participation Index (ZPYKAT), identified the manufacturing industry as a notably preeminent sector in both indexes. The research contrasted the filtering criteria of the indices, noting that the financial metric barrier was established at 30% for KAT50, but it was 33% for ZPYKAT. The results indicate that the criteria used in the formulation of the indices vary, and these variations are immediately manifested in the sector weights of the indices and investment preferences.

Buğan et al. (2019) conducted a study using daily data from 2011 to 2019 to examine the weak-form efficiency of the Participation 30 Index. In light of the current discourse in the literature about financial market efficiency, they used ARFIMA and FIEGARCH models in their study. The models used in the research are regarded as extremely effective instruments for analyzing long-term dependency and volatility structures of market prices. The investigation indicated that the Participation 30 Index, albeit one of the Islamic finance indices in Türkiye, did not demonstrate enough performance for weak-form efficiency.

Özkan and Çakar (2020) investigated the weak-form informational efficiency of the Participation 50, Participation 30, and Model Portfolio indexes in Türkiye using weekly data. The findings indicated that while the indices were mostly weak-form efficient, they exhibited variations from this efficiency during some periods. The study's results indicate that investors may forecast future outcomes and achieve abnormal returns by using historical index values.

Karakuş and Vural (2022) examined the correlation between BIST participation indicators and the overnight average interest rate as well as the exchange rate. The data indicate a weak correlation between participation indices and independent factors.

Kotan and Özdemir (2025) investigated the performance and portfolio allocations of the ten largest participation equity funds by portfolio size. The investing strategy of the analyzed funds favored

financial instruments aligned with participation financing principles and placed considerable emphasis on big, liquid corporations included in the BIST Participation All Index.

Yiğiter et al. (2018) used *k*-nearest neighbors (KNN) models to forecast prices for 1, 3, and 5 days ahead, using Vakıf Portfolio Lease Certificate prices. A total of 143 data points were used for training, while 95 were allocated for testing. The analytical findings indicate that the efficiency coefficients of the models were 0.98, 0.96, and 0.94, respectively, signifying extremely accurate predictions. Büyükkör and Doğan (2024) used random forest (RF), XGBoost, and CatBoost ensemble machine learning techniques derived from decision trees to forecast the trajectory of the BIST-100 index, given their enhanced predictive capabilities. The study's findings indicated that the performance of all three machine learning approaches was very similar. The XGBoost algorithm distinguished itself for its exceptional performance, even with imbalanced datasets. Although the RF and CatBoost techniques yielded results comparable to those of the XGBoost approach, neither demonstrated an advantage in accuracy. Çevik and Vuran (2025) predicted a financial time series (S&P 500 index) using random forest, XGBoost, and long short-term memory (LSTM) models in their research. The results indicated that the random forest model generated the highest success in forecast accuracy and investment plan performance. The XGBoost algorithm yielded successful outcomes and showed more consistency than LSTM, mostly owing to its parametric flexibility.

In Tayalı's (2025) research, a total of 469 months of data from 1986–2025 were used to estimate Türkiye's industrial production index. The study compared the performance of the XGBoost and ARIMA models to estimate Türkiye's industrial production index and showed that both models yielded similar results. While XGBoost requires a more complex optimization process, both models offered limited prediction accuracy because they did not directly include seasonality and exogenous macroeconomic variables. According to Tayalı (2025), stronger predictions can be made in the future using hybrid models and more comprehensive sets of variables.

Although recent studies have demonstrated the effectiveness of machine learning methods in forecasting financial and economic indicators, the existing literature has predominantly focused on conventional market and economic indicators, such as the BIST-100 Index, the S&P 500 Index, and industrial production. In particular, Büyükkör and Doğan (2024) examined BIST-100, Çevik and Vuran (2025) focused on the S&P 500, while Tayalı (2025) investigated industrial production using machine learning-based forecasting approaches. In contrast, studies focusing specifically on machine learning-based price prediction for participation indices, particularly XKTUM, remain limited. Addressing this gap, the present study investigates the predictability of the XKTUM using four macro-financial variables, namely USD/TRY, gold prices, Brent crude oil prices, and the Turkish lira overnight interest rate. In addition, LightGBM and XGBoost are employed and comparatively evaluated to examine their forecasting performance. Beyond the model comparison, the study also provides a six-month forward-looking forecast for the XKTUM, thereby extending the analysis beyond historical prediction performance and offering an additional perspective on the future movement of the participation index.

4 Data and Method

This research uses LightGBM and XGBoost algorithms to predict the closing price of XKTUM. The dataset consists of daily closing values of XKTUM (index points), the USD/TRY exchange rate (TRY per USD), the gold price (USD per ounce), the Brent crude oil price (USD per barrel) and the Turkish lira overnight interest rate (%) between 16 November 2021 and 2 December 2025. All five series were obtained from Investing.com (https://www.investing.com). The series are aligned on common Borsa Istanbul trading days and contain no missing values. The final dataset contains 1,015 daily observations. Table 1 presents the descriptive statistics of the variables.

The four explanatory variables enter the models with a one-day lag, so the value of XKTUM on day t is predicted with the values of the predictors on day $t-1$. This structure avoids look-ahead bias and leaves 1,014 usable observations. The sample is split chronologically without shuffling. The first 80% of the observations (17.11.2021–07.02.2025, $n = 811$) are used for training, and the remaining 20% (10.02.2025–02.12.2025, $n = 203$) are used for testing. Hyperparameters, namely the number of

Table 1. Descriptive statistics.

Variable	Unit	Mean	Std. Dev.	Min	Max
XKTUM	Index points	7,192.40	3,427.04	1,577.38	13,406.26
USD/TRY	TRY per USD	26.85	8.95	10.34	42.48
Gold	USD per ounce	2,302.90	607.24	1,623.60	4,274.80
Brent oil	USD per barrel	82.99	12.86	60.23	127.98
Overnight rate	%	30.32	16.65	7.63	52.99

Note: Daily data, 16.11.2021–02.12.2025, $N = 1{,}015$. *Source:* Investing.com.

trees, the learning rate and the tree size, are selected with five-fold time-series cross-validation on the training set. The selected settings are 500 trees, a learning rate of 0.1 and 31 leaves for LightGBM, and 500 trees, a learning rate of 0.1 and a maximum depth of 6 for XGBoost. The analyses are carried out in Python 3.11 with the `lightgbm` (4.7.0), `xgboost` (3.2.0) and `statsmodels` (0.15.0) packages.

LightGBM is a decision tree-based machine learning technique that functions inside a rapid, distributed, and high-performance gradient boosting environment. The efficiency of this approach relies on two techniques, Gradient-based One-Side Sampling (GOSS) and Exclusive Feature Bundling (EFB). GOSS reduces the size of the training data by keeping the observations with large gradients and randomly sampling those with small gradients. EFB bundles mutually exclusive sparse features into denser features, which reduces the number of features and the complexity of the model during learning (Üstüner and Balık Şanlı, 2020). The LightGBM technique enhances accuracy and significantly accelerates training in big datasets with many features (Ağaslan, 2025).

XGBoost is an ensemble learning framework that employs decision trees and the boosting methodology, whereby several weak learners work together to provide a strong prediction (Şekeroğlu and Acılar, 2025). The XGBoost approach employs a gradient boosting framework designed to minimize the loss function using gradient calculations and iterative model updates (Çelik and Gür, 2024).

5 Findings

A substantial body of literature indicates that the Mean Absolute Percentage Error (MAPE) is widely adopted as a performance evaluation metric in forecasting studies (Öncü and Gündüz, 2024). The Symmetric Mean Absolute Percentage Error (SMAPE) normalizes the error by the average of the actual and predicted values, thereby mitigating the excessively large or infinite error values that MAPE produces when actual values approach zero, while also penalizing under- and over-forecasts more symmetrically. This research uses SMAPE to assess the alignment of the predictions with the actual data. Table 2 reports the SMAPE values of the two models on the test set. LightGBM produced a lower SMAPE (17.47%) than XGBoost (20.48%).

Table 2. SMAPE values of the models on the test set (%).

Method	SMAPE (%)
LightGBM	17.47
XGBoost	20.48

Figure 3 shows the actual values of XKTUM (black) together with the LightGBM (blue, dashed) and XGBoost (red, dotted) predictions for the test period. Both models followed the index closely in February and March 2025, when XKTUM stayed within the range observed in the training period. After April 2025, the index rose steadily while the predictions of both models remained flat.

The gap between the actual and predicted values widened from July 2025 onward, when XKTUM exceeded 11,000 points. LightGBM predictions stayed closer to the actual series than XGBoost predictions for most of the test period, which is consistent with its lower SMAPE.

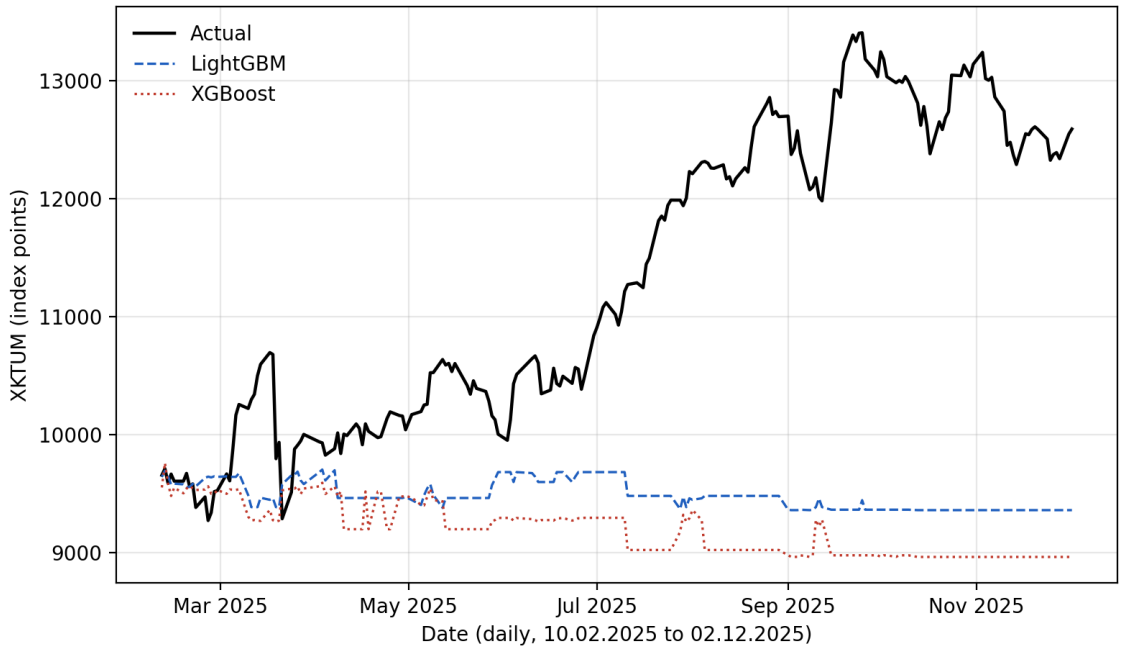


Figure 3. Actual and predicted XKTUM values in the test period, 10.02.2025–02.12.2025 (black: actual; blue: LightGBM; red: XGBoost).

Table 3 reports the relative importance of the explanatory variables based on the gain measure of both models. USD/TRY is by far the most important predictor, with a share of 0.976 in LightGBM and 0.986 in XGBoost. The overnight interest rate ranks second (0.016 and 0.008), while gold (0.005 in both models) and Brent oil (0.003 and 0.001) contribute little. The dominance of the exchange rate reflects the close link between the depreciation of the Turkish lira and nominal equity prices in Türkiye. Both USD/TRY and XKTUM rose steadily over the sample period, so the exchange rate largely captures the nominal trend of the index. The low importance of gold differs from Emeç (2021), who reports a long-term common movement between gold prices and the participation index. A likely explanation is that gold and USD/TRY carry overlapping trend information, and tree-based models tend to credit the variable that splits the data first.

Table 3. Feature importance of the explanatory variables.

Variable	LightGBM (gain)	XGBoost (gain)
USD/TRY	0.976	0.986
Gold	0.005	0.005
Brent oil	0.003	0.001
Overnight rate	0.016	0.008

Note: Gain-based relative importance. Values sum to 1 within each model.

These results carry several implications for investors in XKTUM. First, the exchange rate is the main macro-financial signal for the nominal level of the index, so investors in participation funds can monitor developments in USD/TRY closely. Second, level forecasts from tree-based models become unreliable when the index moves into a new price range, so these models should not be used alone for buy or sell decisions. Third, investors who use such models can retrain them frequently or combine them with models of returns, which are less affected by the extrapolation problem.

Figure 4 presents a six-month forward forecast of XKTUM for 03.12.2025–27.05.2026, which covers 126 trading days. Since the future values of the explanatory variables are not observed, each variable is first projected with a univariate ARIMA(1,1,1) model with drift estimated on its logarithm. Both models are then re-estimated on the full sample, and the projected values enter

them with a one-day lag. Under these projections, USD/TRY rises to about 50.55 by the end of the horizon. The LightGBM forecast ranges between 12,432 and 12,642 points, and the XGBoost forecast ranges between 12,577 and 12,788 points, compared with the last observed value of 12,591 points. The forecast therefore suggests limited variation in XKTUM over the horizon. The models cannot forecast values above the highest level observed in the training data, and the forecast depends on the assumed paths of the explanatory variables. The forward forecast is therefore presented as an illustrative scenario and not as a point prediction for investment decisions.

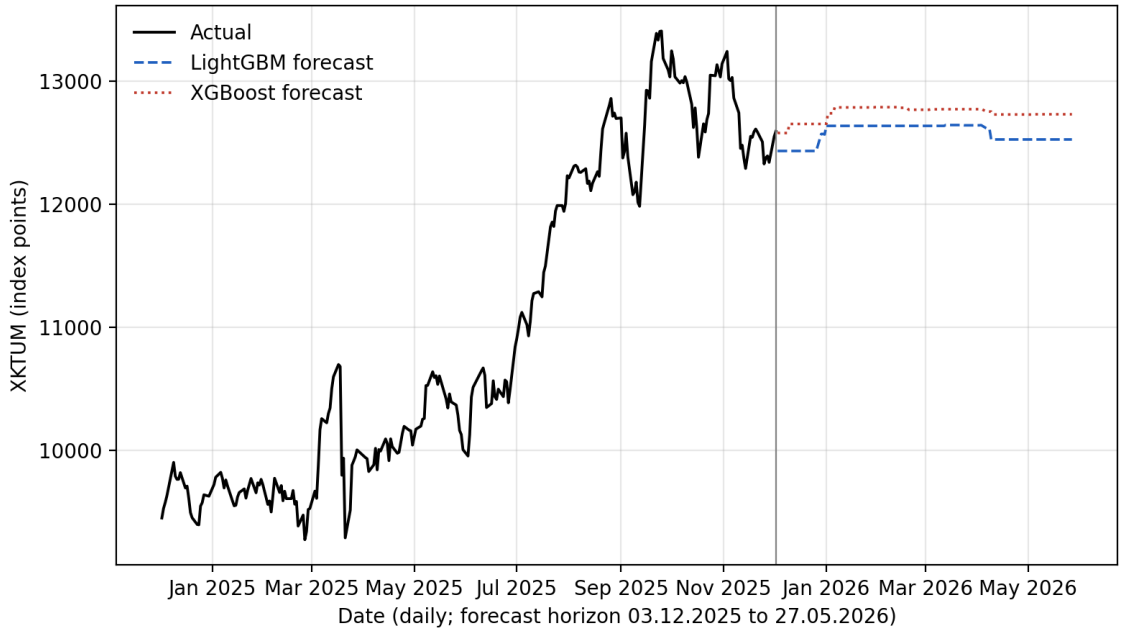


Figure 4. Six-month forward forecast of XKTUM, 03.12.2025–27.05.2026 (black: actual; blue: LightGBM; red: XGBoost).

6 Conclusion

Islamic economics is a system whereby individuals engage in economic activities in accordance with Islamic law (Öztürk and Özdemir, 2024). The Islamic stock market index monitors the shares of firms that do not engage in the production or trading of items and services considered haram (forbidden) in Islam, according to the constraints established by Islamic law. In Türkiye, it is designated as the Participation Index, although in academic literature, it is often referred to as the "Sharia Index" or "Islamic Index" (Öztürk and Özdemir, 2024).

This research used LightGBM and XGBoost to forecast the price of XKTUM. The USD/TRY exchange rate, the gold price (USD per ounce), the Brent oil price, and the Turkish lira overnight interest rate were used as inputs for forecasting. LightGBM produced a lower forecasting error than XGBoost, with SMAPE values of 17.47% and 20.48%, respectively. Both models tracked XKTUM while the index remained within the range of the training data, and both failed to follow the strong upward trend after mid-2025. USD/TRY is the dominant predictor in both models, while gold, Brent oil and the overnight interest rate contribute little. The six-month forward forecast points to limited variation in XKTUM, although this result depends on the assumed paths of the explanatory variables. Several implications follow for investors. The exchange rate is the main macro-financial indicator to monitor for the nominal level of XKTUM. Level forecasts from tree-based models should be combined with other information, since their accuracy falls sharply when the index enters a new price range. Portfolio managers of participation funds can use such models as a complementary tool for scenario analysis. The study has some limitations. It uses only four explanatory variables and two tree-based algorithms, and these algorithms cannot extrapolate beyond the range of the

training data. Future research can model returns instead of price levels and extend the analysis with additional variables relevant to Islamic finance, such as sukuk yields and participation bank profit-share rates, and with alternative approaches including artificial neural networks, LSTM and hybrid models.

Declarations

Funding This research received no external funding.

Conflict of interest The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability The data used in this study are available from the corresponding author upon reasonable request.

Use of generative AI Claude (Anthropic) was used solely for language translation and editing purposes. The authors reviewed and revised the AI-assisted content and take full responsibility for the final manuscript.

Author contributions All authors contributed equally to this study and approved the final version of the manuscript (conceptualization, methodology, software, validation, formal analysis, investigation, resources, data curation, writing – original draft, writing – review and editing).

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